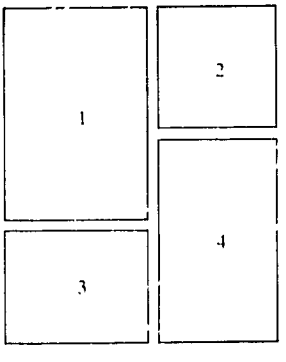
CIP 1989

Worldwide Potato and Sweet Potato Improvement



Cover:

1. Sweet potatoes for sale at a New Guinea Market.
2. CIP staff member studying specimen box with farmers in Ollantaytambo, Peru, for identification of local pests.
3. Hand-emasculation of potato flowers for TPS production, Chile.
4. Testing for the presence of viruses, using nucleic acid spot hybridization.

International Potato Center

Annual Report 1989

Worldwide Potato and Sweet Potato Improvement

Errata

Please insert these corrections in CIP Annual Report 1989

page		for	read
48	column 1, line 2	*dahaliae*	*dahliae*
60	column 1, line 38	myclomas	myelomas
61	column 1, line 19	... systemically with *Ipomoea nil* and *I. setosa.*	...systemically with *Ipomoea nil* and *I. setosa* infected with the virus.
63	column 1, line 5	scions infected with *Ipomoea nil*	scions infected with *Ipomoea nil* infected with the virus.
154	column 1, line 1	Gregory J. Scott	Scott, Gregory J.

International Potato Center
Apartado 5969, Lima, Peru

1989

The **International Potato Center (CIP)** is a nonprofit, autonomous scientific institution established in 1972 by agreement with the Government of Peru. The Center develops and disseminates knowledge to facilitate use of the potato and sweet potato as basic foods in the developing world. CIP is one of 13 nonprofit international research and training centers supported by the Consultative Group for International Agricultural 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.

In 1988, through the CGIAR, CIP received funding from the following donors: the governments of Australia, Austria, Belgium, Finland, France, Germany, India, Italy, Japan, Mexico, Netherlands, Norway, People's Republic of China, Philippines, Spain, and Switzerland; the Canadian International Development Agency (CIDA); the Danish International Development Agency (DANIDA); the European Economic Community (EEC); the Inter-American Development Bank (IDB); the International Fund for Agricultural Development (IFAD); the Swedish Agency for Research Cooperation with Developing Countries (SAREC); the United Kingdom Overseas Development Administration (UKODA); the United States Agency for International Development (USAID); the OPEC Fund for International Development; the United Nations Development Programme; the World Bank (IBRD); and the Consultative Group Secretariat.

The 1989 *Annual Report* is published in English and Spanish by the International Potato Center (CIP). This report covers the period from 1 November 1987 to 31 October 1988. Mention of specific products by trade name does not imply endorsement of or discrimination against such products by CIP.

Citation:
International Potato Center. 1989. Annual Report CIP 1989. Lima, Peru. 194 p.

Printed by the International Potato Center, Apartado 5969, Lima, Peru, July 1989.
Copies printed: 3100.

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Foreword

Our host country for CIP's headquarters has suffered especially severe security and economic problems in recent months, prompting widespread speculation in the international press. Local papers reported that we were leaving the country, and this information eventually found its way into the global mass media. As a result, there has been increased concern among the families of international staff back home, along with donor preoccupation about the safety of both our staff and their investments in CIP facilities.

CIP is facing these local problems squarely, and our report this year reflects some of the ways we have adapted our programs and shifted resources to surmount these constraints. In the process, we have been hard pressed to maintain CIP's low-profile approach that has been established over the past two decades.

Over the past months, we have curtailed on-farm research and road transportation to CIP experiment stations in many parts of the country. After the security leader at CIP's Huancayo station was killed in late 1988, all of the scientific staff posted at this principal highland station were moved to other sites and security measures were tightened at all CIP locations.

Despite these tragic setbacks, however, CIP harvested a normal crop from well-cared-for research plots in Huancayo in March and April of 1989. Even though deeply shocked by the killing of their colleague, more than 80 workers stayed on the job—loyally caring for CIP research plots and following their customary schedules. Although none of CIP's professional staff remained at Huancayo, many of the local workers have been on the job for more than 15 years, and they have repeatedly proven themselves to be top professionals in their own right.

In related efforts, CIP is establishing an experiment station in nearby Quito, Ecuador for our scientists working on problems of highland-potato production who must monitor their plots on a daily basis. CIP also upgraded its aircraft in 1988 so that scientists can better service all experiment stations in Peru and Ecuador, from a Lima base. We will transfer a team of five scientists from CIP headquarters to the Ecuador station, thus providing a backup facility for maintaining the world potato and sweet potato collections.

Although CIP's diversification of program activities from headquarters to regional programs and into country networks has been accelerated by our host-country's problems, we continue to maintain substantial investments in staff and facilities at the Peruvian locations. We have built a tremendously capable work force of well trained loyal staff of over 500 Peruvians, and it would take years to establish a similar capability at another location. Our experience this past year has clearly demonstrated the responsibility and loyalty of these veteran workers during difficult times.

We will continue to decentralize, bringing our programs closer to the more than 80 countries with which we are collaborating. And, as long as lives are not endangered, we also will continue to work in Peru, which probably provides a better climate for improving potato and sweet potato germplasm than does almost any other country. In the coming months, our decisions will be governed to a great extent by the following priorities, which were affirmed in recent discussions with the CIP Board of Trustees. First, the lives of our people cannot be replaced, thus we must ensure adequate personal security. Second, much of CIP's germplasm cannot be replaced and thus must be protected for use by both present and future generations. Third, bricks and mortar can be replaced, so we must make sure that our facilities are adequately designed for optimum flexibility and adaptation. Thus, under adverse conditions, CIP's operations could be modified or moved with minimum effect on staff or budget.

As we chart our course for the next decade, which is outlined in the following section on CIP's self-study and plan for change, I would like to pay personal tribute to all CIP staff for their excellent support during this very difficult year. I would also like to offer special acknowledgement for the dedicated work of the Peruvian staff and our host-country colleagues. Our successful collaboration will continue through good planning.

Richard L. Sawyer

Richard L. Sawyer
Director General

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CIP's Self-Study and Change Plan

CIP is well into a process of self-evaluation and change. In 1988, we launched a full-scale analysis of our organizational and management practices that we hope will give rise to many improvements over the next decade. Working from within the institution, we've now entered the implementation stage of our plan-for-change. This brief summary documents the progress to date and outlines some considerations for the future.

Our Rationale

While a self-study can be useful for most institutions, such analysis is now particularly valuable for CIP in addressing some fundamental administrative and operational concerns. First, our administrative leadership will soon change. In its 20-year history, CIP has had only one director general and he has strongly influenced the strategies and direction of the institution. The intent of the self-study process is to provide a constructive atmosphere for the change in management and to encourage all staff to contribute to the planning process.

Second, CIP has grown rapidly with a philosophy based on user needs, and our programs have diversified through operations in more than 80 countries. Thus, a self-study has served as an internal review to ensure that our organizational changes keep pace with growth, that our servicing capabilities are appropriate for research-project requirements, and that our facilities meet operational needs. For example, most of CIP's management staff have attended specialized management courses. The self-study has provided an opportunity to put their collective training to use in improving the institution. Staff functions and strategies that have served the institution well during the growing years are being examined and revised, based on current conditions and on input from all operational levels. Perhaps most importantly, the self-study has provided an environment and a basis for continuing discussion of needed improvements and for identification of alternative

approaches. And, in the process, staff have worked together to contribute new insights.

Third, CIP will be involved in 1989 in external program and management reviews, which are part of the monitoring process for the programs and management of all CGIAR centers. Our self-study has helped to mirror CIP's activities, thereby providing a framework for preparing for these reviews.

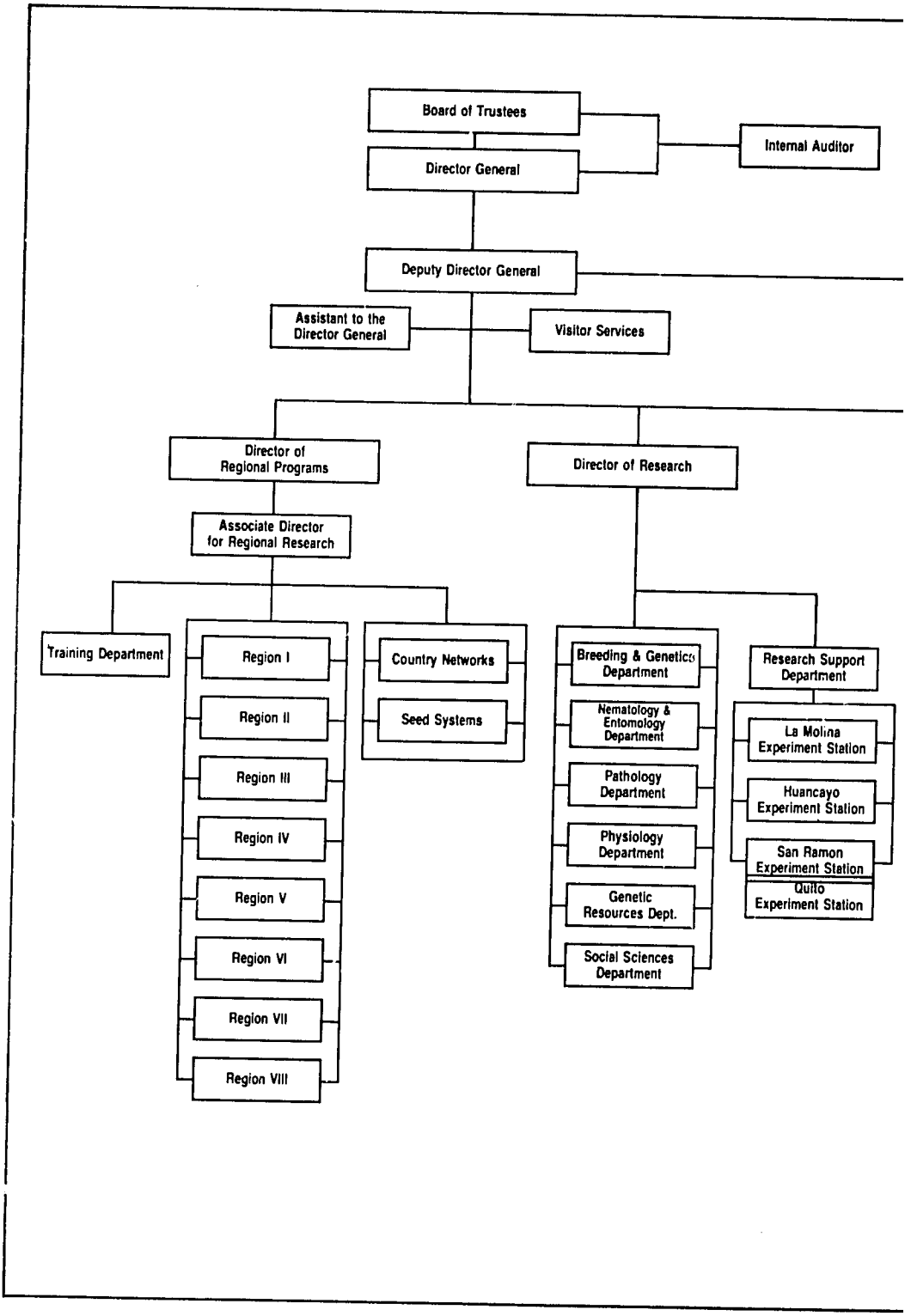
Fourth, the process can help generate the flexibility and responsiveness needed to plan effectively during the current period of economic and social turmoil in CIP's host country (see Foreword).

The Plan-For-Change Process

Our self-study is the first phase in a long-term planning process that began with the Board of Trustees' approval. External management consultants then were chosen to guide CIP staff through the process, and we selected a working group from within our staff to critically evaluate CIP's total organization, with input from all departments of the Center. Their findings were presented to management as a base for continued discussion and decision-making. Next, CIP's management committee developed a preliminary Plan-for-Change document, building upon the findings of the working group. The Plan is now being implemented and monitored, with periodic updating scheduled to include feedback from all CIP operations.

For four months, our self-study committee interviewed CIP staff at all levels and stimulated constructive criticism on all phases of CIP work. Management practices were analyzed at all levels and constructive feedback provided to all managers. The findings of our study committee were presented to staff and the Board prior to the 1988 annual review. They have also provided the base for the next step of the process — the development of a change plan by the management committee.

Our management committee is composed of all management-level staff, plus the controller, the executive officer, the head of the information sciences department, and the head of the social sciences department. For six weeks, the management committee,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Region III
Region IV
Region V
Region VI
Region VII
Region VIII
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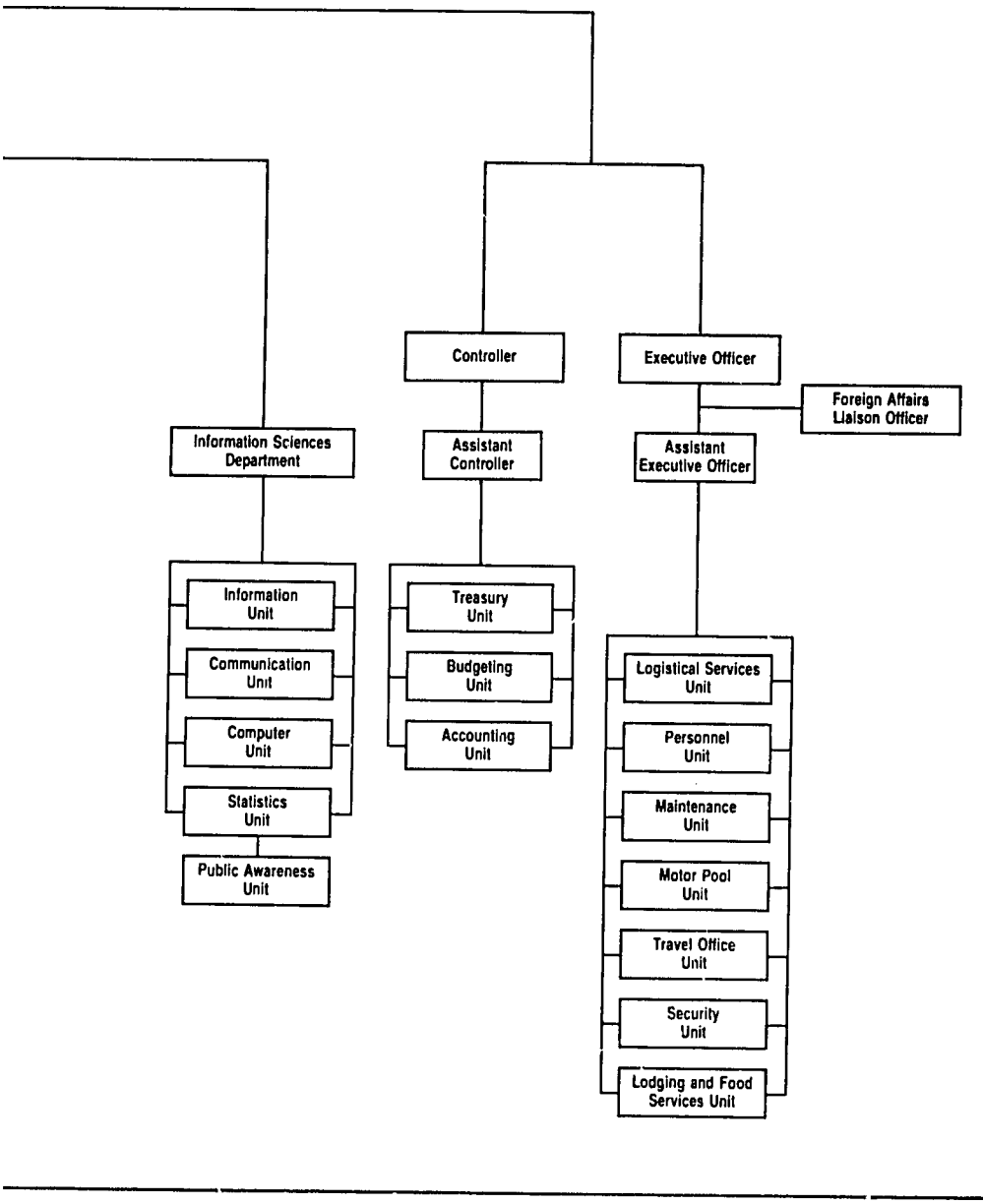
Seed Systems
Breeding & Genetics Department
Nematology & Entomology Department
Pathology Department
Physiology Department
Genetic Resources Dept.
Social Sciences Department
Research Support Department
La Molina Experiment Station
Huancayo Experiment Station
San Ramon Experiment Station
Quito Experiment Station

CIP Organizational Chart



in a consensus approach, addressed the major problem areas that had been identified by the study committee, as well as other pressing concerns. The result is a plan-for-change that designates responsibilities and proposes a time schedule for implementing the changes. The plan document was given to all our staff and the Board of Trustees for final revision before being distributed outside the CIP family. Most of the changes will be implemented prior to the external reviews in late 1989.

Our Initial Findings

Our study was designed to identify both the strengths and weaknesses of the present CIP structure, so that changes could be built around our strong points. We are proud of our many accomplishments. CIP is recognized as an exceptionally productive, cost-effective institution, with a dedicated work force of both local and international staff. The change plan goal is to guide our "A" class institution into "A+" performance over the next decade.

The preliminary findings clearly indicated that the organizational chart needed updating, with some changes in lines of responsibility. All of the research thrusts and departments named in the new chart are now the responsibility of the director of research. The research program has been restructured as a single unified program with a continuum of research activities. Thrust managers lead this research at headquarters. They also work on collaborative research projects with the regional and national programs. In recent years, CIP's expanding research activities in all regions have generated many excellent collaborative projects with national scientists. Our plan-for-change helps bring the programs at headquarters and in the regions together into an integrated program.

Our findings indicated that the executive office has not been able to expand its supportive capabilities fast enough to keep pace with the increase in research programs in recent years. Consequently, there was a need to reorganize the executive office and to add staff so that services could be streamlined. Personnel and purchasing, formerly headed by one person, has now been divided into two positions, with the addition of a local professional personnel officer. Another staff member was assigned to work directly under the executive officer to implement administrative decisions. The

department of communications and training also has been divided into two departments: the director of regional research will now be responsible for training and the director general's office will be in charge of the information sciences department.

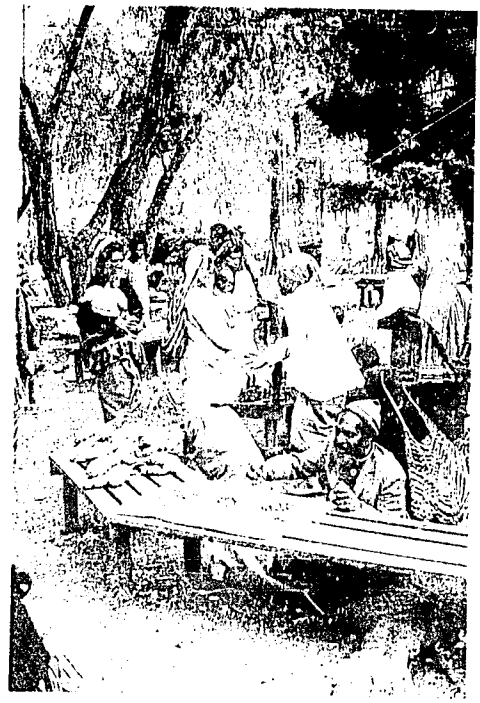
Previously, CIP staff had noted the need to have the monthly responsibility reports coincide with the departmental budget presentations. Our Change Plan complements this recommendation and provides a budgetary structure whereby costs can be properly identified by either department or thrust. This change will provide management with quicker and more comprehensive information about potential adjustments in funding.

Another measure taken as a result of our self-study was the hiring of a team of research-communications computer consultants to develop a plan that will bring CIP up-to-date with computer hardware and software for our institution's many research and information needs. This plan will be implemented as soon as the necessary funds become available. The many databases that were being developed throughout CIP are now being integrated so that computers and software will be more compatible. With the diversity of CIP's program, these improvements could well be some of the most valuable changes generated by our self-study.

While our study findings recognized the value of CIP's low-profile approach and modest facilities that have produced excellent research, a better working environment was recommended. Space and facilities are needed for the greatly expanded staff. To respond to this need, two new buildings are under construction and staff will be redistributed there when they are completed.

As our plan moves rapidly into the implementation phase, the Plan-for-Change document has been published and is available for use by others. A sister center has already followed CIP's lead with a self-study of its own, and others are considering the possibility. Although our study required more time than originally anticipated, the consensus is that the effort has been highly productive. We recommend the self-study process as an effective tool for monitoring the operations of international centers and other agricultural research institutions and for building change into their programs.

Richard L. Sawyer
Director General



CIP Collaborative Regional Bridges

CIP manages its global research and development program within a regional network through which CIP and national program scientists systematically evaluate technologies under a range of local conditions. This approach takes into account the farmer, consumer, and agribusiness community at all research levels, from the moment a problem is identified, through experiment station and on-farm testing and adaptation, until an effective solution is accepted by local potato and sweet potato producers.

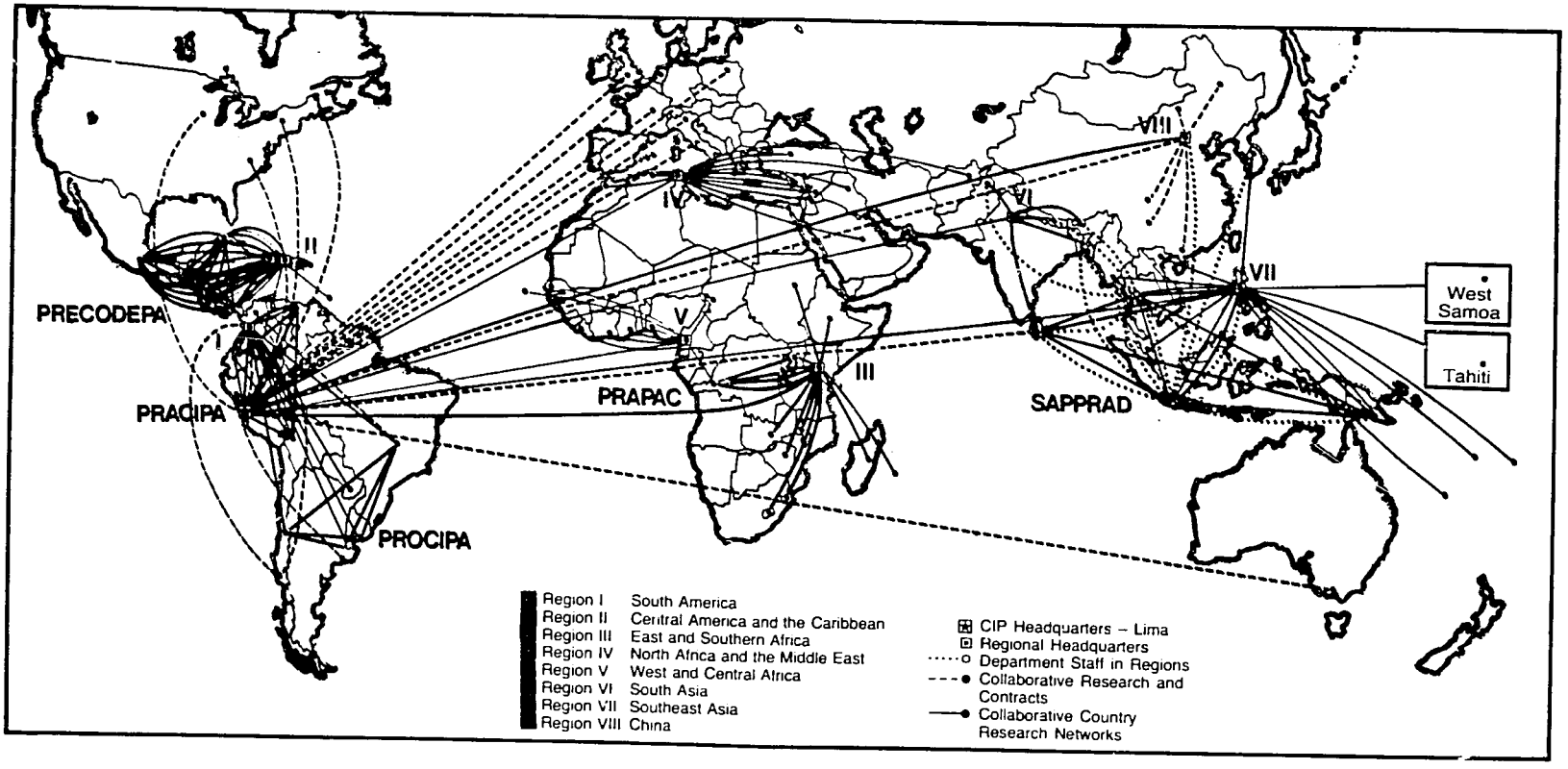
Rapid and continuing feedback from these evaluations plays a key role in guiding CIP's overall research program at headquarters in Lima, Peru. (see overview, next page)

CIP's capabilities are enhanced by numerous research and consultancy contracts that take advantage of the expertise and facilities available at other institutions, often in collaborative research in developed countries. Through contracts with developing-country institutions, we share specialized human and physical resources to focus on high priority local research.

Country Networks

CIP has helped to develop five unique collaborative research networks. In these networks, several countries in a geographical area pool their resources to solve common production problems. Once priorities have been assessed, each country undertakes the projects for which it has a comparative advantage, sharing its results with the others. CIP participates in the networks as an equal partner, providing technical assistance in its areas of expertise, as well as administrative guidance. The distribution of efforts allows CIP and the member countries to utilize their resources efficiently.

This system of shared responsibility and active interchange differs fundamentally from other agricultural networks that are designed primarily to aid in germplasm distribution. The members benefit from a wide range of research results, and at the same time their interests are consolidated and their self-reliance is strengthened.

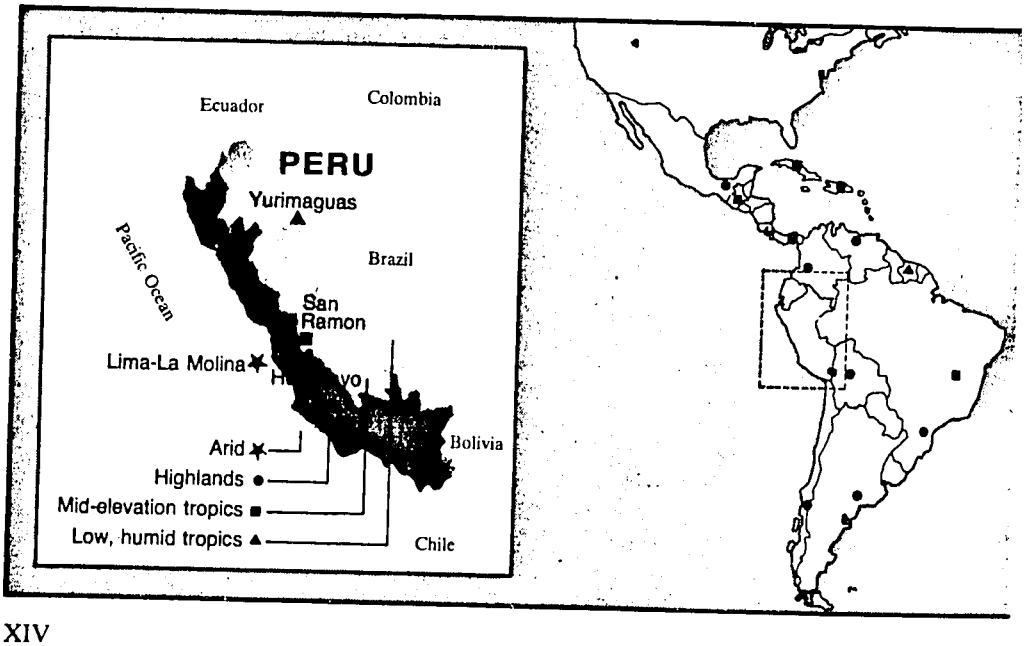


Agroecological Zones and Related Thrust Research in 8 CIP Regions

CIP has four experiment stations in Peru, one in each of the major agro-ecological regions of the country. Our headquarters is located at a coastal desert site near Lima (240 m altitude), where facilities include general research and administrative offices, as well as laboratories, greenhouses, refrigerated and diffused-light stores, growth chambers, and experiment fields. A second station, in the cool Andean highlands near Huancayo (3,260 m), is the home of CIP's World Potato Collection. The remaining two stations are in the Amazon region: one in the mid-elevation jungle of San Ramon on the eastern slopes of the Andes (800 m), and the other in the hot, low jungle of Yurimaguas (180 m).

CIP research sites in Peru and the potato-growing seasons, with meteorological data for 1988 crop year.

Site:	✶ Lima-La Molina		● Huancayo	■ San Ramon		▲ Yurimaguas
Latitude:	12°05'S		12°07'S	11°08'S		5°41'S
Altitude:	240 m		3280 m	800 m		180 m
Growing season:	Jan-Mar 88	May-Nov 88	Nov-May 87 88	Nov-Mar 87 88	May-Aug 88 88	May-Aug 88 88
Air max (° C)	28.62	23.16	20.80	31.07	29.03	31.58
Air min (° C)	19.31	13.27	6.74	14.54	11.13	19.20
Evaporation (total mm)	452.00	568.90	1001.84	1372.98	534.18	220.10
Rainfall (total mm)	0.90	4.80	661.90	1474.20	222.80	334.30
Solar radiation (daily MJ/m^2)	17.32	12.05	19.89	17.84	18.29	no data



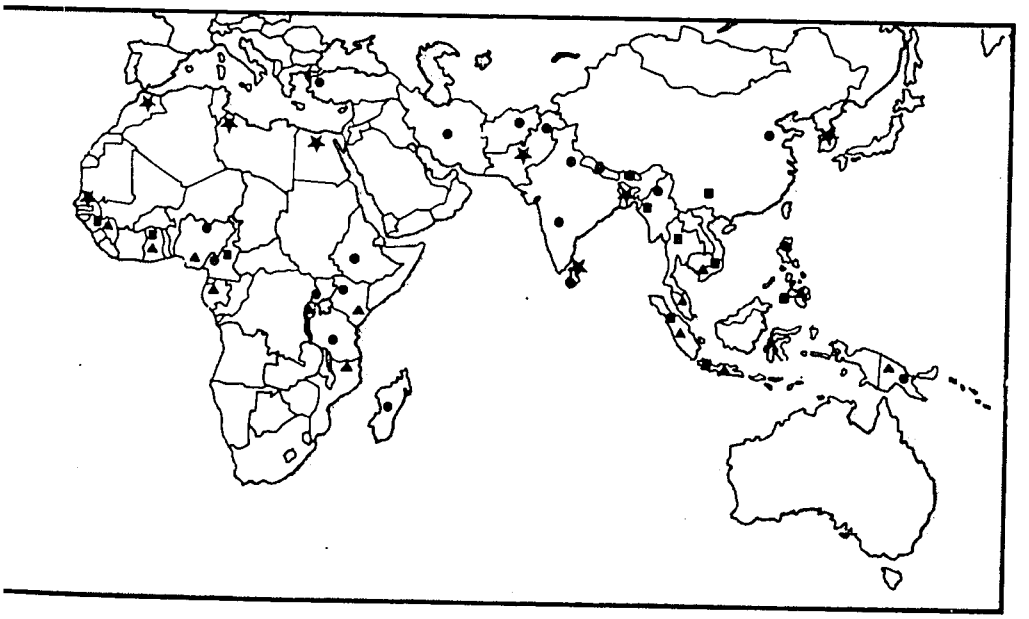
CIP's international staff includes nearly 100 scientists, administrators, and other experts from over 20 countries. Many of our international staff members are stationed at CIP regional headquarters located throughout the developing world (next page), where they collaborate directly with the national programs. In Lima, Center operations are supported by more that 500 supporting scientists, technicians, administrative personnel, secretarial and clerical support staff, and specialized workers.

CIP's six research departments–Breeding and Genetics, Genetic Resources, Nematology and Entomology, and Social Sciences–are staffed and headed by international experts from developed and developing countries.

Our interdisciplinary research is concentrated within ten "Thrusts", which combine the work of specialists from several disciplines to improve potato and sweet potato production and use.

CIP's Thrusts

I	**Collection, Maintenance, and Utilization of Unexploited Genetic Resources**
II	**Production and Distribution of Advanced Breeding Material**
III	**Control of Bacterial and Fungal Diseases**
IV	**Control of Virus and Virus-Like Diseases**
V	**Integrated Pest Management**
VI	**Warm-Climate Potato and Sweet Potato Production**
VII	**Cool-Climate Potato and Sweet Potato Production**
VIII	**Postharvest Technology**
IX	**Seed Technology**
X	**Potato and Sweet Potato in Food Systems**



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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

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Summary of Research Programs

CIP has markedly increased workloads of Thrust research within the regions of Latin America, Africa, and Asia. An emerging priority within this continuing emphasis on global regionalization is for collaborative teams to create improved varieties by crossing local potato varieties with materials from CIP. These teams are comprised of NARS and CIP scientists, and the CIP contributions provide combinations of resistances and tolerances to biotic and abiotic stresses. Materials from selected sources other than the Center's breeding program are also being promoted. For example, clone B71-240.2 (bred in Argentina), and cultivar Mariva (from Peru), show wide adaptability and are being used in several tropical countries around the world.

The strong trend towards regionalization extends throughout our Thrust research activities. CIP's scientists and NARS counterparts are increasingly working together in the regions to improve integrated pest and disease control methods, to develop potato seed production schemes that produce clean planting materials (considered by many countries to be as important as the development of new varieties), and to develop new postharvest methodologies.

Similarly, CIP is emphasizing the regional approach in sweet potato research, where we have centered initial attention on the collection, distribution, and pathogen cleanup of germplasm. This expanding program also includes socioeconomic studies on production, utilization, production and marketing patterns, as well as research on breeding, integrated pest and disease management, and postharvest methodologies.

In this summary, we have highlighted results of some major activities in each of CIP's research Thrusts. The findings represent the work of CIP's headquarters and regional research teams in collaboration with NARS and others.

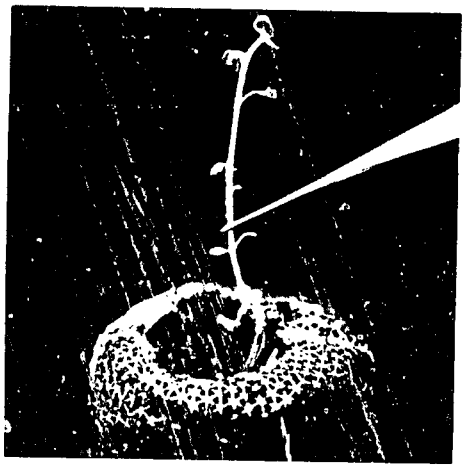
Germplasm and Breeding

New accessions for the World Potato Collection continue to be identified, and we are focusing on geographical areas that are not well represented. In 1988, we obtained 156 new accessions from Guatemala, Mexico and Ecuador, and our Collection now maintains a total of more than 4,200 non-duplicate potato clones. The wild species collection contains over 1,450 taxonomically classified accessions, with about 200 yet to be classified.

CIP's sweet potato collection, already the world's largest, is expanding rapidly: 13 sweet potato collecting expeditions gathered 620 accessions from 240 sites worldwide in 1988. This collection now holds 4,326 cultivated accessions and 1,160 wild accessions. Introduction of clonal accessions to in vitro culture is progressing well, as is the evaluation of agronomic and nutritional characteristics.

In biosystematic research on the potato, we are emphasizing the use of the endosperm balance number (EBN) to help understand and predict the crossability of wild potato species with each other and with cultivated potatoes. This work has included analysis of several wild Peruvian coastal and highland potato species. In addition to facilitating the more effective use of the species, the EBN data also help explain past failures to cross some species belonging to the same taxonomic series.

Utilization studies concentrated on *Solanum acaule*, a wild species that provides a source of resistance to PLRV, and we now have experiments under way to determine the basis of this resistance. *Solanum acaule* also has been shown to be a reliable source of resistance to PSTV, and our initial findings suggest



that PSTV resistance can be successfully transferred from *S. acaule* to cultivated genetic populations. These findings are especially important in the worldwide application of TPS technology, because PSTV is transmitted through sexual reproduction.

In recent years, CIP has developed a large population of diploid potato clones that have resistances to cyst nematodes, root-knot nematodes, bacterial wilt, early blight, late blight, PVY, and PLRV. We are adding to our comprehensive database to document the parental value of such material for tuber yield.

The genetic base of the 2x potato population was broadened by the introduction of new wild species that show promise for improving the earliness of the 2n pollen producers. We expect that the diploid clones will play an increasingly important role in the overall breeding program.

In sweet potato breeding, we have only begun to use the wild *Ipomoea* species, because of cytological and genetic complications with this species. However, wild *Ipomoea* germplasm has an array of resistances that are not found in cul-

tivated germplasm. The wild germplasm, for example, shows resistance to the sweet potato weevil, an insect that is a major, global constraint on production.

In a major cytological discovery, our CIP-based research has demonstrated that wild germplasm, especially that from the taxonomic series Batatas, can be manipulated successfully for use by commercial breeding programs. Using this new technology, we have crossed synthetic hexaploid plants and 3x clones (that produce 2n pollen) with sweet potato cultivars, and some of these crosses have produced plump seed. These seed represent 6x hybrids that contain three genomes from the cultivated sweet potato and three genomes from the wild species, *Ipomoea trifida*. We are now evaluating these hybrids in the field.

Genetic engineering experiments using DNA constructs have opened up new possibilities for development of genetic resistance to bacterial-wilt disease caused by *Pseudomonas solanacearum*. We transformed several potato clones that are normally susceptible to bacterial-wilt disease, using *Agrobacterium tumefaciens* carrying DNA sequences that code for the production of the highly bactericidal compounds, cecropin and attacin. Some promising plants, obtained from susceptible mother plants, have survived soil inoculation that would normally cause wilt. Tests are under way to determine whether these plants have been definitely transformed. This approach has an advantage over conventional methods because the resistance obtained is more likely to be useful against most, if not all, strains of *Pseudomonas solanacearum*. We obtained the DNA constructs through a CIP contract with Louisiana State University.

In developing potato populations for widespread use in tropical regions, research continued to focus on technology that would allow resistances or tolerances to pest diseases and stresses to be combined with attributes for high yield, good tuber characteristics, and processing quality. Selection emphasized the general combining ability of the progenitors.

In Peru and Brazil, advancements included selection of high-yielding, early-maturing clones with heat tolerance, immunity to PVY and PVX, and resistance to late blight. In addition, clones were identified that have resistance to PLRV, immunity to PVY and PVX, high dry-matter content, and excellent processing quality for potato chips and french fries.

Other advances included the systematic introduction of combined immunities to PVY and PVX into populations oriented to either variety selection or use of TPS for seed and ware potato production. To widen the genetic base of resistant materials, we have introduced PVY- and PVX-immune clones through contracts with Cornell University (New York, USA) and the Agricultural University (Wageningen, The Netherlands).

In genetic studies of a lowland tropical potato population with early blight resistance, our findings suggest that several important traits can be combined successfully. Attributes of this population include resistance to bacterial wilt and to early and late blight, immunity to PVY and PVX, earliness, heat tolerance, and good agronomic traits. The heritability estimates confirmed earlier findings and helped explain our rapid progress in combining early blight resistance with attributes for earliness. Other genetic

studies of potato processing quality indicate good potential for selection based on attributes such as tuber yield, specific gravity, and reducing-sugar content.

Programs for germplasm evaluation and selection of superior clones are now under way in Brazil, Uruguay, Tunisia, Cameroon, Bangladesh, the Philippines, and Vietnam. We have distributed a potato population carrying a combination of several resistances, tolerances, and other attributes to CIP regions and national programs in 56 developing countries and 14 developed countries.

Integrated Control of Diseases and Pests

Latent infection is a major problem in controlling bacterial wilt disease. In 1988, we identified two high-yielding clones that are highly resistant to bacterial wilt infection and latent infection within the tetraploid material. These clones are being considered for incorporation into CIP's pathogen-tested collection, and also are being evaluated for their parental values.

In contract research with the University of Wisconsin, we are identifying stable new sources of resistance to bacterial wilt disease. The highest levels of resistance to three different strains of *Pseudomonas solanacearum* (including a highly virulent Mexican strain) were found in accessions of *S. acaule, S. commersonii,* and *S. demissum.* We are now using these accessions as sources of resistance in protoplast fusion experiments with *S. tuberosum* for incorporation into agronomically acceptable genotypes.

Seven clones from the pathogen-tested list were found to be resistant to Verticillium wilt and five were rated as resistant to powdery scab.

We are following up on some of our earlier research that identified multi-factorial components in potato resistance to PLRV, by examining antibiosis and antixenosis as components of resistance to aphid vectors. This technology makes use of an electronic feeding monitor to examine clones from CIP's pathogen-tested list. Several clones showed antixenosis; however, antibiosis was not detected, except in *S. neocardinasii.* These data are vitally important to the further development of tropical potato genotypes with high resistance to PLRV.

In studies of the variability of PLRV, in collaboration with the Scottish Crops Research Institute in Great Britain, we identified serologically different isolates of PLRV that might require the development of strain-specific antiserum for routine detection of PLRV on a global scale. We are now analyzing the significance of this data with respect to stability of resistance to PLRV.

Our genetic studies on resistance to PVY using subspecies *andigena* and *S. stoloniferum* show that two non-allelic genes are involved in resistance. The results also showed that environmental conditions modified the expression of the gene for hypersensitivity. These findings provide a better understanding of the

deviations from expected ratios that were found in screening for resistance to PVY. The information will also help to improve inheritance of PVY immunity at the diploid level.

ELISA tests were used to examine the variability of PVX and PVY and to monitor the stability of resistance in germplasm being evaluated in the regions. Our data reveal no problems related to variability in PVY strains that are found in North, Central, and South America, and in Bangladesh, China, Europe, and Africa. PVX isolates detected in different parts of the world were classified into four serogroups and two serotypes. Serotype PVX_0 was found in North, Central, and South America, and in Europe, Bangladesh, and India. The PVX_A type was detected only in Peru and Bolivia, occurring mainly in the Lake Titicaca plateau. Fortunately, the strain PVX_{HB} that breaks the immunity to PVX found in potato is included in the highly localized PVX_A type. The stability of immunity to PVX appears to be established, unless PVX_{HB} is dispersed from its local area.

We have found that NCM ELISA is slightly more sensitive and less susceptible to background reactions than is DAS ELISA. The NCM ELISA kits are also easier to prepare and to transport, and the technique can be used for detection of PVX, PVY, PVS, PVT, APLV, and APMV. The proven practical usefulness of NCM ELISA tests has stimulated the production of test kits and protocol manuals that are now being tested under field conditions in selected CIP Regions.

We have introduced and tested the NCM ELISA technique in China, for example, in a joint project with Inner Mongolia University. This technique may replace DAS ELISA, which is routinely used by national programs to detect potato viruses in the main cultivars and for quality control of seed potatoes.

Because some polyclonal or monoclonal antibodies for virus detection are difficult to produce, we are developing a simple, rapid, and less-expensive procedure that uses a selected antiserum to multiply idiotypic antibodies that are virus-specific. In this approach, rabbits are injected with selected idiotypic antibodies. The resultant antibodies (antiidiotypic) are used to reproduce the idiotypic antibodies (anti-antiidiotypic). We have used similar methodology successfully in production of anti-anti-monoclonal antibodies for detection of PLRV.

We are also developing virus-specific nucleic acid probes to search for more sensitive and efficient methods of virus detection. New probes have now been developed for detection of the potato viruses PVX, PVY, PLRV, and APLV, and the sweet potato virus SPFMV.

In sweet potato research, we are continuing intensive work to identify sweet potato viruses. Four sweet potato viruses that had not been described previously are being identified and fully characterized. SPFMV isolates that showed minimum serological variation were found to differ substantially in some characteristics, such as infectivity and symptom production.

Collaborating with the Volcani Center, Israel, we began a search in CIP's germplasm collection for accessions with immunity. Of a total of 1,641 accessions, 30 were shown to be resistant, even after grafting to infected sweet potato scions. Some of the more resistant accessions may carry genes for immunity, and we are using aphids and grafting techniques to reinoculate these accessions.

In selections for good agronomic characteristics in combination with resistance to the cyst nematode (*Globodera pallida*), yields of many selected clones exceeded those of local check cultivars, and some clones also showed resistances to late blight and viruses. We sent advanced clones to the National Potato Research Program of Peru, and tuber families were delivered to Ecuador, Colombia, Panama, and Pakistan to initiate selection cycles.

Wild and cultivated diploid potatoes and pathogen-tested clones were screened for resistance to the root-knot nematode *Meloidogyne incognita*. Tests also were performed on TPS materials, and useful levels of resistance were identified in both types. We identified clones with high levels of resistance to root-knot nematode within cultivated sweet potato germplasm collected from Peru. Interestingly, the largest number of highly resistant clones came from the Department of Lima, indicating the effectiveness of selection pressures applied by farmers in their sweet potato cultivation practices.

Potato clones were selected that showed high levels of resistance to the potato tuber moth under storage conditions. The clones included tetraploids, diploids, and pathogen-tested genotypes.

In Colombia, potato families with *S. berthaultii* ancestors were tested for adaptation and for resistance to potato tuber moth. The promising results obtained are probably due to glandular trichomes on the foliage of these materials.

Excellent levels of control were obtained by use of granulosis virus formulations against potato tuber moth under field and storage conditions in Peru. A parasitoid, *Copidosoma desantisi*, was introduced from Peru to several areas in Colombia, and substantial parasitism was recorded.

In studies of sex pheromones, we have focused on methods that can lower costs of formulations and some of the findings suggest good economic potential. To provide guidance in control measures, pheromone traps were used to study the seasonal counts of the potato tuber moth in Ethiopia and Burundi. In Egypt, several studies examined the control of

potato tuber moth in stores and evaluated the degree of susceptibility to this pest in commercial cultivars and other genotypes. Integrated control measures included use of insecticides, granulosis virus, *Bacillus thuringiensis*, as well as wire-screened stores, light traps, pheromone traps, and *Lantana camara*. Several combinations of control methods provided excellent protection.

Production and Postharvest Technology

The role of nitrogen fertilization in adaptation of the potato to the warm tropics was examined in a series of experiments that we completed in Peru in 1988. Clone LT-7 was the top-yielding entry, showing a greater ability to utilize nitrogen fertilizer, with less reduction in partitioning of dry matter to tubers at high nitrogen levels.

As part of an increasing effort to develop potatoes for production under hot, arid conditions, studies were made of methodologies to identify drought-tolerant parental material. Findings indicated that tuber yield of potato under drought stress is related to the force required to pull plants out of the soil. We are further developing this methodology, along with complementary measurement approaches related to root growth, leaf-water potential, stomatal conductance, and leaf appearance.

Drought studies of storage-root yield of sweet potato showed a lack of interaction between clones and irrigation treatments. This finding suggests that selection for vigor and high yield under suitable irrigation conditions could facilitate simultaneous selection of clones able to yield well under drought conditions.

A range of potato cultivars, breeding lines, and species was subjected to periods of heat stress in controlled growth chambers at the Nova Scotia Agriculture College, Canada. The experiment made substantial progress in

determining the genetic and physiological basis of heat tolerance.

For relay cropping or intercropping potato with annual or perennial crops, CIP has advocated a system that features avoidance of competition for solar irradiance. However, in analyzing intercropping combinations with potato, we have found that some shade tolerance may be desirable. At Nova Scotia Agriculture College, potato clones and species were screened for shade tolerance, and related work explored physiological parameters associated with shade tolerance. We are now assessing the importance of interactions between levels of irradiance and growth temperatures, as compared with the effects on growth and photosynthesis.

Collaboration with national programs to analyze field performance of relay cropping and intercropping systems is yielding results that now are being transfered to farmers' fields. For example, in

Egypt, relay cropping of potato into an existing maize crop is an experimental practice gaining favor among farmers who wish to plant in the hot-season period before the traditional planting date. Higher maize crop yields are an additional benefit from this relay system.

CIP contract research on intercropping continues at the Southern China Potato Research Center at Enshi, Hubei Province. This work demonstrated the yield advantage of alternating double potato rows with double rows of maize, a practice that was particularly effective at higher altitudes. Other cropping patterns are being analyzed for use at different elevations.

At the Yunnan Academy of Agricultural Science, CIP contract research has examined the benefits of strip-cropping of maize and potato, on factors in addition to yield, such as incidence of soil-borne diseases and the reduction of water, soil, and nutrient losses on sloping soils. Intercropping, and contour plowing (instead of surface tilling) proved to be effective in reducing runoff from sloping fields. In western Hubei, China, two clones (bred in China) were selected that are well adapted to intercropping with maize.

The Bangladesh Agriculture Research Institute and the Sugarcane Training and Research Institute, Bangladesh are also working with CIP under contract to collect additional data on the technical and economic feasibility of intercropping potato with sugarcane. In these studies, cane yields were not reduced when the traditional single-row system for planting sugarcane was changed to a double-row system in which more space was available for the potato intercrop. However, sugarcane benefitted from residual effects of potassium and phosphorus, as well as from nitrogen applied to, but not used by, the potato crop. Other intercropping studies are under way in Burundi, the Philippine lowlands, and Indonesia.

The combined findings suggest that continued work on genetic improvement of potato for use in intercropping—fully complemented by agronomic and physiological studies—will likely yield substantial payoffs at many tropical locations.

In related efforts, participants from eight Asian countries attended a workshop held in China to discuss the status and future priorities of agronomic research that can establish potato as a major crop in hot climates. The needs cited included improved cultivars and development of appropriate methods for managing planting material. Agronomic research priorities included studies on production under suboptimal conditions, including drought.

In collaboration with the national potato program in southern Chile, non-Andean populations were developed for frost tolerance in combination with earliness and immunity to viruses X and Y. Advanced selections were made with high yield potentials and high specific gravities. In the research to adapt the cool-environment potato population to long-day environments, yields as much as 35% higher were obtained.

We selected several outstanding clones with resistance to frost and late blight in collaborative work with the national potato program of Peru, and some clones show promise as varieties. A second recombination cycle is under way to increase the frequency of genes for horizontal resistance to late blight from using sources of resistance free of R genes (Population B). Our preliminary

assessments of heritability suggest that rapid progress can be made and that some selected seedlings now have high levels of horizontal resistance.

Studies of potato storage technology concentrated on storage of consumer potatoes in warm-dry and warm-humid conditions. Methods to control postharvest losses were studied in storage experiments in Peru, Kenya, India, Pakistan, Thailand, and the Philippines. Special study interests included storage pests and diseases, water loss, and sprouting.

Our research is stressing use of integrated storage methodologies that are appropriate to local conditions. For example, in cooperative work with the Horticulture Research Institute and the Agriculture Engineering Division of the Department of Agriculture in Thailand, a farmer survey identified specific postharvest problems in the northern lowlands. On average, about half of the potato growers reported yields of less than four tons of potatoes per farm. The potatoes are commonly stored for up to three months in heaps covered with straw or dry grass. Potato tuber moth was the most important storage problem. The survey showed that 75% of the farmers would choose to improve their present storage systems, if the required investment cost would not exceed $13 per ton of potatoes. Based on these needs assessments, on-farm research tests were made to improve storage methods. Bamboo storage boxes lined with rice husks were assembled and then filled with tubers and covered with the rice husks for protection against the potato tuber moth. The boxes reduced total tuber weight loss and afforded complete protection against potato tuber moth damage. During the storage period, potato prices increased by 50%. The returns on the capital investment (storage structure and potatoes) were negative for the control and plus 27% for the boxes. This study illustrates the approach that CIP and collaborators will be establishing in the warm tropics.

In Peru, our potato-processing activities concentrated on transfer of processing technology and related training. Several small processing units are under construction in the highlands of Peru, with technical support from CIP. We are also providing technical support for the processing work of Centro Ideas, whose processing plant at Huancayo is using the technology developed at CIP's pilot plant. The Huancayo plant is now processing several Andean root and tuber crops and operates throughout the year. Products are dehydrated using a combination of solar and artificial drying.

CIP, in cooperation with ENEA, Italy, has begun designing solar dryers equipped with additional artificial drying systems, in response to a need for low-cost drying systems that are more efficient than solar drying alone. We are testing these systems at CIP's experiment station in Huancayo.

In Thailand, evaluation of clones for processing quality has been a high priority in collaborative work with the Agricultural Chemistry Division of the Department of Agriculture. All advanced clones are now routinely tested for processing quality and for domestic cooking quality.

In cooperation with Kasetsart University, Bangkok and with the Horticulture Research Institute, CIP completed a study on the demand for potatoes and potato products in Bangkok. About one-third of the total potato production there is consumed as processed products. The study predicted an increase in demand for consumer potatoes, and recommen-

dations were made for the establishment of production and postharvest programs that will gradually reduce potato retail prices (a major limiting factor for potato consumption) while increasing quality of consumer potatoes. We have found these studies especially valuable in helping to identify leverage points for improvement in the food system, and we are promoting further studies involving scientists within NARS.

The International TPS progeny evaluation trials continue to produce new high-performing progenies and this work is being greatly facilitated by our high-volume production unit in Lima. In 1988, 35 new hybrid combinations were distributed to countries participating in the international trials.

Studies continued on TPS germination and early seedling emergence responses, as well as on parental effects on rooting capacity and early field establishment of potato seedlings. Factors such as location, seed maturity and supplemental nitrogen were shown to be important in effective selection of more vigorous TPS crosses during early seedling emergence and development. It was also shown that high levels of supplemental nitrogen during seed production and proper seed development at harvest are essential for enhancing seed vigor and for preserving vigor during long-term storage.

The performance of planting materials from comparable genetic backgrounds was evaluated for effects of tuber origin, single sprout seedling tubers, stem cuttings, and apical cuttings. The results suggested that differences in tuber number and size distribution were more clearly related to the physiological origins of the plant materials than to differences in their genetic backgrounds.

To help sweet potato breeders plan effective crossing blocks, studies were made of flowering induction. Accessions from CIP's sweet potato germplasm collection were grouped into three categories, high, moderate, and low, to indicate flowering capacity. Only 3% of the accessions were rated as high capacity, 88% were moderate, and 9% were low.

A case study of the seed potato system in Ecuador was completed as part of the series designed to identify strengths and weaknesses of seed systems. The series includes similar reports on the Philippines (CIP Annual Report, 1988), Kenya (in progress), and a combined report on Canada, the Netherlands, and the United Kingdom (CIP Annual Review, 1988). In Ecuador, the findings indicated that institutional and coordination problems, rather than technical problems, are limiting the effectiveness of the seed program.

Training in seed production continued in South America, Africa, and Asia. An international seed production course organized by CIP-UNA in Lima, Peru, was attended by participants from 10 South American countries. In other training activities in Peru, more than 40 scientists from around the world visited CIP-Lima to gain practical experience with in vitro and rapid multiplication techniques. Huancayo had 30 visiting scientists from outside Peru, who were involved in seed production technology, seed program development, and on-farm research. A formal seed production course was held at Cuzco for 68 Peruvian scientists, workshops on basic seed distribution were held in Cuzco and Huancayo, and a short course on basic seed production was held in Lima. A seed production course in Rwanda focused on TPS as an alternative to traditional seed schemes. In Bangladesh, 99 participants

attended a course at BARI on use of TPS transplants, seedling tubers and tuberlets. In Santa Lucia (the Philippines), trainees from the Philippines, Vietnam, and Bhutan studied innovative, low-cost appropriate technology on rapid propagation techniques for TPS. In China, farmers and scientists worked together in a course to demonstrate new seed technologies.

Food Systems Research

A survey of National Program Leaders indicated that the principal constraints to production and use of potatoes and sweet potatoes are found in the postharvest phase of the food system.

Marketing work emphasized the importance of backstopping studies conducted by NARS scientists. Surveys of National Leaders indicated that CIP had contributed significantly to national program capacity for training, seed production, storage, and breeding. Benefits at the farm level had been achieved principally through improvement in seed quality, and also through the supply of better varieties.

Studies in Kenya and Peru revealed that farmers' criteria for evaluating new potato varieties often differ sharply from the criteria used by breeders and agronomists.

Farmers generally look for varieties that meet several minimum criteria rather than varieties that fulfill only one or a few criteria. An on-farm research study in Indonesia provided a mechanism for farmers to contribute directly to the development of TPS technology.

Future Challenges

The above findings reflect substantial progress in both potato research and in the relatively new area of sweet potato research. We must now meet the challenge of more precisely assessing the impact of CIP work on NARS and on the farmers they serve. We are seeking a deeper and clearer understanding of where our research fits within the priorities of both the national programs and the farm families in developing countries. We are finding that adoption and local adaptation of the new varieties and technologies are difficult to quantify because this kind of data is seldom reflected in official statistics. In countries where surveys have been made or where official statistics have been available, CIP's impact has been clearly illustrated in seed scheme improvement and in several other areas. More complete information is needed, however, and we are exploring new methodologies for impact assessment, with the NARS expected to play a large role in the process. We anticipate enormous benefits from this collaborative feedback process, which is designed to evaluate our progress and to focus on how to better serve the NARS.

Collection, Maintenance, and Utilization of Unexploited Genetic Resources

Thrust Profile: 1989

In biosystematic research, the Endosperm Balance Number (EBN) was determined for several wild Peruvian coastal and highland species. An EBN provides a measure for predicting the crossability of these wild species with each other and with cultivated potatoes. The Peruvian coastal potato species *S. mochicense* was found to be an ideal test species for determining the EBN of wild South American potato species. Utilization studies concentrated on identifying resistance to PLRV and to PSTV in the wild species *S. acaule*. Low frequencies of usable resistance to both pathogens were identified, and studies are under way to investigate the genetic basis of these resistances and their utilization in breeding.

The World Potato Collection received a total of 156 new accessions from Guatemala, Mexico and Ecuador, areas which are not yet well represented in the collection. Duplicate accessions continued to be identified and were eliminated from clonal maintenance after sufficient true seeds for long-term storage were obtained from these accessions. The transfer of the World Potato Collection to in vitro culture is virtually complete, with 3,340 accessions maintained in vitro. Tests on CIP's clonal potato collection indicated that it is free of PSTV. A population of diploid potato clones with useful traits was evaluated for its breeding value, and new wild species accessions have entered this diploid breeding program. CIP's first set of clonal transformation experiments for resistance to bacterial diseases using *Agrobacterium tumefaciens* as vector, yielded positive preliminary results.

In 1988, 13 sweet potato collecting expeditions gathered a total of 620 accessions in 240 localities. About 2,000 cultivated sweet potato accessions from Peru were field-evaluated in 1988, and evaluation of agronomic and nutritional characteristics continues. The introduction of clonal accessions to in vitro culture is now a routine procedure. Following approximately 35,000 controlled pollinations, cytogenetic research yielded a series of unexpected positive results that will permit the utilization of some wild *Ipomoea* species in breeding.

CIP scientists selecting potato cultivars.

Biosystematic Studies of Potatoes

In 1988, biosystematic research studies focused on determining the EBN of several Peruvian coastal and highland species. The EBN concept has been developed in the last decade and is extremely useful in understanding and predicting the crossability of wild potato species with each other and with cultivated potatoes. The evolutionary origin that accounts for the EBN is not yet completely understood. Results have shown, however, that the EBN is an indicator for an effective biological isolation mechanism that enables a species to maintain its specific integrity after it has colonized ecological niches within hostile environments. This concept has led to research that makes it possible to determine the EBN of coastal Peruvian species found in a hostile desert environment.

In these studies, hundreds of crosses were made between diploid coastal and highland species from the taxonomic series Conicibaccata and Tuberosa. Two species were each found to have an EBN of 2: *S. chomatophilum* from series Conicibaccata, an Andean species with resistance to *Phytophthora infestans* and to frost; and *S. bukasovii*, an Andean species from series Tuberosa with resistance to *Globodera pallida* and to frost. The identical EBN of the two species indicated that they should easily cross, and crosses between these two species were made without difficulty, although they belong to different taxonomic series.

Identification of the EBN of wild potato species will allow utilization of these species in more predictable and effective ways. The two diploid coastal species from series Tuberosa, *S. wittmackii* and *S. medians*, were found to be reproductively isolated from each other. *S. wittmackii* was found to have an EBN of 1, whereas *S. medians* had an EBN of 2, thus, this difference accounts for the failure of past attempts to cross these two species. Such biological isolation would be necessary in the harsh coastal environments in which hybridization would quickly erode any specialized advantage the different species might have had in coastal ecological niches.

The diploid Peruvian coastal species *S. mochicense* from the taxonomic series Tuberosa has been shown to be an excellent test species for determining the EBN of other species, because it has an EBN of 1 and because it flowers abundantly under both short- and long-day conditions. With *S. mochicense* serving as tester, 11 species were found or confirmed to have an EBN of 2. Two other species with an EBN of 1 have also served as test species: *S. chacoense* and *S. commersonii*, which belong to the series Commersoniana, from eastern South America.

Utilization Studies in Potatoes

Screening of accessions of the wild species *S. acaule* was continued to determine resistance to PLRV and to PSTV. In tests for resistance to PLRV, the accessions of *S. acaule* to be screened were infested with PLRV-carrying green peach aphids, the natural vector of this virus. In the first tests of resistance levels to PLRV within this population, levels varied from 0% to 100% per accession. Of the 61 accessions tested, 13.1% were highly resistant, 26.2% moderately resistant, and 60.7% were susceptible. An additional series of tests identified four genotypes that are apparently resistant to the replication of the virus, and five

genotypes with resistance to the green peach aphid. These nine resistant genotypes represent a low percentage (0.54%) of the tested population. However, this wild species has now been positively identified as an additional source of resistance to PLRV, and studies are under way to determine the genetic basis of this resistance.

The same population was tested for resistance to PSTV, and 9.7% of the tested accessions were found to be highly resistant, 18% moderately resistant, and 72% susceptible. These percentages indicate that genes for resistance to PSTV are fairly widespread in populations of *S. acaule*, although at a relatively low level.

Resistance to PSTV was determined successfully by mechanical inoculation and by the much more severe test of inoculation with transformed strains of *Agrobacterium tumefaciens* carrying either a monomer or a dimer full-length PSTV-cDNA insert in their genomes.

The most severe screening tests for PSTV are graft inoculation and inoculation with a transformed strain of *A. tumefaciens* carrying a trimer full-length PSTV-cDNA insert in its genome. These more severe tests broke the resistance of all the genotypes that had previously withstood infection by tests using mechanical inoculation or inoculation with *A. tumefaciens* carrying a monomer or a dimer full-length PSTV-cDNA insert.

Graft testing and challenges with transformed strains of *A. tumefaciens*, which do not occur in nature, were made to study the resistance mechanisms that protect *S. acaule* from PSTV. Mechanical transmission is the only mechanism of

A dyad found in a 3X plant, demonstrating 2n pollen production in the plant.

transmission known in nature, and ample useful resistance to such transmission has been clearly identified.

Tests were also made of the effect of temperature on the infectivity of two PSTV-carrying strains of *A. tumefaciens*. Eight genotypes of *S. acaule*, which apparently were resistant when challenged at 20° C, showed no resistance at 30° C. This finding suggests that temperature influences infection, translocation, and replication of the pathogen. This might be one explanation for the absence of PSTV in the high Andes, where temperatures never reach 30° C.

Transfer of the identified resistances to cultivated material and studies of the genetic basis of the resistances are now under way, and first indications are that resistance to PSTV can be successfully transferred from *S. acaule* to cultivated genetic populations. *S. acaule* is the only known species with resistance to PSTV, and the utilization of *S. acaule* in breeding is well understood, although the use of bridging species and various steps of ploidy manipulation are involved. Reliable sources of resistance to PSTV will become especially important in the worldwide application of TPS technology, because this viroid is also transmitted through sexual reproduction, which normally eliminates most kinds of viruses.

Potato Germplasm Collection

Collecting Activities

The World Potato Collection received new accessions from areas that had not been well represented. Thirty-two new accessions were collected in collaboration with ICTA, the national agricultural research organization in Guatemala. Another 51 native accessions were collected in Mexico in collaboration with INIFAP, the national agricultural research organization of that country. A donation of 73 accessions was received from INIAP, the national agricultural research institute of Ecuador, as a part of an ongoing project of collection and collaboration between IBPGR and CIP.

Elimination of Duplicates

A total of 250 new duplicate accessions that were found to be morphologically and electrophoretically identical to other Andean potato cultivars in CIP's collection have now been included in the group of clones to be converted to TPS. A total of 387 previously identified duplicate accessions have produced sufficient TPS for long-term storage, thus this group has now been eliminated from clonal maintenance.

In recent years, 671 accessions that were received as donations or collected have been found to be morphologically identical to 280 cultivars already maintained in the collection. After their duplicate status has been electrophoretically confirmed, and after obtaining a sufficient amount of TPS for long-term storage, these duplicates will be eliminated from clonal maintenance.

Data on plant and floral characters of 651 accessions were obtained from Argentina, enabling CIP workers to refine the groupings made the previous year on the basis of tuber characters. Electrophoretic analysis of 383 of these accessions indicated that they represented only 20 different cultivars.

More than 4,219 cultivated potato accessions are now clonally maintained at CIP. The wild species collection contains a total of 1,450 taxonomically classified accessions and about 200 accessions yet to be classified.

In Vitro Collection of Germplasm

The transfer of the World Potato Collection to in vitro culture is nearing completion, with 3,340 accessions now maintained in vitro. In accordance with CIP's own security procedures and IBPGR guidelines, the in vitro collection is being duplicated outside Peru, and over half of the collection has now been duplicated in vitro in Ecuador. By April of 1989, the complete in vitro collection will have been duplicated in Ecuador, under an agreement with INIAP. INIAP recently received funds from the Andean Development Corporation (CAF) to build cold-storage facilities for the collection. With these facilities, CIP will not need to renew the collections so frequently. Since these renewals are still done in Lima, they require frequent costly shipments of in vitro material from Lima to Ecuador.

PSTV Monitoring of the Collection

PSTV tests were made on 3,398 accessions maintained in the field and on 1,020 accessions maintained in vitro. None of the accessions tested with the NASH test showed any infection with PSTV, indicating that CIP's clonally-maintained potato collection is free of PSTV.

Distribution of Potato Germplasm

Pathogen-tested Andean cultivars from the World Potato Collection were distributed to 12 countries in the form of 778 tubers, 748 in vitro plantlets, 150 in vitro tubers and 1,650 seeds.

Potato Germplasm Enhancement

Diploid Germplasm

At Huancayo, 445 2x potato clones were evaluated for pollen stainability, 2n pollen production, tuber traits, and specific gravity. The genetic background of these clones included haploids from *S. tuberosum*, ssp. *tuberosum* and ssp. *andigena*; diploid cultivated species; and the wild species *S. stoloniferum*, *S. chacoense*, *S. sparsipilum*, *S. microdontum*, and *S. vernei*. A total of 119 clones was selected, based on 2n pollen production and known resistances to cyst nematodes, root-knot nematodes, bacterial wilt, early blight, late blight, PVY, and PLRV. Information from this selection and related data are being used to develop a database on parental value for tuber yield.

New accessions of the wild species *S. berthaultii*, *S. bukasovii*, *S. canasense*, *S. chacoense*, *S. microdontum* and *S. tarijense* were introduced into the diploid breeding program and were screened for 2n pollen production. Of these, 21 genotypes were found to produce 2n pollen: 16 from *S. berthaultii*, 1 from *S. bukasovii*, 1 from *S. chacoense*, and 3 from *S. tarijense*. Hybrids obtained from crosses of early-maturing haploids with selected wild accessions also were checked for 2n pollen production. Of these hybrids, 1,168 genotypes were tested, and 174 produced 2n pollen. At harvest, 34 clones were selected for 2n pollen production and superior tuber traits. This new material will help to widen the genetic base of CIP's 2x potato population and to improve earliness of the 2n pollen producers.

At San Ramon, yield trials were conducted during the dry and rainy seasons to evaluate the parental value of the 2x progenitors for 4x x 2x crosses. In these trials, 20 of the 4x x 2x crosses yielded better than did the best 4x x 4x check (an Atzimba x Katahdin cross that yielded

396 g/plant, on average), when harvested 90 days after transplanting during the rainy season. The best-yielding family was 78.13.13F2 x 84.101.1, which yielded almost 700 g/plant. Two families, ND 860.2 x P-127.3 (which yielded 532 g/plant) and Atlantic x P-127.3 (which yielded 516 g/plant) had a higher degree of tuber uniformity and vine earliness than did the 4x x 4x check.

This research on 2n gametes and ploidy manipulation is undertaken to take advantage of the relative ease with which genetic characters can be combined at the diploid level in comparison to recombinations at the tetraploid level. This type of diploid breeding program permits the ready utilization in modern plant breeding of the vast genepool of diploid wild potato species. Diploid genotypes that are found to be of superior parental value will be freed of virus and pathogen-tested as soon as possible. They will then be made available to breeding programs at CIP centers and national breeding programs around the world. The results obtained in 1988 clearly indicate that steady progress has been made over the past decade in this area of long-term research.

Many TPS families from the 4x x 2x material with a series of known resistances have already been widely distributed to CIP researchers for tests in San Ramon, Huancayo, Burundi, Kenya, India, Indonesia, and the Philippines.

Protoplast Culture and Fusion

A special project on asymmetric protoplast fusion for the transfer of cytoplasmic male sterility (CMS), funded by the Agency for International Development (AID), was completed at the Weizmann Institute of Science in Israel, and the first set of material has been passed on to CIP scientists for field evaluation.

Genetic Engineering

Preliminary results on CIP's first set of clonal-transformation tests for resistance to bacterial diseases were obtained in 1988 using constructs of *Agrobacterium tumefaciens*. These constructs, which were obtained through a research contract with Louisiana State University, have DNA sequences that code for the production of the highly bactericidal compounds cecropin and attacin in their genomes. Several potato clones that are normally highly susceptible to the bacterial wilt caused by *Pseudomonas solanacearum*, were used in these transformation experiments.

In addition to the code for bacterial resistance, a sequence coding for resistance to the antibiotic kanamycin was also incorporated into the *Agrobacterium* genome. If transferred into the potato genome, plantlets regenerated from a coculture of *Agrobacterium tumefaciens* with potato cells should exhibit resistance to kanamycin, in media containing this antibiotic. The first selections for kanamycin resistance were made, and then the resistant material was multiplied and tested for resistance to the bacterial-wilt pathogen under strictly controlled laboratory conditions. Some promising plants obtained from susceptible mother plants have survived heavy soil inoculation that normally would cause wilt in the mother plants. Further tests are being made to determine whether these survivors are truly transformed.

Louisiana State University has supplied 55 new constructs, all coding for resistance to bacterial diseases, which will be incorporated into potato clones, singly or in combination, to study the transformed genotypes' potential resistance against bacterial diseases.

Because sweet potato crops in China have been observed to be affected by bacterial wilt, transformation work on sweet potatoes has been initiated using constructs of *Agrobacterium rhizogenes* coding for resistance to bacterial diseases. Five Chinese sweet potato cultivars have been included.

Sweet Potato Genetic Resources

Sweet Potato Germplasm Collection

Collecting activities and taxonomic identification. During 1988, 13 expeditions were made: nine inside Peru, and one each in Argentina, Bolivia, Paraguay, and Jamaica. A total of 620 accessions were collected in 240 different localities. Of these 620 accessions, 490 belong to *Ipomoea batatas*, the cultivated sweet potato. Other *Ipomoea* species were identified in the remaining 130 accessions. These accessions were taxonomically identified by Dr. F. Austin of the University of Florida at Boca Raton. In this classification, 33 accessions were found to belong to six species of the section Batatas—the taxonomic section of the cultivated sweet potato. Of these 33 accessions, 31 were found to belong to five known species of section Batatas, and two accessions were identified as *I. umbraticola*, a species new to section Batatas. Some accessions were found to belong to species that are not included in section Batatas, and one of these is new to science. Several others in this group of 29 accessions, although known species, had never before been found in South America (Table 1-1). Articles about these discoveries will be published in the appropriate scientific journals.

Sweet potato germplasm donations. Donations of 280 cultivated accessions were received from Argentina, Venezuela, Guatemala, and Cuba. These included 42 accessions from the Argentine collections maintained by INTA at San Pedro and at the University of Tucuman; 21 accessions from the University of Maracay in Venezuela; 112 accessions from the collection maintained by San Carlos University and ICTA of Guatemala; and 105 accessions from the collection maintained by the National Institute for Research in Tropical Roots and Tubers (INIVIT) at Santo Domingo of Villa Clara in Cuba. With these donations, CIP's sweet potato germplasm collection now contains a total of 4,326 cultivated and 1,160 wild species accessions.

Germplasm maintenance. A large-scale experiment was conducted to determine the feasibility of maintaining stem cuttings under slow-growth condi-

Table 1-1. Taxonomic identification and geographic distribution of wild *Ipomoea* species collected in 1988.

Species	Distribution[a]					
	ARG	BOL	JAM	PAR	PER	Total
Section Batatas						
I. cordatotriloba	9	0	0	0	0	9
I. grandifolia	1	0	0	0	0	1
I. x leucantha	4	0	0	0	0	4
I. ramosissima	0	5	0	0	1	6
I. tiliacea	0	0	11	0	0	11
New species						
Section Batatas						
I. umbraticola	0	2	0	0	0	2
Other species	0	2	2	1	24	29
Undetermined	0	0	2	46	21	68
						130

[a] ARG Argentina, BOL Bolivia, JAM Jamaica, PAR Paraguay, PER Peru.

tions in the screenhouse. Stem cuttings of approximately 1,000 cultivated accessions were maintained for six months in bottles containing water or were planted in peat-moss pots. These basic treatments were modified by foliar fertilization and by pruning the apical shoots after three months. Cuttings maintained in bottles had low percentages of survival, and greater losses were observed in the accessions with thin stems.

The cuttings in the peat-moss pots generally had high survival rates. When the surviving stem cuttings were transplanted to the field, those grown in bottles showed a survival rate ranging from 50% to 70%, whereas those grown in peat-moss pots had a survival rate of 80% to 100%.

Storage-root yields were about the same for plants obtained from the two treatments and from plants that had been grown from cuttings obtained from field-grown plants.

Future maintenance of sweet potato stem cuttings will be done under slow-growth conditions in the screenhouse, using peat-moss pots.

Germplasm evaluation and distribution. Data on 7 storage-root characters of approximately 2,000 accessions from Peru have been recorded at harvest, using the descriptor list developed at CIP.

Living material from the collection was distributed for use in research projects at CIP, including storage roots from 672 accessions, stem cuttings from 431 accessions, and seeds from 171 accessions. Results of analyses carried out in Peru showed a total carotene content in fresh storage-root samples that ranged from 0.03 mg/100 g to 9.14 mg/100 g fresh weight in 50 accessions that had different flesh colors.

In Vitro Collection of Sweet Potato Germplasm

A successful protocol that avoids the formation of callus has been developed for the introduction of clonal accessions into in vitro culture, and this method is now considered routine. Experiments to restrict growth of in vitro plantlets have been conducted in collaboration with the Peruvian National Agrarian University (UNA) at La Molina, and cultures can now be stored for approximately one year without subcultures.

More than 1,000 clonal accessions are now maintained in vitro. Material continues to be received from outside Peru as part of an IBPGR-financed project designed to assist national programs in maintaining sweet potato collections in vitro.

The Venezuelan International Institute of Higher Studies (IDEAS) in Caracas has agreed to maintain a duplicate of CIP's sweet potato in vitro collection.

Utilization of Sweet Potato Germplasm

Ploidy of hybrids between 6x sweet potato cultivars and 2x wild species I. trifida. Utilization of wild *Ipomoea* species in sweet potato breeding began relatively recently. Cytological and genetic complications connected with the use of wild species in sweet potato breeding have stymied research in this area. Nevertheless, wild *Ipomoea* germplasm has an array of resistances that are not found in cultivated germplasm, particularly to some species of the highly damaging sweet potato weevil, which is found worldwide.

The following research results represent a cytological breakthrough in the utilization of wild *Ipomoea* germplasm, and they demonstrate conclusively that

wild germplasm, particularly from the taxonomic series Batatas, can be successfully manipulated for eventual use in commercial breeding programs. Preliminary results indicate that, after the wild germplasm has been sufficiently manipulated for use in breeding, its utilization will become relatively easy.

More than 22,000 controlled pollinations resulted in a total of 730 seeds. Due to the poor germinability of these seeds, only 250 seedlings were transplanted to the field. Counts of chromosome numbers of 242 plants identified plants with unexpected ploidy levels. As expected, 187 plants were tetraploid. Four of these hybrid plants were found to be pentaploid, indicating the functioning of 2n pollen of the 2x male parent used in this cross. Forty-one plants were hexaploid, which could be due to incomplete expression of self-incompatibility of three sweet potato female parents, or the result of parthenogenetic development of 2n eggs. Two plants had 105 chromosomes, which makes them 7x, and this result probably was due to the fertilization of 2n eggs (6x) with normal pollen (x) (Table 1-2).

In field studies at Lima and San Ramon, the tetraploid plants are being evaluated for the potential development of tetraploid sweet potato cultivars and for the use of such 4x clones as testers of 2x and 4x wild germplasm.

The production of synthetic 6x clones. A total of 812 axillary buds of 120 different *I. trifida* hybrids were treated with a colchicine solution to double the chromosome number. These hybrids had been derived from crosses between 4x and 2x *I. trifida* accessions. Studies of pollen samples revealed 55 shoots that were producing pollen with a high degree of stainability. Meiosis studies have indicated that 23 shoots are true hexaploids (6x), and 32 are triploids (3x) with 2n pollen production.

A total of 1,963 controlled pollinations among the plants that produced pollen with a high degree of stainability resulted in 220 seeds. These seeds represent a valuable 6x *I. trifida* population that combines germplasm of many 2x and 4x *I. trifida* accessions from different geographic regions.

The synthetic hexaploid plants and the 3x clones producing 2n pollen were crossed with sweet potato cultivars in 7,651 controlled pollinations, and 1,126 plump seeds were obtained. These seeds represent 6x hybrids that contain three genomes from the cultivated sweet potato and three from wild *I. trifida*. These hybrids will be field-evaluated during 1989.

Table 1-2 Number of progenies with different ploidy levels from 6x x 2x crosses of Ipomoea species

Ploidy level	No. of progenies	Possible origin
4x	187	expected hybrids (3x · x)
5x	4	functioning of 2n pollen (3x · 2x)
6x	51	parthenogenesis of 2n eggs (6x)

Regional and National Programs

Paraguay. A collecting expedition for wild species of *Ipomoea batatas* was organized in six regions of Paraguay, and 47 accessions were collected and botanical seed harvested. The national program collected 25 distinct varieties, and samples were sent to Lima.

Uganda. The Uganda project to improve the technological support to sweet potato production has just started, with major activities to begin in 1989. Uganda is the largest producer of sweet potatoes in East Africa, growing an estimated 450,000 ha. Objectives are to collect, classify, and distribute the best of the existing varieties to farmers. Introductions will be made from sources with good characteristics for countrywide evaluation, selection, multiplication, and distribution.

The Philippines. Germplasm was collected in the Philippines to develop a collection for breeding purposes. The germplasm was collected in the central and northern Philippines, and more than 100 accessions were maintained and evaluated for biotic and abiotic constraints.

Indonesia. Plans were initiated at the request of the Indonesian government to collect sweet potato germplasm in Irian Jaya, which is an important center of genetic diversity. This will be a collaborative effort involving the Indonesian government, AVRDC, IBPGR, CIP, and possibly IDRC.

China. A total of 209 local sweet potato cultivars was collected in 1988, and total accessions now equal 990. Two surveys of sweet potato distribution and production were made in northeast and southwest China.

Woman selling baked sweet potato in a street of Xuzhou, China.

Collection of sweet potato germplasm in a native market in Concepcion, Paraguay.

Production and Distribution of Advanced Genetic Material

Thrust Profile: 1989

Attributes for resistances or tolerances to pests, diseases,and stresses were combined with those for yield, tuber characteristics, and processing quality. Some of these attributes are polygenic and others are oligogenic. Progenitors were systematically evaluated and selected for high general-combining-ability effects for the polygenic characters. High-yielding, early-maturing clones with heat tolerance, immunity to PVY and PVX, and resistance to early blight have been selected in Peru and Brazil. Also, clones have been identified with resistance to PLRV, immunity to PVY and PVX, high dry-matter content, and excellent processing quality (potato chips and french fries).

The selections of 18 clones duplex at the PVY locus, i.e. (YYyyxxxx), plus a group of 20 new clones simplex at the PVY and PVX locus, i.e. (YyyyXxxx), have facilitated the systematic introduction of these two immunities into the populations oriented to either variety selection or utilization of TPS for seed and consumer potato production. When intercrossed, the PVY-immune duplex clones produce progeny having 97.2% immune individuals. When these clones are outcrossed to a susceptible clone, the resultant progeny have 83% immune progeny. When the PVY and PVX simplex clones are intercrossed, 56.25% of individuals within their progeny are immune to both viruses. When these clones are outcrossed to a susceptible clone, 25% of the individual progenies are immune to both viruses. To widen the genetic base of the virus-resistant materials, PVY- and PVX-immune clones have been introduced from Thrust II research contracts with Cornell University (New York, USA) and the Agricultural University (Wageningen, Netherlands). PLRV-resistant clones have been introduced from the Instituto Nacional de Tecnologia Agropecuaria (INTA, Balcarce, Argentina). These clones are currently utilized in the breeding program.

Two genetic experiments, using a diallel mating design and a NC design I mating design, were conducted at both La Molina and San Ramon to determine parameters of genetic variation for early-blight resistance in a lowland tropical population. This population has attributes that include resistance to bacterial wilt and to early and late blight; immunity to PVY and PVX, earliness, heat tolerance, and good agronomical traits. Average narrow-sense heritability estimates were $h^2 = 0.50$ for yield and $h^2 = 0.80$ for earliness. For early-blight resistance, an estimate of $h^2 = 0.80$ was obtained 55 days after transplanting, $h^2 = 0.72$ after 65 days, and $h^2 = 0.77$ after 75 days.

Farm level production of seedlings from TPS in Paraguay

These results confirmed similar estimates obtained in previous years and help explain the significant progress made in combining early-blight resistance with earliness.

An 8 x 8 diallel mating design was utilized to investigate genetic parameters for quantitative variation in processing quality. Narrow-sense heritability estimates of $h^2 = 0.47$, $h^2 = 0.70$, $h^2 = 0.25$, and $h^2 = 0.41$ were obtained for tuber yield, specific gravity, and reducing-sugar content at 10 and 60 days after harvest. These estimates indicated that consistent progress can be expected as a result of selection, particularly if progenitors are chosen by progeny testing.

The population carrying a combination of several attributes, including resistance and tolerance, has been widely distributed to CIP regions and national programs in the form of tubers or TPS or both. In 1988, 14 developed countries and 56 developing nations received these materials. Programs of germplasm evaluation and selection of superior clones are in progress in several national programs and in CIP regions in Brazil, Uruguay, Tunisia, Cameroon, Bangladesh, the Philippines, and Vietnam.

Potato Population Development

Major research objectives were to combine resistances to diseases and stresses with good agronomical performance, earliness, and tuber quality. Progenitors were selected for their resistance traits and general combining ability (GCA) for tuber yield, tuber quality, heat tolerance, and earliness.

The previous year's selections of 18 PVY-immune duplex genotypes (i.e. YYyyxxxx), as well as a group of 20 new clones simplex for both PVY and PVX immunities (i.e. YyyyXxxx), facilitated the introduction of these two immunities into advanced populations. These immunities were combined with existing attributes, including resistances. Simplex genotypes for both PVY and PVX immunities, combined with heat tolerance and earliness (i.e. YyyyXxxx x Yyyy-Xxxx), were mated in a group of 200 crosses.

Future selection within the progenies of these crosses will permit the identification of genotypes duplex at both loci (i.e. YYyyXXxx). Crosses of the PVY duplex genotypes to the PVY and PVX simplex genotypes will help identify PVY-triplex genotypes (i.e. YYYy) that will produce progenies that are 100% immune to PVY. These new progenitors should be available by early 1990. (Figure 2-1)

Hybrids obtained in the 1988 summer-season crossing block at the Huancayo Experiment Station (1,280 combinations) combined several attributes (Table 2-1). All groups in Table 2-1 were assembled using mating designs that permit a constant monitoring of the parental

Table 2-1 Combination of traits including yield, disease and stress resistances or tolerances.

Traits[a]	No. of progenies
Increased gene freq. for Y + X	169
Yield, Earl., Y + X	149
Yield, Earl., LB, Y + X	108
Yield, Earl., BW, Y + X	50
Yield, Earl., LB, EB, Y + X	62
Yield, Earl., LB, BW, PLRV, Y + X	65
Total	603

[a]HT Heat tolerance, Earl Earliness, Y + X Immunity to PVY and PVX, LB Late blight, EB Early blight, BW Bacterial wilt, PLRV Potato leaf roll virus

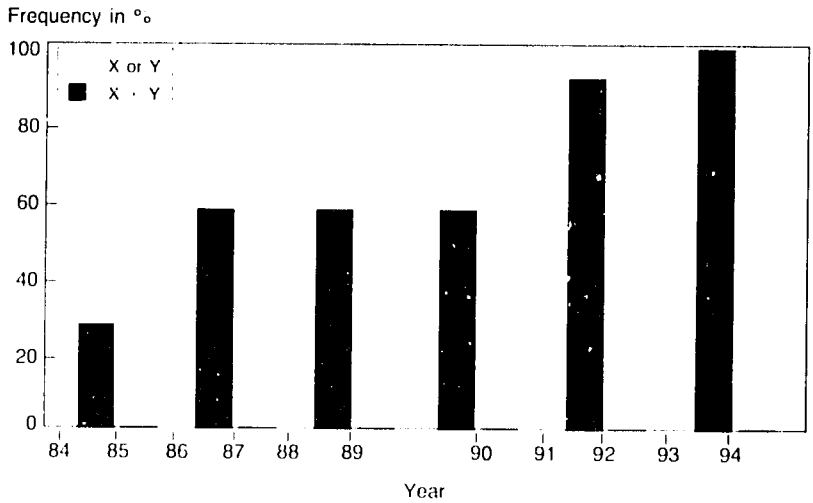


Figure 2-1. Increase in phenotypic frequency for PVX & PVY immunities at the population level.

value of the progenitors, and of the relative magnitude of the genetic variability and its components. This information is also important for evaluating the efficiency of the breeding methods and for making adjustments.

Evaluations and selections of these materials are made at CIP headquarters in Peru, and within CIP regions where regional breeders have been posted.

Tables 2-2 and 2-3 show top-performing clones in which traits for heat tolerance and virus resistance and/or immunity have been combined with medium to early maturity and high yield, with good tuber characteristics.

Advanced clones yielding up to 24 t/ha in a growing period of 75 days, have been selected in other experiments with similar materials further selected for earliness.

Genetic experiments at San Ramon, Peru examined parameters of genetic variation in two populations. One experiment used a 9 x 9 diallel mating design to combine resistance to bacterial wilt, late blight and early blight; immunity to PVY

Table 2-2. Top-performing, heat-tolerant and PVY + PVX-immune clones selected at San Ramon. Summer 1988 (growing period: 90 days)

Clone	Yield (t/ha)	Earliness[a]
(Atlantic x Y84.007) 5	39.3	7
(Y84.007 x Atlantic) 4	30.5	7
(LT-8 x 575049) 19	24.9	5
(LT-8 x Y84.001) 9	24.6	7
(LT-8 x C83.119) 15	23.9	5

[a]Earliness: 1 very late, 5 medium, 9 very early

Table 2-3. Top-performing, heat-tolerant, PLRV-resistant and PVY + PVX-immune clones grown at La Molina. Summer 1988 (growing period: 90 days)

Clone	Yield (t/ha)	Earliness[a]
(Pirola x LT-9) 13	40.3	5
(Utatlan 69.1 x 7XY.1) 9	35.7	7
(Serrana x 7XY.1) 2	35.3	3
(LT-8 x Atlantic) 9	24.6	7
(LT-8 x Katahdin) 7	21.7	7

[a]Earliness: 1 very late, 5 medium, 9 very early

and PVX, earliness, heat tolerance; and good agronomical traits. The second population was assembled in a North Carolina mating design I (10 male clones each mated to a random sample of 5 females). In both experiments, narrow-sense heritability estimates were high for yield ($h^2 = .50$) and for earliness ($h^2 = .80$). For early-blight resistance, an estimate of $h^2 = 0.80$ was obtained 55 days after planting, $h^2 = 0.72$ after 65 days, and $h^2 = 0.77$ after 75 days. These medium- to high-heritability estimates have permitted the rapid introduction of early-blight resistance into the early-maturing population adapted to the warm and hot tropics. This population also carries a medium level of resistance to late blight and immunity to PVY and PVX, and has good agronomical traits. These materials also have been successfully used in other developing countries. (Uruguay, Brazil, and the Philippines).

Of 1,437 clones tested for late-blight resistance in the field at Rio Negro, Colombia, 128 were selected at harvest. The same set of 1,437 clones was tested in Toluca, Mexico, and the data are being analyzed.

Trials to study the stability of resistance to late blight are under way in some CIP regions. However, the selected materials contain major genes in addition to horizontal resistance. In some regions, horizontal resistance may be difficult to assess if compatible races are not present to overcome the resistance of R genes. Results of a trial conducted in Huanuco, Peru are underscoring this problem, showing that the highest-yielding clones, including one of the controls (Atzimba), were not infected by late blight. This indicates that the local isolates do not have the complex races to overcome the resistance provided by R genes in some clones (including the control Atzimba). However, the local control Revolucion was severely attacked early in the growing season.

Research in tropical countries has made substantial progress in developing populations and clones with good processing characteristics for the fast-food industry (french fries and chips). Clones with adequate specific gravity and low reducing-sugar content were selected at both San Ramon and La Molina during the summer season. The yield of these selected clones ranged from 25 t/ha to 30 t/ha.

An 8 x 8 diallel mating design, including reciprocal crosses, permitted the study of quantitative variation for processing characteristics, i.e. specific gravity and reducing-sugar content. In one evaluation at La Molina, narrow-sense heritability estimates were $h^2 = 0.47$ for tuber yield, $h^2 = 0.70$ for specific gravity, and $h^2 = 0.25$ for reducing-sugar content 10 days after harvest. The estimate obtained for reducing-sugar content 60 days after harvest was $h^2 = 0.41$ (storing the tubers at room temperature, $\pm 25^{o}$ C). These estimates indicate that additive genetic variability is medium to high for all these traits and that selection should provide consistent progress.

In the diallel experiment, no reciprocal effects were found. This suggests that the direction of the hybridization would not alter the mean progeny performance. In addition, among the 8 progenitors utilized in this experiment, the CIP clones LT-7 and TS-2 showed an ability to transmit to their progenies the traits of high yield, adequate specific gravity, and low reducing-sugar content at 10 and 60 days after harvest. This finding is important because, normally, in hot environments the specific gravity is drastically reduced. In contrast, for example, the variety

Table 2-4. Top-selected clones for processing attributes from an early-maturing, heat-tolerant and PLRV–, PVY and PVX–resistant population.

Clone	DM	SG	RS	Attribute
(B-71-240.2 x 7XY.1).026	23.1	1.085	1.66	Chips
(Serrana x LT-9) 041	23.5	1.093	2.20	Chips
(Serrana x LT-9).052	24.0	1.096	2.33	Chips
(Serrana x LT-9).057	20.9	1.084	2.00	French fries
(BR-63.15 x 7XY.1).102	22.9	1.090	1.00	Chips
(Bzura x LT-9).105	25.7	1.106	1.66	Chips
(Bzura x LT-9).109	25.8	1.100	2.00	French fries

DM Dry matter SG Specific gravity RS Reducing sugars
1 0%, 2 .1%, 3 .25%, 4 .5%, 5 2% or more
Less than 3 is adequate.

Katahdin from the USA transmitted low yield, low specific gravity and very low reducing sugars.

In 1988, a sample of 110 heat-tolerant, early-maturing, PLRV-resistant, and PVY- and PVX-immune clones was evaluated for processing attributes and for french-frying and chipping abilities. These clones had been exposed to virus infection during four seasons. In a field trial at Ica (300 km south of Lima), 43 clones were selected as potentially good for processing (Table 2-4). They also had excellent agronomical attributes and virus resistance.

A sample of CIP's pathogen-tested clones was evaluated for processing quality at San Ramon. The clone 720091 (Mex-32) was found to be excellent for making french fries, while the clones 800943 (Saturna), 676014 (CFC-69.1), 720111 (Aracy), 720119 (Esperanza), and 800956 (Shuang Feng) showed good qualities for making chips.

In evaluations of selected clones at La Molina and San Ramon (summer season), excellent results were obtained from clones from the progenies of the CIP progenitors LT-7 and TS-1, crossed to the European varieties Cleopatra, Aphrodite, Bernlef, and Altema and the CIP BL-2.5 and BL-2.9.

True-Potato-Seed Research

Two experiments were conducted at San Ramon and Huancayo to study early growth characteristics: root length, hypocotyl length, length of first internode, and number of internodes. Measures of these characteristics were analyzed with those for reproductive and agronomical traits (obtained during the growing period and at harvest). Multiple correlation analysis showed low associations. This finding suggests that selection of superior progenies should not be based solely on evaluations of their performance at the early stages of growth.

These two experiments, which used a North Caroiina mating design II (20 males and 20 females distributed in 5 sets of 4 x 4 progenitors), also obtained estimates for some reproductive and agronomical traits (Table 2-5). Some of these traits have high heritability, which accounts for the rapid progress in improving them.

Experiments utilizing 4x-2x crosses conducted at San Ramon and Huancayo evaluated the parental value of diploid clones producing 2n pollen in their hybrid combinations with tetraploid clones. The results of the experiments indicated that diploid clones will produce later-maturing progenies that perform better under favorable conditions (Huancayo). Furthermore, the progeny performance of the 4x-2x matings depends heavily on which tetraploid female progenitor is used.

The stress conditions at San Ramon strongly affected the agronomical and reproductive characteristics. These results suggest that selection of the diploid populations should focus on adaptation and agronomical traits to enable selection of better progenitors. This emphasis would maximize the theoretical potential of the 4x-2x breeding approach.

At San Ramon and La Molina, studies were made of the cytoplasmic effects on reproductive and agronomical characteristics of TPS progenies. In a sample of 24 progenies, 12 reciprocal pairs were compared for 14 characteristics. Performances among the 12 reciprocal pairs clearly differed, indicating that certain combinations of progenies are significantly superior to others, regardless of the direction of the cross. However, there were no differences within each individual pair of reciprocal crosses, indicating that reciprocal effects were insignificant in the population that was analyzed.

Table 2-5 Heritability estimates for TPS traits from the NC Design II experiment evaluated at San Ramon and Huancayo (1988)

Traits	h^2
Plants at harvest	0.12
Yield/plant	0.55
No. of tubers/plant	0.44
Earliness	0.23
Days to flowering	0.63
Flowering intensity	0.30
Style length	0.51
Pollen production	0.43

Maintenance, Multiplication and Distribution of Pathogen-Tested Materials

The following materials are now available from the CIP pathogen-tested list: 227 advanced cultivars and varieties, plus 22 in the cleanup process; and 139 accessions from native and wild germplasm, plus 6 in the cleanup process.

Ten sweet potato cultivars are now in the process of thermotherapy, the first stage of cleanup for this crop.

TPS production in Chile during 1987 and 1988 produced the highest yields to date, approximately 31 kg of usable seed from 6 progenies.

Potato genetic materials in various forms were distributed to 14 developed countries and 56 developing countries. (Table 2-6).

Regional Germplasm Evaluation

Brazil. In May, 1987, a sample of 37 progenies, some of which combined *Alternaria solani* and virus resistance, were introduced from CIP-Lima. Seedlings were transplanted to pots in the greenhouse and the tubers obtained were used during the following season for a preliminary field evaluation. The best progenies were Atlantic x NDD 277.2, Atlantic x TS-2, Maine-28 x TS-2, Maine-47 x TS-2, Y-84.004 x NDD 277.2, and LT-9 x NDD 277.2. The average percentage of selection in these progenies was extremely high at 49%. Both TS-2 and NDD 277.2 are excellent progenitors.

Seventy-three clones selected the previous year were evaluated in 1988 for

Table 2-6. Distribution of germplasm, 1988.

Region	Clones		In Vitro		In Vitro Plantlets		Tuber Tuberlets		TPS Family		TPS Progeny	
	Units	Accs.	Units	Accs.	Units	Accs.	Units	Accs.	Units	Accs.	Units	Accs.
– (14)	583	69	589	284	0	0	3366	29	19082	245	17435	35
I (10)	3731	565	517	108	235	4	10963	345	71120	361	257700	164
II (12)	3453	402	275	114	485	12	1109	42	0	0	44000	13
III (11)	4000	394	402	153	550	19	7791	362	29995	189	39200	26
IV (5)	3205	208	0	0	0	0	8877	227	14200	71	124600	105
V (3)	1527	178	0	0	0	0	2058	71	0	0	166000	54
VI (6)	1194	47	317	156	0	0	2425	41	6600	51	3791500	102
VII (8)	2233	152	74	37	0	0	2072	65	42545	254	613800	137
VIII (1)	0	0	48	24	0	0	0	0	0	0	0	0
Total 70	19926	2015	2222	876	1270	35	38661	1182	183542	1171	5211150	636

yield performance, tuber characteristics, and resistance to *A. solani*. Twelve clones showed early maturity, good yield and tuber characteristics and 25% foliar damage or less caused by the fungus. The progenitors of most of these clones were Serrana and NDD 277.2.

Thirty-four progenies combining PVY immunity with other resistances (LB and EB) were inoculated at the seedling stage with the PVY^n and PVY^0 strains. On average, the segregation ratio was near to the expected, 1 susceptible to 1 immune. The immune-selected genotypes will be further tested for yield and tuber characteristics.

Uruguay. Seventy virus-resistant clones from several germplasm introductions of the 1982 to 1984 seasons were evaluated at the CIAAB experiment station at Las Brujas for virus symptoms and at the Salto station for yield. Twenty-four clones revealed neither mosaic nor leaf roll symptoms and their yields ranged from 0.5 kg/plant to 1.5 kg/plant. Many of the selected clones had the clone 7XY.1 as progenitor.

Tunisia. During 1985-1986, evaluation and selection of germplasm with virus resistance permitted the selection of 8 clones which were planted in 100-hill plots for the 1988 Tunisian variety trial. Yields of these virus-resistant clones ranged from 428 g/plant to 721 g/plant while the check Spunta yielded 772 g/plant. These clones will be introduced to the Tunisian variety trials in 1989 in 100-hill plots with 4 replications.

From the virus-resistant tuber families introduced in early 1988, 45 clones were selected for further evaluation. The CIP clone LT-8 is progenitor of 60% of the selected clones. This clone is early-maturing, heat-tolerant, and PVY- and PVX-immune. This confirms the evidence of the good parental value of the clone, as indicated in earlier results from Peru, Uruguay, and Bangladesh.

Cameroon. Ninety-five late blight-resistant clones from CIP-Lima were planted at the Upper Farm (2,000 m) for multiplication and evaluation. The plants were not protected and the late-blight epiphytotics were very severe. Seventy-eight clones had a final late blight-resistance score of 4 (25% foliar damage or less), and 14 clones had yields of more than 1 kg/plant.

Thirty-three heat-tolerant, early-maturing, virus-resistant tuber families

(with a total of 834 genotypes) received from Lima, were planted at Upper Farm. Selection was for yield, tuber characteristics, and maturity, and 144 clones were retained. Progenies from the parental clone 7XY.1 had the highest yields.

Bangladesh. A sample of 3,822 genotypes (belonging to 21 tuber families) received from CIP-Lima, were tested for performance against locally-cultivated commercial varieties used as checks. These materials were selected for high yield, earliness, heat tolerance, resistances to PLRV, bacterial wilt, and late blight, and immunity to PVY and PVX. In all but two progenies, the percentage of selection at harvest was high (up to 45%). The best progenies were Serrana x LT-7, B71-240.2 x 575049.2, B79.636.1 x LT-9, and B79.636.1 x 575049.

Another set of 38 tuber families, consisting of 2,425 genotypes, immune to PVY or PVY + PVX, were planted late in the season to expose them to the peak aphid season in order to provide an adequate selection pressure against PLRV and other viruses. In spite of the late planting, a number of genotypes gave yields of 500 g/plant.

Evaluation of F_1 C_2 clones: These materials were selected from single hills in 1987. A total of 602 clones grouped into 24 progenies were field-evaluated against the local varieties Cardinal, Patrones, and Diamant. At harvest, 208 clones were retained for yield and tuber characteristics. Table 2-7 shows the yielding ability of these clones. Heat tolerance, earliness, and disease resistance are also major attributes of these clones. Analysis of the field data showed that Serrana, B71-240.2, LT-8, LT-9, 377964.5, Maine-28, and Maine-47 were good progenitors, as indicated by the high percentage of selected genotypes from their progenies.

Evaluation of F_1 C_3 clones: This material, consisting of 91 clones, has been studied for the last three years. From these clones, 37 were selected for their consistent good performance and other economic characteristics. Eleven of the 37 clones were considered to be outstanding in comparisons made with European varieties (Table 2-8).

Evaluation of F_1 C_6 clones: These genotypes introduced as tuber families from CIP-Lima in 1981-1982 are in the final phase of selection. Fifteen of these clones were planted in Bangladesh in four locations that represent distinct ecological zones: Joydebpur, Chittagong, Bogra, and Munshiganj. These clones were compared with the Cardinal variety; the seed stocks of the clones were in clonal generation 6, whereas Cardinal was grown in Bangladesh only once after certified seed was introduced (Table 2-9). The clones had a very low degeneration rate, maintaining a yield comparable to or higher than the check. Therefore, these clones do not need their seed stocks changed as often as do the costly European cultivars that usually degenerate at a faster rate. Additionally, CIP hybrids have very early to medium maturity rates, for example, 379673.150 ma-

Table 2-7 Range of yielding ability of F_1 C_2 selected clones Munshiganj, Bangladesh, Feb. 1988

Range of yield (g/plant)	No of genotypes	Mean yield (g/plant)
Above 1000	5	1140
800-900	27	840
500-799	120	598
Below 500	56	373

Table 2-8. Performance of top F_1 C_3 clones.

Clone	Pedigree	Yield (t/ha)
384068.55	CH 103209 x Atlantic	57.8
384109.264	C83.155 x 377888.7	55.2
384084.315	LT-7 x TS-2	51.2
384077.184	C83.258 x Katahdin	45.8
384078.217	C83.119 x Sto. Amor	44.1
384093.844	(378015.17 x 377904.1).2 x Katahdin	38.1
384081.275	377959.9 x LT-9	42.0
384077.193	C83.258 x Katahdin	38.1
Cardinal (main crop check)		32.3
Patrones (early maturity check)		21.1

tures in 70-80 days; 379667.501, in 80 days; and 379688.230, in 90 days.

The Philippines. From August 1987 to August 1988, the Regional Redistribution & Training Center at Santa Lucia distributed the following pathogen-tested germplasm to nine countries in CIP regions VI, VII and VIII: in vitro plantlets (102 units), tuberlets (8,380 units), stem cuttings (600 units), and TPS (633,300 units).

Fifteen tuber families with earliness, heat tolerance, early-blight resistance, and some with PVY and/or PVX immunity, were field-tested at Canlubang (150 m). There was little early-blight infection. The best-adapted families were 385380 (378676.6 x AVRDC 1287.19), 386466 (Maine-47 x C83.119) and 386180 (Maine-47 x 7XY.1). The selected materials will be evaluated for early-blight resistance in a trial including the appropriate checks.

In the Philippine highlands, several trials with advanced genetic materials as clones and tuber families were conducted to evaluate late-blight resistance. A group of clones previously selected for late-blight resistance at Sayangan, Atok was tested at La Trinidad. Yields were variable, but the resistance to late blight was usually higher than that of the well-adapted varieties used as checks.

A set of 16 tuber families originating from CIP-Lima was tested under severe, late-blight attack at La Trinidad. Some of

Table 2-9. Advanced regional trials at four locations in Bangladesh, February 1988.

	Yield (t/ha) and Location			
Clone	Joydebpur	Chittagong	Bogra	Munshiganj
379673.151	17.6	19.1	–	12.7
379667.501	17.4	14.2	30.0	14.4
379688.230	15.3	11.6	29.8	17.5
Cardinal	15.7	18.9	28.6	15.1
379667.421	16.9	–	28.4	19.7
379673.150	12.8	11.1	28.1	16.0
B71.240.2 (CIP 720088)	14.4	8.4	23.3	9.4

these families are early maturing and, in spite of being almost as susceptible as the check, their yields were better or equal. This was probably due to an earlier and faster bulking taking place before the foliage had been drastically damaged by the fungus.

A set of 25 clones was tested for late-blight resistance against two well-adapted varieties used as checks. Both the yields and the resistance levels of CIP clones were superior to Cosima and Granola.

A sample of 26 advanced clones from the CIP breeding program and check varieties was tested at Canlubang for yield, earliness, and early-blight resistance. Although the damage caused by early blight was severe in the three highest-yielding clones, their respective yields were higher and their size larger than those of the check Cosima. This suggests that a rapid tuber bulking took place, which permitted the attainment of high yields in spite of the foliar damage by *Alternaria*.

After two seasons of field testing for yield and tuber characteristics, a set of 317 field-selected clones was evaluated for tuber-seed quality, following 9 months in diffused-light storage (DLS). The DLS had minimum temperatures ranging from 21.5° C to 21.9° C and maximum temperatures ranging from 28.3° C to 31.8° C. After the DLS storage, 155 of the 317 clones were retained for field testing. At harvest, 53 clones (34%) were selected for yield and tuber characteristics (Table 2-10). The performance of the best-yielding clones is remarkable, considering that the tuber seed had been stored at high temperatures. The ability to maintain high tuber-seed quality after extended storage is an important attribute that significantly facilitates potato production in the hot lowlands.

Table 2-10 Tuber yields of the best 10 clones out of 155 advanced clones and cultivars at Canlubang (150 m) Laguna, December 31, 1987 to April 8, 1988

Clones Cultivars	Pedigree	Average tuber wt. (g)	Yield (t/ha)	Earliness
384081 2	377959 1 x LT-7	83	36.7	5
384065 4	378015 25 x 3780 bulk	57	31.7	5
384091 11	377887x(377887 17x(LT- 7)21	68	30.9	7
384068 6	CH103209 x Atlantic	66	29.2	6
384069 11	378676 6 x Atlantic	51	27.9	5
2-482	Serrana x DTO-33	66	27.3	5
384104 13	ZPC-72-F96 x 377904 10	112	24.7	7
2-447	Serrana x DTO-33	52	24.1	6
384707/1 9	Atzimba x NDD-277 2	35	22.9	7
417 3	65-ZA-5 x 378015 18	42	22.9	5
Serrana (check)		86	18.5	7
Berolina (check)		55	17.3	7
Cosima (check)		50	14.4	8
Grand mean		56	18.7	6
LSD (.05)		15	3.0	NS

Earliness: 1 very late, 5 medium, 9 very early

A second set of 199 clones from CIP-Lima TPS progenies was field-selected at Canlubang and segregated for resistances to late and early blight, bacterial wilt, PLRV, PVY, and PVX. This set was tested after 9 months of DLS storage, and 155 clones were retained and planted in the field. The five highest-yielding clones were 385389.5 (Mex 750815 x AVRDC 1287.19), 50.4 t/ha; 385306.5 (Bzura x LT-9), 42.5 t/ha; 385306.2 (Bzura x LT-9), 41.5 t/ha; 385376.9 (C83.119 x AVRDC 1287.19), 41.2 t/ha; and 384556.6 (Atzimba x AVRDC 1287.19), 40.7 t/ha. Check yields were low: B-71-240.2, 20 t/ha; Serrana, 16.3 t/ha; and Desiree, 14.7 t/ha.

A set of 666 PVY-immune clones from CIP-Lima tuber families was selected at Canlubang for heat tolerance, earliness and tuber characteristics. These clones were stored in DLS for 9 months and 417 of them were evaluated under field conditions. The yields of these clones were very high (32.4 t/ha-39.6 t/ha) in spite of their early maturity, and all clones had higher yields than did checks B71-240.2 and Serrana, but not higher than CIP clone LT.

The pedigrees of the top-performing clones presented in Table 2-10 include the progenitors LT-7, Serrana, Atlantic, and 378015.16 (TS-2), which are characterized by a high general combining ability for yield, heat tolerance, and good tuber characteristics. The clone LT-7 is also capable of maintaining good tuber-seed quality after 9 months in DLS. The clone apparently transmits this desirable attribute to its progenies.

A set of promising clones and cultivars was tested at Canlubang and Santa Lucia for tuber yield, dry-matter content, and chipping and frying quality. The CIP clones LT-7, 378597.1; Mex-32, 380584.3; and the cultivar Atlantic received the highest ratings. The two clones with the highest yields were LT-7 and Atlantic. The results indicate that it is possible to produce good quality raw materials for both french frying and chipping, even under hot conditions. This can be achieved either by testing existing cultivars or, better still, by selecting clones that, in addition to good adaptation and tuber quality, carry resistance or tolerance to some of the most important biotic or abiotic stresses.

Control of Bacterial and Fungal Diseases

Thrust Profile: 1989

Research advances included higher levels of resistance to bacterial wilt (*Pseudomonas solanacearum*), reduced incidence of latent infection, greater frequency of resistance in the potato breeding population, and higher yields. Breeding work has begun to develop some levels of resistance in TPS families. In China, two CIP clones were selected for breeding for wilt resistance, and extensive trials were begun for two other clones.

The University of Wisconsin research contract continued to identify new, stable sources of resistance by exposing 60 previously selected accessions to three *P. solanacearum* strains. The highest levels of resistance to these strains were found in *Solanum acaule* (PI 498183, 498178, 498081); *S. commersoni* (PI 320267); and *S. demissum* (PI 175423). Studies of resistance to *P. solanacearum*, using a tissue culture system, demonstrated that virulence and hypersensitive response genes are located in the same DNA region and are closely linked.

Bacterial soft rot of tubers (*Erwinia* spp.) at harvest was significantly lower in plots where calcium sulphate was applied prior to transplanting of TPS families, and the harvested tubers were more resistant to *E. chrysanthemi* in inoculation tests. Plantings with seed tubers demonstrated that potato-clone effects had more influence than did calcium application effects on soft rot induced on tubers after harvest. Resistance to soft rot was confirmed in two of the six clones selected the previous year, and screening for resistance to both soft rot and blackleg was initiated with 64 clones. Interactions of *Erwinia* and fungal pathogens were also noted.

Race 0 of *Phytophthora infestans* was used to screen for horizontal late-blight resistance, and a complex race was used to screen for horizontal resistance in the presence of R genes for vertical resistance. Field screening was done in Huanuco, Peru, in collaboration with staff of the National Potato Program (INIAA). At Huancayo, Peru, 16 selected late-blight-resistant clones were progeny-tested to determine the general combining ability for tuber yield and the best parents were selected to continue the crossing program.

Establishment of *Beauveria* in the central Andean area of Peru.

Early-maturing, early-blight resistant clones were identified at La Molina and San Ramon. Seedling screening for early blight will continue in the field at San Ramon using artificial inoculation. PVY immunity has been incorporated into the breeding population. Of 113 clones from the pathogen-tested list, 30 were shown to be resistant to early blight at San Ramon.

Seven of 77 clones from the pathogen-tested list were found to be resistant to Verticillium wilt. In another screening experiment, five of 72 clones showed resistance to powdery scab. Among seven treatments for chemical control of soilborne pathogens at San Ramon, the two providing the best control were Busan 1020 + APCA and Methyl bromide.

Bacterial Wilt Disease of Potato

Breeding for Resistance to Bacterial Wilt

Peru. The large, highly variable population of tetraploid bacterial wilt-resistant material continued to be evaluated and field-tested under different environmental conditions, and in the greenhouse at Lima. Greenhouse tests concentrated on the detection of resistance to *Pseudomonas solanacearum*. Two high-yielding clones, BWL-87.105 and BWH-87.446, were highly resistant to infection and did not show latent infection when tested in warm environments (30° C to 32° C). Their average yields were 0.84 kg/plant for clone BWL-87.105 and 0.74 kg/plant for clone BWH-87.446. These clones are being evaluated for their parental value and are being considered for incorporation into CIP's pathogen-tested collection for distribution.

In another trial, 43 selected clones with a yield average of approximately 1 kg/plant were evaluated for wilting in the field and for latent tuber infection after harvest (Table 3-1). Eight clones showed neither field symptoms nor latent infection, whereas the remaining 35 clones

Adult Andean weevil infected by *Beauveria* sp. under lab conditions.

showed both, at levels ranging between 1% and 50%. Within this group, 5 yielded nearly 1 kg per plant. Controls (cv. Yungay) had bacterial wilt and latent infection levels varying between 20% and 100%. Further trials are being conducted to confirm these results.

Greenhouse screening of seedling populations showed that a new population screened last year produced between 38% and 65% of resistant genotypes per progeny for race 1, and between 30% and 70% of resistant genotypes for race 3. Survivors of this evaluation were intercrossed and 72 families from the resulting progenies were tested in 1988. As a result of the intercrossing, resistance frequencies increased to between 75% and 95% per progeny for race 1, and to between 30% and 84% for race 3. A second screening test will check these results.

Of 256 clones tested in the greenhouse for resistance to strain 204 of race 3, 48 (18.8%) were resistant. Between 60% and 100% of bacterial wilt was observed after inoculation of these resistant clones, three of which were totally unaffected. Of 230 different clones screened against strain 235 of race 1, 84 (36.5%) had levels of resistance ranging from 60% to 100% of wilt-free plants per clone. Eight of these clones remained 100% wilt-free.

A new group of 353 clones has been highly selected for yield and agronomic characteristics and will now begin field and greenhouse selections for resistance to wilt and latent infection. In a yield trial at La Molina, 285 clones with a yield of between 0.8 kg and 2.5 kg per plant were selected for further trials from among 627 clones with proven resistance, excellent agronomic characteristics, and strong heterosis. However, only 4.2% of 5,880

Table 3-1. Newly developed potato clones selected for their yield and high levels of resistance to bacterial wilt[a]. This material was grown under conditions of natural infestation in a farmer's field at Obraje, Carhuaz, Ancash Department, Peru at 2,810 m[b].

Clone number	Total yield of 3 repetitions in kg	Number of plants harvested	Yield/ plant in kg
1 BWS-87.2	16.4	15	1.09
2 BWS-87.21	16.2	15	1.08
3 BWS-87.23	10.5	9	1.16
4 BWL-87.10	10.6	10	1.06
5 BWH-87.38	15.4	15	1.02
6 BWH-87.105	12.0	12	1.00
7 BWH-87.134	14.7	12	1.22
8 BWH-87.172	11.6	10	1.16
9 BWH-87.203	15.0	15	1.00
10 BWH-87.211	7.8	6	1.30
11 BWH-87.233	12.0	11	1.09
12 BWH-87.236	9.2	9	1.02
13 BWH-87.247	14.6	12	1.21
14 BWH-87.250	8.0	8	1.00
15 BWH-87.257	10.5	10	1.05
16 BWH-87.271	16.0	15	1.06
17 BWH-87.289	17.5	15	1.16
18 BWH-87.291	15.2	15	1.01
19 BWH-87.296	12.3	12	1.02
20 BWH-87.305	14.4	12	1.20
21 BWH-87.315	11.0	9	1.22
22 BWH-87.332	13.4	12	1.11
23 BWH-87.354	9.9	9	1.10
24 BWH-87.364	10.8	8	1.35
25 BWH-87.365	9.0	9	1.00
26 BWH-87.366	10.0	8	1.25
27 BWH-87.368	13.7	12	1.14
28 BWH-87.383	12.0	11	1.09
29 BWH-87.389	17.7	15	1.18
30 BWH-87.432	16.0	15	1.06
31 BWH-87.446	14.0	12	1.16
32 BWH-87.464	15.0	15	1.00
33 BWH-87.466	10.2	9	1.13
34 BWH-87.473	9.9	9	1.10
35 BWH-87.487	8.1	8	1.01
36 BWH-87.489	10.9	9	1.21
37 BWH-87.511	12.0	10	1.20
38 BWH-87.515	10.2	9	1.13
39 BWH-87.517	13.8	12	1.15
40 BWH-87.534	9.3	8	1.16
41 BWH-87.535	11.0	10	1.10
42 BWH-87.541	13.3	12	1.15
43 382296.106	14.0	12	1.16

[a] Percentage of wilting in the field:
- In resistant test clones: 0-40%
- In susceptible check: 20-100%

[b] Five tubers per clone were interplanted with five tubers of the susceptible check, the Peruvian variety "Yungay".

Number of repetitions 3 in Randomized Complete Block design.

These selected clones are now being further evaluated for latent infection or resistance to wilt.

seedlings from recent crosses were selected for further trials, since climatic factors had severely retarded seedling growth and vigor.

From a total of 373 clones selected from a TPS population during the 1986/87 growing season at Huancayo, 315 clones (84.4%) were selected for their yield (ranging from 1 kg to 2.53 kg per plant) and their excellent agronomic characteristics. High levels of resistance to bacterial wilt, regardless of the race of *P. solanacearum*, were demonstrated in 106 of the selected clones during a severe greenhouse test. The resistance levels observed against race 3 (strain 204) ranged from 70% to 100% of wilt-free individuals in 28 clones (5 clones remaining 100% wilt-free). In the other 78 clones, the same resistance levels (70% to 100% of wilt-free individuals) were observed in tests against strain 235 of race 1 (10 resistant clones remaining 100% of wilt-free).

In San Ramon, 27 clones (35%) were selected for BW resistance in combination with earliness (90 days), from a total of 76 clones. During the rainy season of 1987/88, 54 TPS families were evaluated and 320 clones selected with yields ranging from 0.43 kg to 1.25 kg per plant. When these clones were tested for latent infection, two families were found to be completely free, 14 families showed latent infection in between 1% and 5% of harvested tubers, and 38 families had ranges of up to 30%.

Integrated Control of Bacterial Wilt

Peru. As part of a new project to identify components for integrated control of bacterial wilt, screenhouse experiments were conducted at San Ramon to study the effect of soil amendments on the the incidence of the disease. Amendment mixtures containg urea, quick-lime, and composts of coffee pulp and sugar cane bagasse, were incorporated into sterilized soil that was then inoculated with *P. solanacearum* (Biovar 1, race 1). The rate of incorporation was 1% (by weight). When potato seedlings of a susceptible family (Atzimba x R 128.6) were transplanted into the soil one month later, the incidence of bacterial wilt was 19%, compared with 95% in amended soil. Field experiments are in progress to study the practical value of these findings.

To study the effect of crop rotation on the survival of soilborne *P. solanacearum* (race 1), experiments were conducted under field conditions in San Ramon. Different rotation crops were planted in heavily infested soil in five replicated blocks. The population of *P. solanacearum* in samples of rhizosphere soil was estimated monthly by dilution plating on Granada's selective medium. Two months after planting, *P. solanacearum* could not be detected with this method in the rhizosphere of maize, field bean, cowpea, and sorghum, but it was detected in soils from the crotalaria, sweet potato, weed-fallow, and bare-fallow plots. After three months, the bacteria could be detected in only one plot of sweet potato, thus the rhizospheres of these crops do not appear to promote growth of the potato pathogen that would contribute to its maintenance in soil.

Resistance to *P. solanacearum* bred into TPS Families.

Peru. The feasibility of conducting seedling screening tests to determine resistance to bacterial wilt in TPS families was studied under screenhouse conditions in San Ramon. Standard methodology was used. For each progeny, 3 trays containing approximately 50 seedlings each were inoculated with a locally-isolated virulent strain of *Pseudomonas solanacearum*

(Biovar 1, race 1). A total of 3 separate tests was made on 28 progenies from 14 crosses and their reciprocals from the TPS breeding program. When the progenies were evaluated 28 days after inoculation, the percentage of wilting did not differ among replicates of the same progenies. Progenies from reciprocal crosses between the same two progenitors did not differ in percentage of wilting, except in one case during the third evaluation. However, significant differences in wilting incidence were detected among different progenies. The total disease incidence varied among the 3 evaluations, with mean percentages of wilting measured at 33%, 49%, and 54%, respectively.

When progenies were ranked according to frequency of susceptible genotypes, no correlation was observed between the relative behavior of each progeny on different evaluation dates. Genetic variation among seed lots of the same progeny did not explain this phenomenon, because results from replicate lots of each progeny were similar for each evaluation. It was assumed that differences in screenhouse environmental conditions between evaluations were responsible for the differences in wilting incidence and disease intensities.

Similar results were observed when an additional 12 families were tested at each of the evaluation periods. Since effective screening is essential to a successful improvement program, future research will examine factors affecting this process, both in the greenhouse and in the field.

New Sources of Resistance

To identify new, stable sources of resistance to bacterial wilt, more than 60 accessions, previously rated as highly resistant, were retested at the University of Wisconsin by stem inoculation with three strains of *P. solanacearum*. Because one of the isolates used was the highly virulent Mexican strain S276, survival rates were lower than in the previous tests. The highest levels of resistance to the three strains were found in *Solanum acaule* PI 498183, 498178, and 498081; *S. commersoni* PI 320267; and *S. demissum* PI 175423. Survivors are now being used as sources of resistance in protoplast fusion experiments with *S. tuberosum* subsp. *tuberosum* cultivars.

Studies of Resistance to Bacterial Wilt

At the University of Wisconsin, a tissue-culture system is being used to study bacterial wilt resistance. The research focuses on the physiology and genetics of the hypersensitive response induced in tissue cultures of *S. phureja*. Progress has been made in cloning genes of the strain B1 that control the production of a 60 kd protein. This protein, produced by the bacterium when it comes into contact with plant cells, appears to cause the browning and death of potato cells. Two Tn *5* mutants have been used (BJA34 from strain B1 and KD688 from strain K60), which do not cause the hypersensitive response in callus tissues or intact plants and which do not produce the 60 Kd protein. In these two mutants, Tn *5* is inserted in the same *Eco*R1 DNA fragment (7.0 kb).

When the cloned fragment from BJA34, pT34, was transformed into strain K60, all of the Km-resistant and Amp-sensitive transformants carried the fragment containing the Tn *5* instead of the wild-type fragment. The fragment exhibited the same DNA hybridization pattern as does BJA34. With pT34 as a probe, the corresponding wild-type fragment was identified in a K60 genomic library, and was then subcloned and conjugated into K60 transformants. All of the

transconjugants restored the virulence and positive hypersensitive response phenotype of K60. These results suggest that the virulence and hypersensitive response genes are located in the same DNA region (*hrp*) and are closely linked.

Next, saturation mutagenesis was conducted on the 7.0 kb fragment, using Tn *5-lac*, which contains a promoter-less *lac* gene that enables it to be used as a reporter for induction of DNA transcription. When the mutants were tested for hypersensitive response and virulence, two separate regions were evident: one (1.5 kb) controls both virulence and HR; the other (1 kb) affects only virulence. The direction of transcription in these two regions has been established. In addition, it was found that plant extracts induce the 1.5 *hrp* region at levels two to three times higher than background levels. This region is of particular interest because it appears to control production of the 60 kb protein that also is induced by plant tissues. The 1.5 kb region is now being studied to see if it contains the gene that codes for the 60 kb protein. If this is determined, the next steps will be to: 1) establish the limits of the gene by further Tn *5* mutagenesis and 2) obtain the nucleotide sequence of the gene.

Studies of this type, which provide the plant pathologist with specific information on host-pathogen interactions, will potentially lead to the development of alternative strategies for plant breeding, biological control, and pathogen identification.

Burundi. Control of bacterial wilt continues to be the major research emphasis. The symptomless carriers with latent infection are of special interest. Four apparently tolerant clones are being stored in diffused light at 28° C - 32° C to test for latent infection.

Seed crop studies have shown that removal of a diseased plant and its two adjacent neighbors reduces both the incidence of bacterial wilt during the season and the percentage of rotten tubers at harvest. Efforts will be made to introduce this type of roguing in all seed-production units.

China. For the last three years, clones 800928 (MS42.3) and 800935 (MS-IC.2) have been found to be resistant to race 3

Establishment and multiplication of *Beauveria* under field conditions.

of *P. solanacearum* at stations at Penxian, Sichuan Province and at Enshi, Hubei Province. These two clones are being used as parents crossed with local cultivars at the Potato Center, southern China and at the CAAS Institute of Plant Protection. Two other clones, 377852.2 and 381064.8, have proven moderately resistant to wilt at the Penxian and Enshi stations and have produced high yields of 1,390 g and 1,965 g per hill in Zhangbei County, Hubei Province. After further adaptation trials, these clones will be proposed for introduction into the local potato production.

The Philippines. A large scale breeding and evaluation program continues in Mindanao in collaboration with the Philippine Department of Agriculture. A total of 64 advanced clones were evaluated for bacterial wilt and *Erwinia* resistance, adaptation, and yield. Six of these clones have now been sent to PRI for clean up.

Clones with a combined resistance from four wild species continue to be evaluated with promising results. Following selection for adaptation under hot lowland conditions, the clones are now being screened for BW resistance. Promising clones also were selected from local crosses. *Erwinia* spp. is becoming an increasingly important problem. A cross between 381064.7 and 378597.1 (*Erwinia*-resistant parent) has given several promising clones with both bacterial wilt and *Erwinia* resistance.

Bacterial Soft Rot and Blackleg of Potato

Effect of Calcium

Peru. The effect of calcium nutrition on the incidence of *Erwinia* diseases during production and storage of potatoes from TPS was further studied in San Ramon. Calcium sulphate was applied in the row before transplanting and incorporated together with the compound fertilizer used. When potato seedlings (Atzimba x R 128.6 and Atzimba x DT033) were transplanted in a randomized block design with four different levels of calcium application, the number of plants with above-ground symptoms did not vary significantly with the calcium treatment.

Table 3-2 shows the causal agents of stem diseases in the field, where 31.6% of post-transplant losses were due to non-pathogenic causes such as insect damage and environmental stress. At harvest, the number of plants with soft-rotting progeny tubers and the total percentage of rotting tubers were significantly lower in plots with higher calcium applications (Table 3-3).

Healthy tuber yield average increased to 19.56 t/ha with the highest application

Table 3-2. Pathogens isolated from wilting potato transplants from the field in San Ramon during the wet season, 1988.

Pathogen	Frequency of isolation
Erwinia chrysanthemi (Echr)	25.5
Erwinia carotovora ssp *carotovora* (Ecc)	12.8
Fusarium oxysporum	8.5
Fusarium solani	2.1
Pythium sp.	4.2
Rhizoctonia solani	2.1
Sclerotium rolfsii	2.1
Ecc + *F. oxysporum*	2.1
Ecc + *R. solani*	2.1
Ecc + *F. oxysporum* + *S. rolfsii*	2.1
Echr + *Fusarium* sp.	2.1
Echr + *F. oxysporum*	2.1
Other causes	31.6

rate of 2,240 kg/ha of calcium sulphate. Application of 1,493 kg/ha resulted in a yield of 17.05 kg/ha; an application of 747 kg/ha resulted in a yield of 15.85 kg/ha. Soft rot then was induced in harvested tubers by inoculation through submersion in a suspension of *Erwinia chrysanthemi* and anaerobic incubation at 25° C for four days. These results confirmed earlier findings that tubers treated with the highest levels of calcium in the field were significantly more resistant to soft rot (Table 3-4).

Studies also were made of the effect of calcium nutrition during potato production from seed tubers. Calcium sulphate was broadcast over the field and incorporated at a rate of 18 t/ha prior to planting of seed tubers of several cultivars. Susceptibility to soft rot was found to be influenced more by the cultivar variety than by calcium treatment. Only for the cultivar Desiree did calcium treatment significantly increase tuber resistance during the dry season. The use of calcium has been shown to increase *Erwinia* resistance in both tropical (San Ramon) and cool (Wisconsin) climates. Future studies should take place at other locations with an added socioeconomic component.

Table 3-3 Effect of calcium sulphate nutrition on the incidence of *Erwinia* diseases in crops produced from true potato seed in San Ramon during the rainy season 1988.*

	Calcium sulphate rate kg/ha			
Diseases	0	747	1,493	2,240
% Plants with soft-rotted tubers at harvest	14.88 a	15.25 a	13.50 b	9.38 c
% Soft rot by weight at harvest	5.27 a	4.06 b	3.63 bc	3.01 c

*Combined means for 2 TPS families (Atzimba x R128.6 and Atzimba x DTO-33)

Numbers followed by the same letter are not significantly different, according to Duncan's multiple range test (P = 0.05)

Table 3-4 Percentage weight of soft-rotted tissue from harvested tubers, 4 days after soft-rot induction (mean of 30 tubers), when harvested from plots with different rates of fertilization with $CaSO_4$.*

	Application rate of $CaSO_4$ (kg/ha)			
TPS family	0	747	1,493	2,240
Atzimba x DTO 33	46.79	39.37	33.19	26.38
Atzimba x R128.6	55.87	55.39	40.72	32.03
Average	51.33a	47.38a	36.95b	29.20c

*Numbers followed by the same letters are not significantly different, according to Duncan's multiple range test (P = 0.05)

Resistance Selection

Peru. Recent reports suggest that *Erwinia* is increasing in importance in several regions. Thus studies have been made of the range of susceptibility among the germplasm distributed from CIP. Screening of 106 potato clones from the pathogen-tested list was done to determine their relative susceptibility to bacterial soft rot caused by *Erwinia chrysanthemi*. Test tubers were field-grown and stored in diffused light in Huancayo and then screened four months later using the vacuum infiltration method (see Annual Report, 1988). After 5 days of incubation at 25° C and 100% RH, the relative susceptibility of each clone was rated according to the mean incidence of rotting in replicated tuber samples. Of 6 clones that showed resistance in tests during the previous year, only 2 (Up-to-date and DGY-73) again showed resistance. Of 21 clones that showed susceptibility the previous year, 20 were again rated as susceptible.

Inconsistencies are probably due to differences in the water potential of tubers, which are least variable immediately after harvest.

Sprouted tubers of 64 potato clones were latently infected artificially by vacuum infiltration in a suspension of *E. chrysanthemi* containing 10^6 colony-forming units (CFU) per ml and then air-dried for 48 hours at 25° C. Inoculated tubers were planted in sterilized soil in pots in the screenhouse, under more natural conditions than the previously described testing, and monitored over a 90-day growing period. The relative susceptibility of each clone was then rated according to the mean number of plants in replicated samples that developed symptoms of either soft rot or blackleg. Clones showing a low relative susceptibility to blackleg or soft rot will be retested to confirm their resistance.

Interaction of Fungal and Bacterial Diseases in Potatoes

At San Ramon, short rotations have resulted in severe losses of potato plants in the pre- and post-emergence stages. A wide range of fungi and bacteria have been isolated from wilting plants and rotting tubers (*Fusarium solani, Fusarium oxysporum, Pythium splendens, Macrophomina phaseoli, Rhizoctonia solani, Pseudomonas solanacearum, Erwinia carotovora* spp. *carotovora* and *Erwinia chrysanthemi*), although their relative importance was not clear. Thus, the pathogens were tested in the screenhouse to determine their pathogenicity and, in some combinations, their increased potency as a result of interaction. Sterile compost was infested by adding the homogenate of an agar culture of each fungal pathogen. Bacterial pathogens were added directly to the compost in aqueous suspensions containing 10^5 CFU per ml at a rate of 20 ml per kg of compost, and 35-day-old potato seedlings (Atzimba x DTO-33) were then transplanted directly into the inoculated soil in pots. Wilting was monitored in three samples of 10 transplants per pathogen and the proportion of rotten progeny tubers was determined after 12 weeks.

Only *P. solanacearum, R. solani,* and *Pythium* sp. induced wilting. Fungal wilting was induced within 1 week after transplanting, whereas bacterial wilt was not observed until several weeks later. *P. solanacearum* and *R. solani* were most frequently isolated in the field.

At harvest, all pathogens had induced tuber rotting and could be recovered from infected tubers. By far the most damaging pathogen was *P. solanacearum,* which was isolated from 71.4% of tubers. Other damaging pathogens included *Pythium splendens* (38.0%); *Fusarium* spp. (26.2%); *Macrophomina phaseoli* (24.6%) and *Erwinia* spp. (13%).

Wounding of stored, well-cured, potato tubers was essential for in vitro infection by *Pythium splendens* and *Fusarium* spp., and it significantly increased the amount of infection by *M. phaseoli*. Bacterial soft rot was not induced when tubers with latent *Erwinia* infection were incubated at 5° C and 85% RH for 7 days. However, interaction with fungal pathogens was demonstrated and soft-rot symptoms were particularly severe when *P. splendens* and *M. phaseoli* were inoculated into tubers following artificial latent infection with *Erwinia chrysanthemi*.

Fungal Diseases of Potato Late Blight

In 1988, 51,676 seedlings were screened against simple race 0 and an isolate of

complex race 1, 2, 3, 4, 5, 6, 7, 10, 11 of *Phytophthora infestans*. Approximately 3,000 seedlings survived the test against each race. Race 0 was used to identify individual plants from these populations that had no R genes for resistance, but that showed some level of horizontal resistance. These plants will be screened against the complex race and also will be tested under field conditions in Colombia and Mexico, where there are high levels of inoculum pressure.

Clones screened with the complex race will follow the International Testing Scheme for clonal selection, in combination with screening for earliness and other desirable agronomic characters. This scheme is now being improved to provide a more reliable test. The effects of R genes in the genetic material will be neutralized by inoculation with the complex race to allow for selection of true horizontal resistance.

Field Testing for Late-Blight Resistance under Local Conditions

Testing under local conditions at Huanuco is being done in collaboration with the National Potato Program to provide advanced genetic material for variety development in Peru. Evaluations were made of a total of 375 clones, of which 10 were arranged in a simple 10 x 10 lattice. The more resistant clones were infected only slightly. The frequency distribution of clones clearly shows that the majority have R genes that are not compatible with local isolates of *P. infestans*, thus limiting the evaluation of horizontal resistance.

Progeny Testing for Tuber Yield of Late-Blight Resistant Clones

Sixteen clones selected through the International Testing Scheme were progeny-tested for tuber yield at Huancayo, using a line x tester design. Some clones showed good ability to transmit their yield potential. Similar progenies were sent for late-blight testing in Mexico, however, findings have not yet been reported.

Selection of parents based on combining ability for yield and resistance to late-blight is becoming a routine procedure in CIP's breeding schemes.

The Philippines. Breeding and selection efforts for late-blight resistance continue in a collaborative effort between CIP and the Northern Philippine Root-Crop Research and Training Center at La Trinidad. Recurrent selection work on populations initially received from Lima has provided improved yields and adaptation while maintaining LB resistance. The next set of advanced clones is now ready for on-farm, multi-locational trials.

Two outstanding clones, I-1085 (CIP 676089) variety Sita in Sri Lanka, and I-1039 (CIP 676008), have been enthusiastically adopted by farmers. Unfortunately, the Sita variety lost its resistance two years after introduction. Because its resistance was mainly due to vulnerable major genes, it was overcome by changes in the pathogen. The same vulnerability could occur with both of these "I-" clones in the Philippines.

Early blight

Peru. A sample of 31 progenies was evaluated for resistance to *Alternaria solani* during the summer of 1988. Individual genotypes were evaluated under greenhouse conditions at La Molina. Cuttings were taken from the same genotypes and evaluated at the adult-plant stage in the field at San Ramon. Although estimated correlations between seedlings and adult plants based on individual readings for each progeny were not significant, they did show a

negative trend. The mechanisms for resistance in seedlings and adult plants may differ and probably involve a complex interaction between growth stage and pathogen. Clones LT-8 x 378676.6, LT-8 x 575049, India 1039 x 378867.6, and PW.49 x BL-2.9 were consistently resistant to *A. solani* and were early-maturing at La Molina and San Ramon.

Two field trials for chemical control of early blight in the early-maturing cultivar DTO-33 were conducted at San Ramon, Peru. During the winter season, the best control was achieved with Euparen + Dithane M45. During the summer season, Euparen + Dithane M45 and Dyrene + Dithane M45 reduced foliar infection and increased yields.

At San Ramon, 113 cultivars from the pathogen-tested list were evaluated under field conditions. Of these, 30 cultivars were evaluated as resistant, 24 as moderately resistant, and 59 as susceptible 80 days after planting. In most of the cultivars, resistance was correlated with lateness.

Uruguay. The 12 clones remaining from the 47 introduced from CIP in 1985 were planted in two regions in late 1988. Two clones were selected and have been included in regional trials; one is being grown in vitro. From the 225 clones introduced in 1987, approximately 13% have been selected. These were exposed to early blight in northeast Uruguay in early 1988. True seed of the best progenies were received from CIP in 1988, and tuber families are being produced in greenhouses for field planting in late 1989.

Powdery Scab, *Spongospora subterranea*

Soilborne Pathogens

Verticillium Wilt (*Verticillium dahaliae*)

Clones from the CIP pathogen-tested list were evaluated for resistance to *V. dahliae* under greenhouse conditions at La Molina. Procedures were reported in the 1988 Annual Report. Of 77 clones, 7 were rated as resistant, 19 as moderately resistant, and 51 as susceptible. The resistant cultivars were CGN-69.1, Seseni, P7, Chata Blanca, CUP 199, 703279, and MEX 750658.

Powdery Scab (*Spongospora subterranea*)

In collaboration with The National Potato Program of Peru (PIPA) and the University of Cuzco, a field trial was established in naturally infested soil to evaluate 72 clones from the pathogen-tested list. Based on percentages of infected tubers and severity of infection, the clones Gabriela, Puebla, G-8142.6, Albina, and G-80041.7 were rated as resistant. During the second season the clone Gabriela showed resistance under field conditions at Cuzco.

Chemical Control of Soilborne Pathogens

A chemical trial to control soilborne pathogens (*Rhizoctonia solani, Pythium spp., Fusarium spp., Macrophomina phaseoli, Erwinia spp.* and *Pseudomonas solanacearum*) was conducted at San Ramon in naturally infested soil where potatoes had been planted for three consecutive seasons. Of the seven treatments tested, the two providing the best control were Busan 1020 + APCA and Methyl bromide. Only 2.8% of the plants in the control plots survived (Fig. 3-1). Bacterial wilt (*P. solanacearum*) was the most damaging disease, killing 70% of the plants.

Incidence of Wilt and Fungal Pathogens on Roots of Potato in the Central Highlands of Peru

A total of 683 stem samples with varying amounts of wilt and 582 tubers with

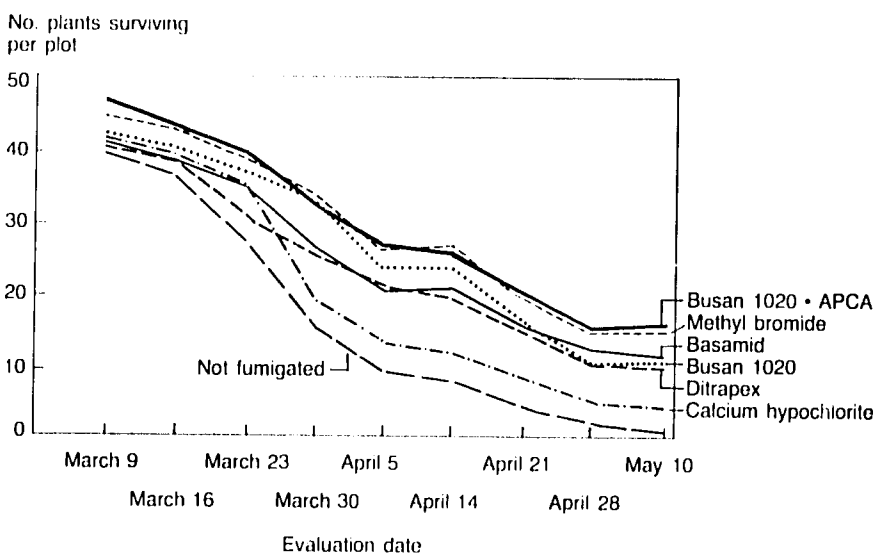


Figure 3-1. Survival of transplants (Atzimba x R 128.6) in plots treated with various fumigants to control soilborne pathogens in San Ramon (1988).

various symptoms of rot were collected from three important potato-producing zones in the central highlands: Comas, Huasahuasi, and the Mantaro Valley.

The pathogens isolated from stem samples were *Fusarium* sp. (18.74%), *Verticillium* sp. (13.03%), *Phytophthora erythroseptica* (2.04%) and *Rhizoctonia* sp. (1.17%). *Fusarium* sp. was the pathogen most frequently isolated in Comas and the Mantaro Valley, whereas the most common pathogen in Huasahuasi was *Verticillium* sp.

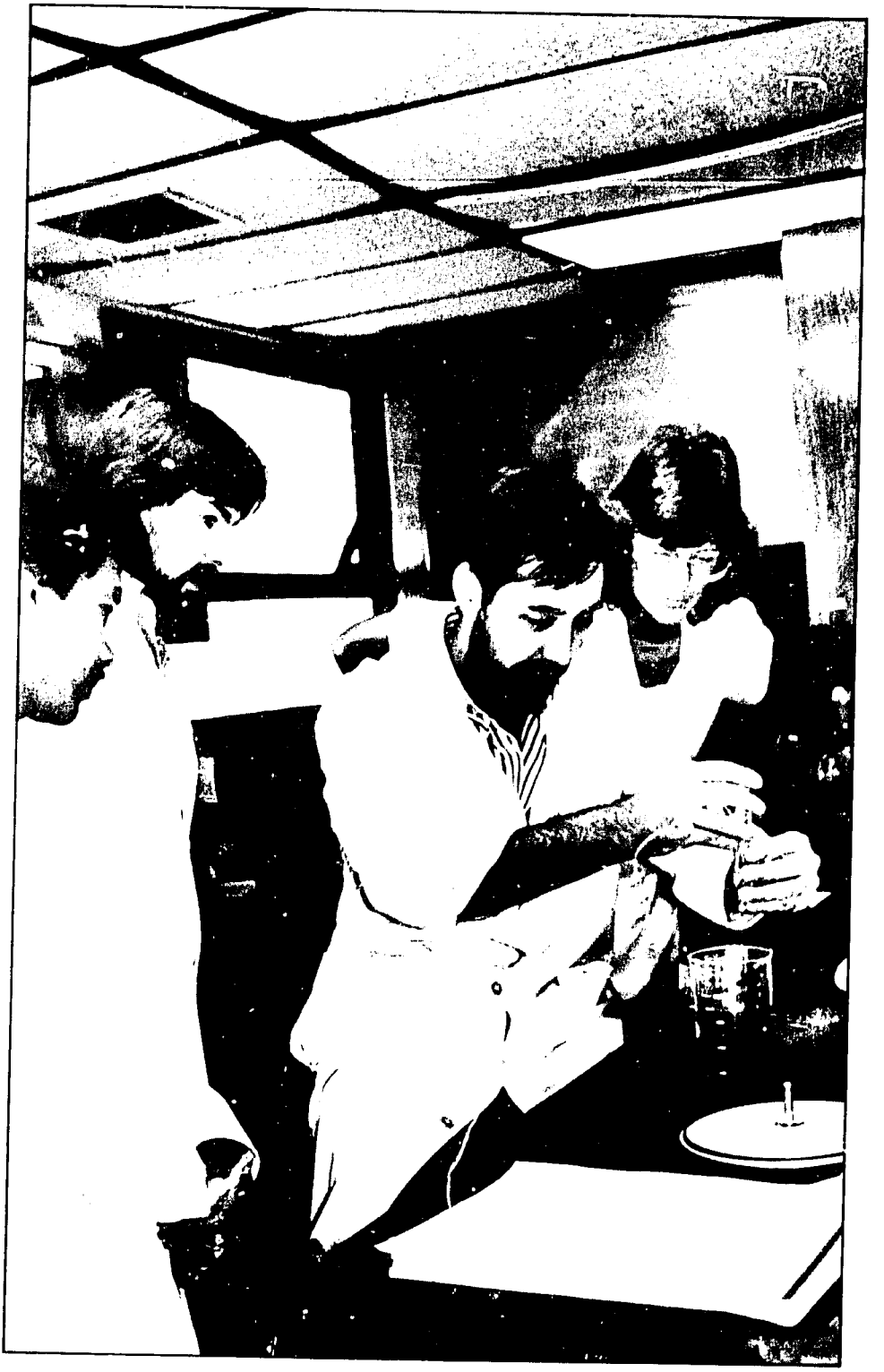
The pathogens isolated from tubers were *Fusarium* sp.(23.53%), *P. infestans* (17.18%), *P. erythroseptica* (14.43%), and *Pythium* sp. (1.54%).

Healthy tubers were collected from each field immediately after harvest to determine levels of latent infection.

Fusarium sp. was the fungus most frequently isolated (6.6%) from 823 tubers, followed by *P. erythroseptica* (0.72%), *Verticillium* sp.(0.24%), and *Pythium* sp.(0.12%). In all three zones studied, *Fusarium* sp. was the most commonly isolated, from either wilt, rot, or latent infection; thus it is the most widespread pathogen in the Peruvian Andes.

The study also showed that *Pythium* sp. was found in various areas of the central Peruvian highlands. Inoculation with this organism caused watery rot in tubers.

Field screening for resistance to bacterial wilt. Susceptible cv. Rosita (*left*), resistant clone BR69.84 (*right*), San Ramon.



Control of Virus and Virus-Like Diseases

Thrust Profile: 1989

In studies of the multifactorial resistance to PLRV in potato, antibiosis and antixenosis were examined as components of the resistance to aphid vectors. The feeding behavior of aphids was analyzed using an electronic feeding monitor on selected cultivars. *Myzus persicae* exhibited antixenosis in clones Pirola, MEX 32, B71.240.2, CFK 69.1, Montsama, and DTO-33, whereas antibiosis was detected only in accessions of *Solanum neocardenasii*. In tests of cv. Mariva, for example, all aphids tested found the phloem rapidly, and fed at length. However, on cv. Tomasa Condemayta, only a few *M. persicae* and *Macrosiphum euphorbiae* aphids found and fed on the phloem.

The genetic resistance to PVY was studied in haploids from resistant clones derived from ssp. *andigena* and from *S. stolonifer.m*. Progenies of their crosses with FDR 2n pollen from clones susceptible to PVY also were studied. Both sources of resistance were shown to have two non-allelic genes involved in the resistance. Results also indicated that environmental conditions modified the expression of the gene for hypersensitivity. These findings provide a better understanding of the deviations from expected ratios, observed in screening for resistance to PVY.

Two PLRV isolates from the Andean region did not react with 10 monoclonal antibodies produced against a PLRV isolate developed in Britain, whereas other CIP isolates showed a varied range of reaction intensities in the ELISA tests. The discovery of a broad-spectrum, anti-PVY monoclonal antibody (MA C-9) suggested that PVY strains having the common epitope recognized by MA C-9 are widespread in potatoes. By using MA against PVX, the PVX isolates from different countries could be classified into two serogroups and two serotypes. Serotype PVX^{O} is common in North, Central and South America, and in Europe, Bangladesh and India. Serotype PVX^{A} has been detected only in Peru and Bolivia. Polyvalent or simultaneous detection of potato viruses can be done easily with NCM-ELISA. Both DAS-ELISA and NCM-ELISA are being used successfully in several cooperative institutions in China to detect potato viruses in seed-production and quality-control programs.

Production of anti-anti-idiotypes was investigated as a way to facilitate production of selected virus antisera. Probes have been developed for detection of SPFMV, PVX, PVY, PLRV, and APLV, and a non-radioactive kit has been developed for detection of PSTV.

Trainees in virology preparing sucrose density gradients for virus purification.

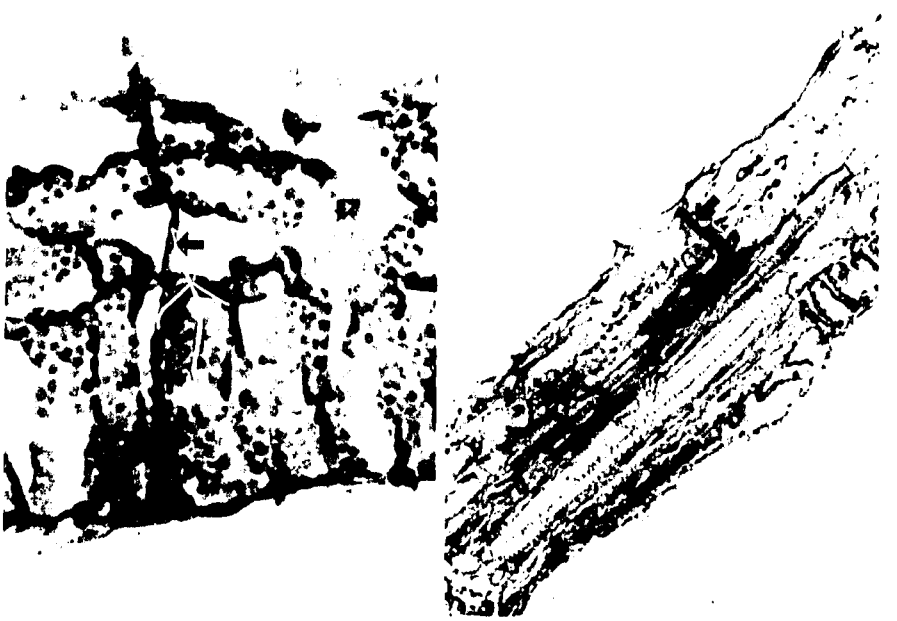
Fourteen isolates of SPFMV in CIP's germplasm collection have been compared with strains reported elsewhere. Four previously undescribed sweet potato viruses are being identified and characterized. In greenhouse experiments, PSTV was found to infect sweet potato cv. Paramonguino by sap inoculation.

Methods have been developed to search for resistance to sweet potato viruses and some accessions in CIP's germplasm collection have remained free of SPFMV after several attempts to infect them.

Resistance to Viruses

The development of cultivars that resist or are immune to viral infections should provide farmers in developing countries with the most effective method for controlling virus diseases. Substantial progress has been made in recent years on the development of cultivars immune to PVX and/or PVY. This success was possible because the immunities are controlled by a single dominant gene for each virus. Current studies on resistance to these two viruses are directed to finding better parental lines, to understanding the basic genetic characteristics of the genes for immunity, and to determining the stability of resistant genotypes under field conditions.

Even though a relatively high degree of resistance to PLRV has been found in a few cultivars, more studies are needed



Feeding behavior of *Macrosiphum euphorbiae* in resistant cv. Tomasa Condemayta (*left photo*) and in susceptible cv. LT-1 (*right photo*). Note stylet (*arrow*) in the phloem bundle in LT-1 and across the leaf in Tomasa Condemayta

to understand the general mechanisms of the resistance to PLRV and especially to the aphid vectors.

Components of the Resistance to PLRV

Previous research has identified multifactorial components in the resistance to PLRV in potato, and some of these factors have been identified in potato genotypes. Resistance to virus multiplication seems to occur, for example, in *Solanum acaule* OCH 13823, where the virus exhibits limited replication and accumulation in the plant tissue. The resistance to infection can be identified by the ability of a particular genotype to escape infection under conditions of high inoculum pressure. Such resistance is found, for example, in the clone Mariva, where it is overcome by previous infection with PVX or PVY (see Annual Report, 1988). Tolerance to PLRV can be observed in LT-1, which does not show severe symptoms even though it carries a relatively high concentration of PLRV.

Studies in 1988 examined resistance in the form of antibiosis and antixenosis to the aphid vectors. Table 4-1 lists the results of the experiments to identify clones from the CIP pathogen-tested list with these components. These results indicated that *Myzus persicae* shows no preference (antixenosis) for clones Pirola, MEX 32, B71.240.2, CFK 69.1, Montsama and DTO-33. However, antibiosis could not be detected in any of the clones, except *S. neocardenasii*.

The methodology commonly used for demonstrating resistance to PLRV infection is based on inoculation using PLRV-carrying aphids. Thus it becomes difficult

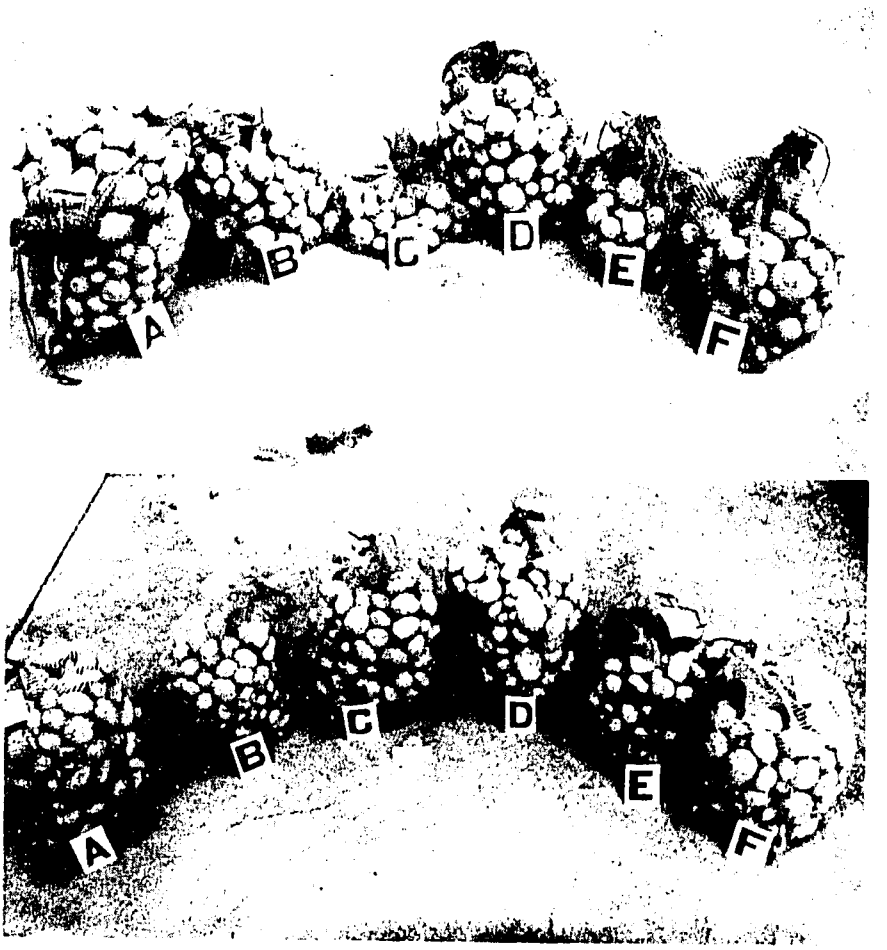
Table 4-1. Survival and multiplication of *M. persicae* in some selected potato clones.

CIP number	Clone	Number of aphids after (hours)[a] 24	72	240
72011	Aracy	10.0	11.6	22.6
800953	Bzura	9.9	7.10	16.0
379706.27	LT-9	9.9	3.1	24.1
	S. neocardenasii	9.7	4.7	1.9
575049	CFK-69.1	10.0	13.7	28.9
800969	Lemni russet	10.0	14.0	37.5
676025	AGB 69.1	5.1	3.3	54.9
800957	Pirola	2.5	2.0	37.3
720091	MEX-32	3.3	2.10	34.5
720088	B71.240.2	2.3	2.6	32.0
800310	Cosima	4.3	2.9	34.9
720084	CFK 69.1	4.4	1.9	26.9
720049	Montsama	1.7	1.7	26.6
800174	DTO-33	4.9	2.9	26.4
800944	65-346-19	3.8	2.4	23.9
800101	Superior	4.2	3.1	24.9
800290	GLKS-58-1642.4	3.4	3.2	30.8
703243	Imilla blanca	3.7	2.8	38.2
720142	Ballenera	4.4	4.4	38.0

[a]average of 10 replicates.

to distinguish between the host's resistance to the virus and the indirect resistance to PLRV through resistance to aphids. An electronic feeding monitor was used to differentiate between these two types of resistance.

Glasshouse observations showed that cv. Tomasa Condemayta is not attractive to aphids. Field observations also indicated that this cultivar is rarely found to be infected with PLRV. Experiments were conducted to study the feeding behavior of aphids on this cultivar, and of the 14 *M. euphorbiae* aphids observed on Tomasa Condemayta, only 2 reached the phloem. Of the 19 *M. persicae* aphids tested, 4 reached the phloem. On the susceptible clone LT-9, all aphids from



Effect of virus resistance on stability of potato clones: (*upper photo*) cv. Rosita, susceptible; and (*lower photo*) cv. Bzura, immune to PVX and PVY. Letters indicate number of field exposures (**A**) 1 exposure at La Molina; (**B**) 2 exposures at La Molina; (**C**) 3 exposures, 1 at Ica and 2 at La Molina; **D** 2 exposures, 1 each at Huancayo and La Molina; (**E**) 3 exposures, 1 each at Ica, Huancayo, and La Molina; (**F**) 2 exposures, 1 each at Ica and La Molina.

both test species reached the phloem and fed longer than on the other cultivars.

This feeding behavior also indicates that Mariva is resistant to the virus and not to the aphid, because the aphid vectors (*Myzus persicae* and *Macrosiphum euphorbiae*) are both capable of feeding on the phloem sap.

Studies on Resistance to PVX and PVY

Haploids from resistant clones and progenies of their crosses with FDR 2n pollen 2x clones susceptible to PVY, were evaluated for resistance to PVY.

All haploids from the cv. Serrana were hypersensitive to PVY. Progenies segregated into hypersensitive and susceptible genotypes. Haploids from the clone XY 13.15 (V2 or CIP 375335.1) with immunity to PVY from *S. tuberosum* ssp. *andigena* were either hypersensitive or immune. Of their progenies, only hypersensitive haploids were susceptible. The immune haploids segregated into immune, hypersensitive, and susceptible phenotypes. The segregated proportions indicate that two non-allelic genes were involved in resistance: one responsible for the immune phenotypes, and the other for the hypersensitive phenotypes. Haploids from 78C 11.5 (V3 or CIP 378650.1) with immunity to PVY from *S. stoloniferum* were immune, low-degree hypersensitive, and susceptible. Their immune haploid progenies were immune or susceptible. The hypersensitive haploids were highly susceptible. These results indicate that this clone carries a gene for immunity, along with another gene for a low degree of hypersensitivity that is modified to yield a susceptible phenotype. This again indicates that two non-allelic genes are involved with the immune and hypersensitive genotypes. Based on these findings, the proper genotypes can be selected to improve the inheritance of PVY immunity at the diploid level. Such selection can also determine the relationship among the genes for immunity to PVY, as obtained from *S. andigena* and *S. stoloniferum*. The findings also indicate modifications in the expression of the gene for hypersensitivity and they clarify the causes of deviations from expected ratios observed in the screening for resistance to PVY. Studies also were made of the appropriate environmental conditions for the expression of the gene for hypersensitivity.

Resistance to the PVX_{IIB} strain is being confirmed in cultivars Bzura (CIP 800953) and Atlantic (CIP 800827) as an additional attribute to their immunity to the common strains of PVX. Preliminary results indicate a similar level of resistance in Serrana. Mechanically-inoculated plants were symptomless, and the ELISA test detected only slow virus multiplication in the few plants infected.

Development of Virus Resistance

Peru. Nearly 400 advanced breeding clones underwent a PLRV field-exposure trial in Ica. Observations for virus symptoms were made in the field 65 days after planting, and selection for tuber shape was done at harvest.

A few clones from these selections with good tuber shape for processing were tested for their reducing-sugar content, dry-matter content, and specific gravity (Table 4-2). These materials (selections from 1986, 1987, 1988) and another 5,000 seedlings with resistance to PVX and PVY from different families, were submitted to a PLRV field-exposure trial at Ica in October 1988. However, the aphid-population data obtained in Ica for 1987 and 1988 indicated higher populations of *Aphis gossipii* and

Table 4-2. Specific gravity, reducing-sugar content, dry-matter content, and tuber shape of some selected clones resistant to PVX, PVY and PLRV.

Pedigree	Clone	Specific dry gravity	Reducing matter	Tuber sugar	Shape
B71.240.2 X7XY.1	86004	1.087	21.84	4.00	round
	86006	1.074	19.81	2.66	oval
	86010	1.083	21.17	2.00	round
	86026	1.085	23.10	1.66	round
	86066	1.086	21.91	1.00	oval
SERRANA X LT-9	86041	1.093	23.48	2.20	round
	86051	1.087	22.15	1.33	oblong
	86052	1.096	24.02	2.33	round
B71.240.2 X	86076	1.086	22.18	1.33	round
575049	86084	1.090	22.81	1.00	round
MARIVA X7XY.1	86090	1.080	22.37	3.60	round
	86092	1.081	20.72	2.00	round
BR63.15 X 7XY.1	86102	1.089	22.87	1.00	round
	86103	1.083	21.08	2.00	oblong
BZURA X LT-9	86105	1.106	25.72	1.66	round
	86109	1.077	20.33	2.00	oblong

Rophalosiphum sp. than of *Macrosiphum euphorbiae and Myzus persicae*. Thus the efficiency of the former aphid species as vectors of PLRV must be determined. With Ica as a testing site, CIP can select for heat tolerance during the second half of the year. A breeding strategy to obtain PLRV resistance also was developed as shown in Fig. 4-1. Of the two populations in Fig. 4-1, the population consisting mostly of *S. tuberosum* (List A) shows promise for adaptation to hot, tropical, long-day environments. This population contains immunity to PVX and PVY, as well as resistance to PLRV.

Two experiments were conducted to optimize the screening method for PLRV resistance in seedlings. The first experiment compared two aphid populations to determine the optimum number of aphids needed for inoculating seedlings during screening. The second experiment compared glasshouse and field-exposure effects in screening for PLRV resistance. In the first glasshouse experiment, three families with different numbers of aphids per seedling were evaluated for infection with PLRV, using a split-plot experimental design. The tested progenies differed significantly and B72.233.5 x 7XY.1 showed the most resistance to PLRV. The number of plants infected was not correlated with the number of aphids used for infection. Therefore, a population of 15 viruliferous aphids per seedling was as effective as a population of 50 aphids per plant in testing for resistance. These findings confirm the results obtained last year.

Uruguay. Two clones selected by CAAB from the 1986 introductions continue to show excellent resistance to PLRV, PVY, and PVX, as well as good agronomic characteristics. These have been freed of virus and are now available in CIP's pathogen-tested genebank. Several crosses were made, and the

parents (the two clones mentioned) and the seeds of six crosses were sent to CIP.

From introductions in 1985 and 1986, 14 clones were selected and the 2 most promising were included in regional replicated trials and maintained with in vitro culture. Of the introductions made in 1987, 228 (11.7%) were retained in the winter crop in the north of the country. The full set of 228 was planted for virus-resistance trials in the spring of 1988 at the Las Brujas Experiment Station.

A selection of 21 clonal cultivars from CIP was evaluated for virus resistance under field conditions. B71-240.2, Pirola, and BR63-76 showed high levels of combined resistance to PLRV, PVY and PVX.

Variability of Potato Viruses

Variability of PLRV. The variability of some PLRV isolates available at CIP was studied in collaboration with the Scottish Crops Research Institute, Dundee, Scotland (SCRI). Isolates were tested for

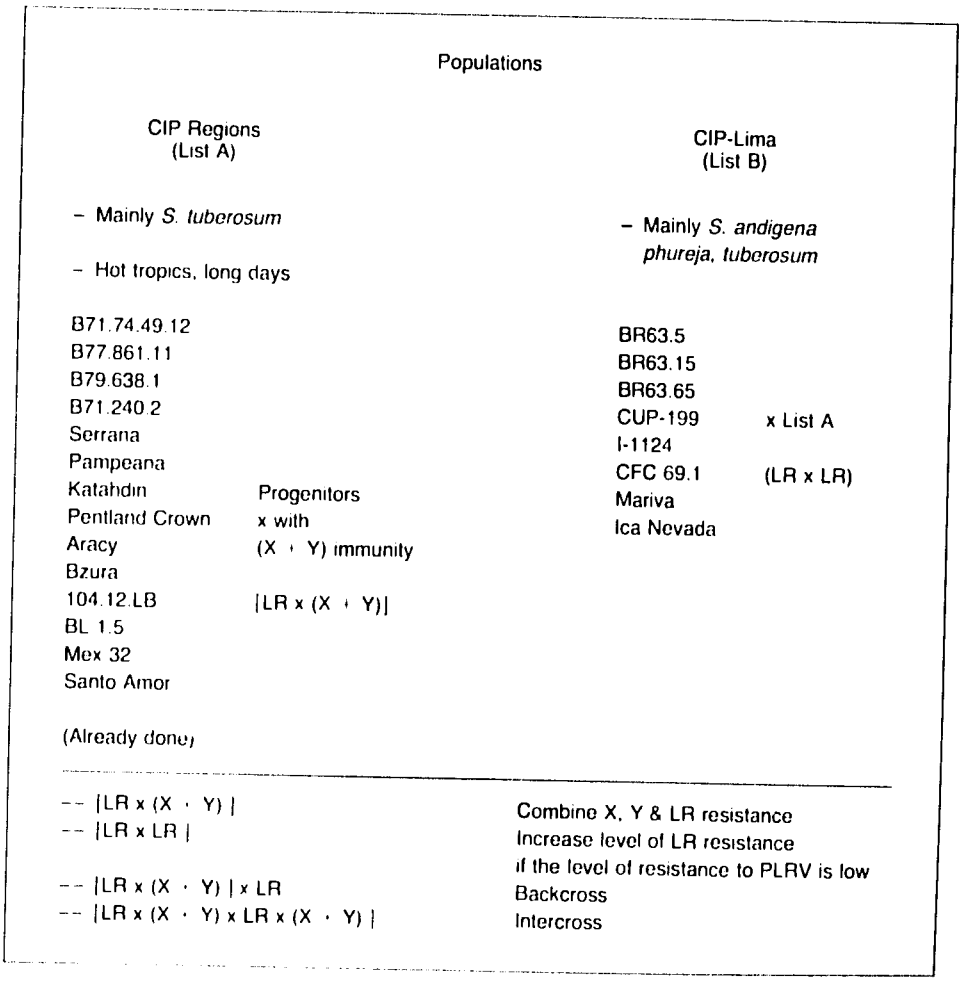


Figure 4-1. Breeding strategy for PLRV resistance.

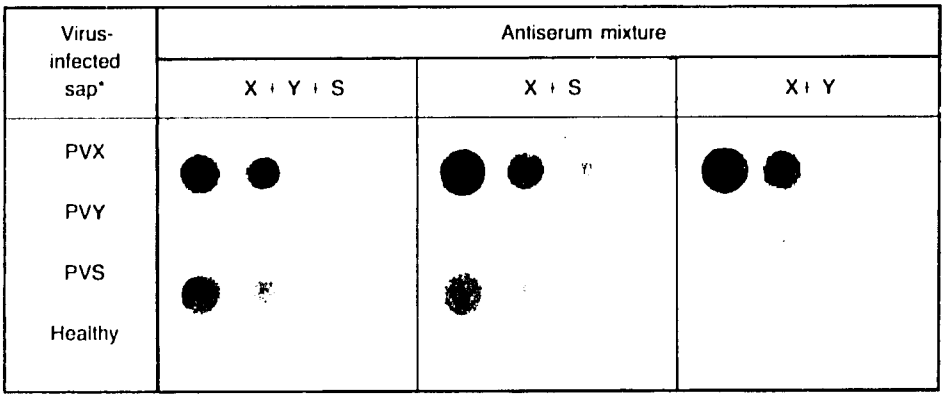
their serological reactions to 10 monoclonal antibodies produced against a British isolate of PLRV. PLRV isolates China and 29 reacted well with the monoclonal antibodies tested, but isolates Korea and Uruguay reacted less strongly, probably because of the low virus concentrations in the plant tissues. Isolates 10 and 01 from the Andean region did not react at all, probably because they belong to a distantly related antigenic PLRV. These results suggest the existence of serologically different isolates of the PLRV that might require the development of strain-specific antisera for routine detection of PLRV. Future experiments will examine the significance of these isolates on the stability of resistance to PLRV so far obtained.

Variability of PVX and PVY

NCM-ELISA tests are in progress to study the variability of PVX and PVY, and to monitor the stability of the resistance in the germplasm being evaluated in the regions. The epitope recognized by the broad-spectrum, anti-PVY monoclonal antibody (MA) C-9 was detected in 40 samples from a test plot in Florida, U.S.A.; in 57 samples of 17 old cultivars grown in Bangladesh; and in Bolivia (10 from Cochabamba, 12 from Toralapa, and 18 from the Lake Titicaca Plateau). PVY strains having the epitope recognized by MA C9 have now been found in North, Central, and South America, and in Bangladesh, China, Europe, and Africa. Using anti-PVX MA 58, 59, and 67, the PVX isolates detected in different parts of the world can be classified into four serogroups and two serotypes (Table 4-3). PVX strains with epitopes recognized by MA 58 and 59 are found in North, Central, and South America, and in Europe, Bangladesh, and India. PVX isolates with these epitopes were clas-

Table 4-3. PVX serogroups (according to Torrance *et al.*) and serotypes, as determined by monoclonal antibodies 58, 59, and 67, detected in potato by ELISA on nitrocellulose membranes (NCM-ELISA).

Number of isolates	Area	Serogroup	Serotype
2	Bangladesh	I or II	PVX^0
1	India	IV	PVY^0
4	USA	IV	PVX^0
1	Guatemala	IV	PVX^0
3	Chile	IV	PVX^0
27	Peru	IV	PVX^0
3	Peru	I or II	PVX^0
1	Peru	III	PVX^A
13	Bolivia (Lake Titicaca Plateau)	I or II	PVX^0
8	Bolivia (Lake Titicaca Plateau)	III	PVX^A
3	Bolivia (Lake Titicaca Plateau)	IV	PVX^0
15	Bolivia (Cochabamba)	I or II	PVX^0
8	Bolivia (Cochabamba)	IV	PVX^0
1	Bolivia (Cochabamba)	III	PVX^A
19	Bolivia (Toralapa)	I or II	PVX^0
10	Bolivia (Toralapa)	IV	PVX^0



* Sap dilution increases from left to right.

Figure 4-2. Polyvalent detection of potato viruses by NCM-ELISA.

sified as the common serotype PVX^{O}. The PVX strains with epitope recognized by MA 67 have been detected only in Peru and Bolivia (Table 4-3), occurring mainly in the Lake Titicaca Plateau. PVX isolates with this epitope were classified as Andean serotype PVX^{A}. The strain PVX_{IIB}, which breaks the immunity to PVX found in potato, is included in the PVX^{A} serotype. Thus, unless PVX_{IIB} is dispersed from its local area, stability of immunity to PVX appears to be guaranteed.

Studies on the serological variability of PVX have shown that, to avoid escapes in the detection of PVX that occur worldwide, an appropriate isolate must be used for production of the PVX antiserum or of conjugates to be used in the direct ELISA test. Differences between serotypes PVX^{A} and PVX^{O} have also been shown by NASH test in collaborative work between PBI, Cambridge, England and CIP. As a first step in selecting MA to monitor through the use of NCM-ELISA, eight MA to a British isolate of Peruvian Tomato Virus (PTV-p) obtained from the SCRI are being evaluated at CIP. The evaluation seeks to determine the importance and incidence of the potato strain of PTV-p in CIP's germplasm being tested in the regions. Two MA have been selected as specific to PTV, and they cover the broad spectrum of strains of PTV so far isolated from potato, tomato, and pepper.

Techniques for Diagnosing Virus and Viroid Detection

ELISA. CIP headquarters emphasized the NCM-ELISA (NC-ELISA in last year's report) to detect PVX, PVY, PVS, APLV, and APMV using CIP's polyclonal antisera. This technique is also reliable for detecting PVX, PVY and PVS in a polyvalent methodology (Fig.4-2). Preliminary results indicate that NCM-ELISA is slightly more sensitive and less susceptible to background reactions than is DAS-ELISA. These kits are also easier to prepare and transport. However, use of this technique to detect PLRV requires further study because PLRV virions are not adsorbed well to the nitrocellulose membrane with the procedures and buffer conditions used for other viruses. To detect PVY, IgG purified by ion exchange chromato-

graphy and/or $F(ab')_2$ fragments of the antibodies should be used.

Studies on the detection of PVA show that using the $F(ab')_2$ fragment of PVA antibodies also permits the detection by NCM-ELISA of isolates of other potyviruses such as PVY and PTV. This represents a great advantage in the detection of potyviruses in potatoes. NCM-ELISA kits and protocol manuals were prepared for testing under field conditions in selected CIP Regions. DAS- and NCM-ELISA have now been tested and introduced in China through a project conducted by Prof. Zhang Heling (Inner Mongolia University, Huhehote). DAS-ELISA is routinely used by national programs to detect all potato viruses in the main cultivars, and for quality control of seed potatoes.

Monoclonal Antibodies

Properly selected monoclonal antibodies have been shown to be more adequate than polyclonal antibodies for the detection of viruses. Tests using virus-specific monoclonal antibodies produce no background reactions and can detect all virus strains if the hybridoma that produces them has been selected for that purpose. Though the initial production of the monoclonal antibodies is laborious, the high quality of the antibodies and the possibility of producing unlimited amounts is worth the effort.

The production of monoclonal antibodies started with SPFMV and PLRV. The first fusion experiments between mouse spleen cells and myelomas did not succeed because of toxicity problems in the media and toxic ion accumulation on glassware during steam sterilization. These problems have been overcome and 13 clones for SPFMV and nine for PLRV are being analyzed for their use in routine detection.

Research on Anti-Anti-Idiotypic Antibodies (AAI-Mab)

Idiotypic antibodies are known to recognize determinants unique to the immunizing antigen. In the case of plant virus antisera, the idiotypic antibodies are those that can recognize only the virus particles. CIP is attempting to develop a procedure to multiply idiotypic virus-specific antibodies from selected antisera. This procedure is a rapid and inexpensive way of producing antibodies for detection of viruses for which polyclonal or monoclonal antibodies are difficult to produce. For this procedure, rabbits must be injected with selected idiotypic antibodies, and the antibodies (anti-idiotypic) so produced are then used to reproduce the idiotypic antibodies (anti-anti-idiotypic).

To test this approach, monoclonal antibodies (MAb's) of PLRV were injected into rabbits to produce anti-MAb's antibodies (these recognize only MAb's). These anti-MAb's antibodies were fractionated and the $F(ab')_2$ fraction injected into new animals to produce anti-anti MAb's antibodies that will detect PLRV.The anti-anti MAb's produced can detect PLRV with the same specificity of the original MAb's. Monoclonal and absorbed polyclonal antibodies to PLRV are being used in further studies of this procedure.

Plasmid and Probe Development

Virus-specific nucleic acid probes are being developed to search for more sensitive and efficient methods of virus detection. Reverse transcription and cloning procedures developed at the Plant Protection Institute, Beltsville, Maryland, have been applied successfully in producing ds-cDNA from PVX,

PVY, APLV, PLRV, and SPFMV. Some of the clones obtained have now been used as probes for both virus detection and studies on strain relationships.

A PVX probe (~ 1200 bp long) is being used for analysis of PVX isolates. The specificity of hybridization of several isolates with the probe can help to confirm recently discovered differences among serotypes. A NASH experiment was performed using a PVX probe prepared for PVX-cp isolates. The degree of hybridization obtained with the isolates 2, 8, GUA, cp, and HB confirms genomic differences between the serotypes PVX^{o} and PVX^{A}.

The NASH test and return-gel electrophoresis are being used by Prof. Zhang Heling to detect PSTV in the main potato cultivars.

Sweet Potato Research

Identification of Viruses

Sweet potato cultivars with different virus symptoms were collected and most reacted to a SPFMV antiserum, indicating that there was little serological variation. Of these, 14 variants of SPFMV were isolated and then infected systemically with *Ipomoea nil* and *I. setosa*. Eight of the variants readily induced relatively large numbers of local lesions on *Chenopodium amaranticolor* and *C. quinoa*. SP-13 and SP-22 isolates induced strong symptoms on *I. nil*. Most of the variants induced chlorotic spots on sweet potato cvs. Paramonguino, Georgia Red and Jewel. Thus, SPFMV isolates differ substantially in some characteristics such as infectivity and symptom production, despite their minimal serological variation.

Studies are under way to identify four virus isolates, C-2, C-3, C-4, and C-5, that are not serologically related to SPFMV, SPLV, SPMMV, or SPCV. C-2 induces chlorotic fine spots and vein clearing on *I. nil*; however, it infects only Convolvulaceae plants. C-2 has a filamentous particle (750 to 800 nm) and is transmitted mechanically. C-3 induces mosaic, leaf deformation, and vein clearing on *I. setosa*, and appears to contain isometric particles. It is transmitted mechanically with difficulty, but not by *M. persicae*. C-4 induces stunting, leaf deformation, and chlorotic and necrotic spots on *I. setosa*. No virus particles have been observed. C-5 induces vein clearing on *I. nil* and has filamentous particles (800 to 900 nm). This virus has been purified and an antiserum is being produced.

Because potato viruses are common in CIP's field and screenhouses, they have been studied as a potential threat to sweet potatoes. Of several potato agents inoculated into sweet potatoes, only the viroid PSTV infected sweet potato cv. Paramonguino. In two experiments, 3 out of 10 plants of cv. Paramonguino became infected when mechanically inoculated with PSTV. No symptoms were observed in the foliage. If infectivity of PSTV is demonstrated in other genotypes, testing for PSTV will be required in routine virus tests at CIP and elsewhere.

Detection of Viruses

SPFMV has been purified at CIP and a polyclonal antiserum has been produced that can be used as the first antibody in DAS-ELISA. New polyclonal and monoclonal antibodies are being tested for their use in detection of SPFMV. SPMMV from Glasshouse Crops Research Institute in England is being purified at CIP, and a polyclonal antiserum is being produced.

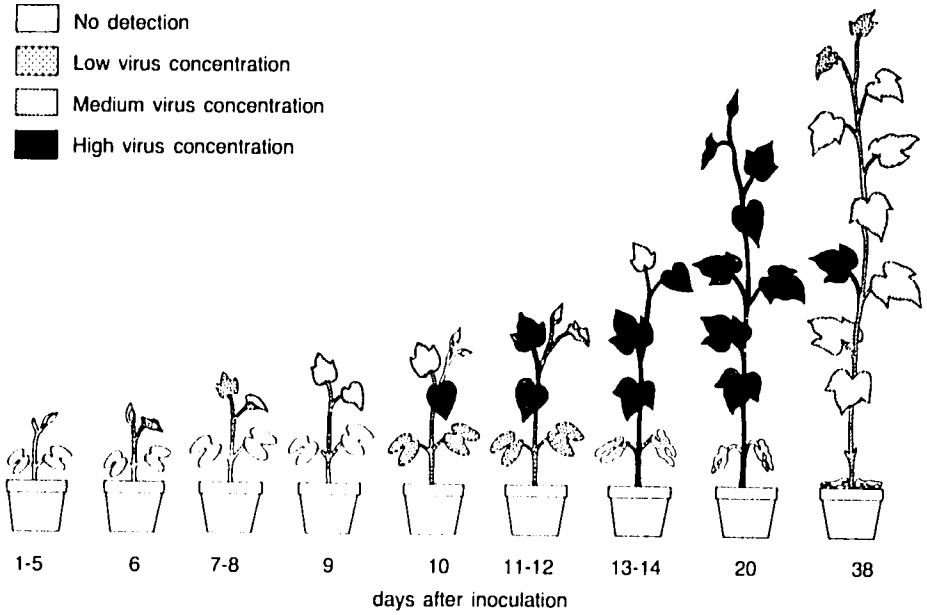


Figure 4-3. Detection of SPFMV (str. C) infection in *Ipomoea nil* at different days after inoculation.

The NASH test is now used to detect SPFMV in sweet potato plants, although the large amounts of latex in the plant tissue caused some initial difficulties. A simple and rapid method has been developed for sample preparation, using 10xSSC and 10% formamide extraction buffer, and no background is found in healthy samples.

The SPFMV probe (~ 1100 bp long) is being used in the NASH test to study virus infection in the plant, and the relationship between detection methodology and symptom development has been recorded. As shown in Fig. 4-3, in NASH tests of the SPFMV in *Ipomoea nil*, detection began 6 days after mechanical inoculation, whereas the first symptoms appeared 10 to 11 days after inoculation. Similar tests are being made of *I. batatas* after inoculation of SPFMV by aphids. The SPFMV probe showed a high specificity for strains C and C_1. However, a low detection rate for strain RC was obtained by using different stringency conditions during hybridization and washing.

Other SPFMV sequences are being studied to find a probe with a broad range of detection. The non-radioactive procedure for detecting PSTV now used at CIP has also been used successfully as a "kit" in Kenya.

Search for Immunity to SPFMV

A search for immunity to SPFMV has begun, using accessions from the CIP germplasm collection and financed in part through a collaborative agreement with the Volcani Center, Israel. SPFMV is widespread, thus ELISA was used to examine accessions for typical symptoms and viral infection. SPFMV-free accessions were taken to the greenhouse and

challenge-inoculated with SPFMV-infected sweet potato scions. When infection was detected, the remaining free plants were again challenged against scions infected with *ipomoea nil*. Those plants that again remain free of SPFMV will be infected with SPFMV by aphids and grafting. Of a total of 1,641 accessions that entered the system, 30 remain refractory to SPFMV infection (Table 4-4). Some of these may carry some genes for resistance (immunity) to SPFMV.

Detection of virus is carried out by ELISA and/or indicator plant testing.

In a survey carried out in China during a survey/training course, no SPMMV or SPCV were found. Results showed that SPFMV and SPLV commonly occur together (Table 4-5). Approximately 21% (17) of the samples contained viruses other than SPFMV, SPMMV, or SPCV. Symptoms associated with SPFMV included mosaic, vein clearing, necrotic rings, and chlorotic spots. Symptoms for SPLV were mosaic, crinkling and symptomless infection (Table 4-5).

Table 4-4. Search for genetic resistance (immunity) to SPFMV in CIP germplasm accessions.

Step[a]	Number of accessions tested	Positive to SPFMV	Accessions with possible resistance
Symptom observation	1641	1478	163
Ind. hosts + ELISA	163	34	129
I. Grafting with infected sweet potato	129	25[b]	104
II. Grafting with infected *I. nil* with SPFMV[c]	104	74[b]	30

[a] Sequential steps followed to determine resistance. Other steps planned are reinoculations (infection) of survivors with SPFMV by aphids and grafting.

[b] By ELISA serology.

[c] Ten accessions were found to be infected in the field after a new field evaluation. Therefore, they were eliminated.

Table 4-5. Presence of virus(es) in samples from four Chinese provinces determined by NCM-ELISA.

Virus(es)	Province				
	Sichuan	Jiangsu	Shan Dong	Beijing	Total
SPFMV	5	4	2	0	11
SPLV	1	4	4	4	13
SPFMV and SPLV	6	18	11	4	39
Other viruses	7	3	0	7	17
Total	19	29	17	15	80

[a] SPFMV Sweet Potato Feathery Mottle Virus.
SPLV Sweet Potato Latent Virus.

Integrated Pest Management

Thrust Profile: 1989

Major research objectives included identification of potato and sweet potato genotypes with resistance to nematode and insect pests, utilization of the resistance, and improved non-chemical pest control methods. The potato cyst nematode breeding program incorporated 12 new *Solanum andigena* accessions from the CIP collection, plus selected new wild sources of genotypes from other countries. In 1988, crosses produced 17 families resistant to *Globodera pallida*, and clones from previous crossing cycles (G84 to G87) were further selected for both resistance to *Globodera pallida* and agronomic characteristics. Yields of many selected clones exceeded those of local check cultivars, and some clones exhibited additional resistance to late blight and viruses. Advanced clones were sent to the national potato research program of Peru and tuber families were sent to Ecuador, Colombia, Panama, and Pakistan to initiate selection cycles. Resistance and chemicals and biological control were studied as components of a *Globodera pallida* management program.

Potato clones from different genetic backgrounds were screened for resistance to the root-knot nematode. These included wild and cultivated diploids, and pathogen-tested clones. Of the Peruvian sweet potato germplasm tested, 2.5% was shown to be highly resistant to the root-knot nematode. Organic matter was shown to increase the effectiveness of the nematode parasitic fungus *Paecilomyces lilacinus* under greenhouse conditions. Under field conditions, yields were increased substantially by applications of chicken manure, aldicarb, and *P. lilacinus* (alone and in combination). However, combinations of aldicarb with *P. lilacinus* lowered potato yields. Other studies focused on the extraction of nematoxic metabolites from selected fungi.

Evaluations were made of the staining methods used to study the root-lesion nematode, *Pratylenchus flakkensis*, the effect of fertilizer application, and the host efficiency of several crops. Investigations were made of the procedures to extract *Nacobbus aberrans* eggs from infected roots.

Six trials were conducted to identify plant resistance to the potato tuber moth under store conditions and in closed containers. Selected clones showing resistance included tetraploids, diploids, and pathogen-tested genotypes. Dust formulations of the granulosis virus were used to improve the control of the tuber moth. Other tuber moth studies investigated low-cost formulations of sex pheromones, the introduction of the parasitoid *Copidosoma desantisi* in Colombia, the seasonal occurrence of the tuber moth in Ethiopia and Burundi, and tuber moth control in Egypt.

Parasitized larva of the potato tuber moth *Phthorimaea operculella*. Insert: Pupae of *Copidosoma* sp. (see arrow) are shown inside the larvae of *Phthorimaea operculella*.

Studies of previously selected potato clones confirmed their resistance to the leaf miner fly. Other clones with glandular trichomes were selected, using *Tetranychus* sp. in screening and assaying for higher levels of aphid antixenosis. In other major studies, species of thrips that damage lowland potatoes were identified in the Philippines. Sweet potato clones were screened for resistance to the West Indian sweet potato weevil. In Peru, investigations continued on the biology and seasonal occurrence of the major sweet potato pests and their natural enemies.

Potato Cyst Nematode

Screening for Resistance

Genetic materials from three different sources were screened for resistance to races P_4A and P_5A of *Globodera pallida*, using the mass seedling, pot, and petridish tests. In a group of 20 progenies obtained from the crosses between wild species considered as potential new sources of resistance, 15 progenies showed good levels of resistance to race P_4A, and 8 progenies showed resistance to race P_5A. In other tests, 50% of the seedlings (2,570) from 64 families of selected resistant parents showed resistance when tested as individual seedlings.

A second group of materials from CIP's breeding program consisted of seedlings, tuber families, and clones that also incorporated viruses X and Y, and late-blight resistance. In screenings for resistance to *G. pallida*, 38% were resistant to race P_4A and 30% to race P_5A.

The third group of materials came from breeding programs in other countries. This group was selected for resistance to *G. rostochiensis* and for other attributes. It was tested against the races P_4A, P_5A, and P_6A of *G. pallida*. Table 5-1 summarizes the screening test results.

New Breeding Material

In Huancayo, Peru, 202 progenies from the 1988 crossing cycle (G88) were evaluated in a mass seedling test. Of these, 47 progenies were rated as highly resistant to P_4A, 53 as resistant to P_5A, and 17 as resistant to both races. To study the transmission of resistance genes, 12 new *Solanum andigena*-resistant accessions were identified and intermated.

A total of 8,200 seedlings were screened, including 60 progenies from crosses of PCN-resistant females and virus-resistant males. Of the selected material, 893 seedlings were resistant to PVX 1,444 were resistant to PVY, and 54 were resistant to both PVX and PVY. For use in the breeding program, CIP received 18 clones of wild species screened in Europe for multiple resistance to several races of *G. pallida* and *G. rostochiensis*.

A total of 202 progenies from the first clonal generation (cycle G87) yielded an average of 37 t/ha per clone or genotype. A selection of 1,870 genotypes was made that included 24 progenies of 4x-2x crosses utilizing the PCN-resistant diploid clone 84-28-58.

Clonal Evaluations

A total of 826 field-selected clones from cycles G85 and G86 were tested for PCN resistance, and 285 of these were rated as double-resistant to races P_4A and P_5A. Of the selected clones planted in observation plots, 148 were selected for replicated yield trials. The average yield of selected clones was 1.3 kg/plant, with 28 clones outperforming cv. Yungay, the

Table 5-1. Screening for resistance to P_4A and P_5A races of *Globodera pallida* in potato genetic material from different sources. Huancayo, 1988.

Material Group Families (F) or Clones(C)	P_4A		P_5A	
	Tested	Resistant	Tested	Resistant
I. Crosses of wild species				
OCH-87(F)	20	15	20	8
OCH-87(C)	2570	1283	—	—
II. PCN breeding program				
SG-83 (C)	57	47	67	63
G-83B(C)	190	135	185	114
F-87 (F)	239	81	249	56
GLB-87 (C)	384	163	378	115
GV-87 (C)	225	75	220	83
G-88 (F)	199	69	199	60
G-85B(C)	259	113	248	121
G-86 (C)	545	199	518	218
III. Other breeding programs				
Cornell 86 (C)	5	5	9	9
Idaho 88 (C)	3	0	3	0
North Ireland (C)	4	2	4	3
France (C)	3	2	3	0
Iwanaga 87 (C)	330	59	330	74

best yielding (2 kg/plant) of the check cultivars.

In Peru, INIAA helped evaluate 193 selected clones from cycle G85. Evaluations were made at two locations with differing ecological and technological characteristics: at CIP's experiment station in Huancayo (3,280 m) and in a farmer's field at Umpa (3,800 m). A total of 50 clones were selected. However, the ratings of the best clones at the two locations showed no correlation.

Resistant selections from cycle G84 were field-tested where different races of *G. pallida* are prevalent at three locations in the Peruvian Andes: Cuzco, La Libertad, and Puno. These plant populations generally are rated as resistant at Cuzco; as medium-level resistant at La Libertad (where race P6A is found in certain areas); and as susceptible at Puno, where the species and race spectra of PCN differ from those in the other two areas.

Combining PCN Resistance with Virus and Late-blight Resistance

Two sources of virus resistance, V2 and I-1039, were used, with I-1039 shown to be a better parent for preserving PCN resistance. CIP now has 26 clones that have resistance to two races of PCN, as well as to PVY. Two clones have resistance to PCN, and to PVX + PVY.

Sixty selected PCN-resistant clones from different cycles were crossed with late-blight resistant clones. A total of 87 clones were selected for observation plots.

Advanced Clones

Advanced PCN-resistant clones were sent to national programs of Peru, Ecuador, Colombia, Panama, and Pakis-

tan. In Peru, selections have been reduced to one clone at Huancayo and to 3 clones at La Libertad. The clones at La Libertad are also tolerant to late blight. Of the clones selected as resistant in Peru, only 30% showed resistance in Panama, where *G. rostochiensis* is found. This finding indicates the low coincidence of the races at both locations and the importance of increased selection using local races of PCN. Tuber families sent to Ecuador, Colombia, and Pakistan were first selected for adaptation and, in Ecuador, they were further selectd for late-blight resistance.

Integrated PCN Management

Several tactics were studied for the integrated control of the PCN. Of 10 clones that were considered to be resistant cultivars, 4 were shown to reduce nematode populations in the field. The clone 280613.13 had the highest yield (1.2 kg/plant). Nine clones considered tolerant to PCN infestation were evaluated under conditions of high PCN field infestations. Two clones produced satisfactorily (0.7 kg/plant and 1.2 kg/plant); when protected with nematicides (aldicarb), their yield increased by only 10%. The maximum multiplication rate of the nematode was 3x for the treated plots and 16x for the untreated plots. Damaging levels of the PCN (*G. pallida*, race P_4A) were determined for Yungay and Maria Huanca cvs. in microplots. Regression lines were calculated for infestation level and plant yield.

The effects of organic and inorganic soil amendments on nematode multiplication and crop yields were studied in a field with natural infestations of PCN. Preliminary findings indicate that fertilizer applications did not affect the multiplication rates of nematodes. Yields increased, however, particularly with the use of inorganic fertilizers.

Effects of *Beauveria bassiana*, an insect parasitic fungus, were investigated in tests for control of *G. pallida* under greenhouse conditions. The fungus affected both cyst and eggs, with about 50 of the eggs infected. This fungus shows promise as a biocontrol agent for the PCN.

Selected granular nematicides were incorporated at planting time into heavily infested soil, and additional treatments were applied at hilling. Effects were evaluated on the nematode population, on the Andean weevil *Premnotrypes* spp. damage, and on yield. Oxamyl and aldicarb reduced the nematode populations, and the addition of carbofuran at hilling decreased damage by the Andean weevil.

Root-Knot Nematode

Potato

Screening for resistance. The evaluation of the root-galling index was made more reliable with a modification of resistance-screening procedures. An index rating of 1 to 5 had previously been used to determine the reaction of plants to M. incognita. This procedure required an estimate of root quantity as related to infection. The modified scheme is based on an index rating of 1 to 6, with the indexing based on the percentage of root infection. This procedure more precisely takes into account the amount of root mass.

Seed of 150 progenies was evaluated for resistance to *Meloidogyne incognita* in a diploid population consisting of inter-

crosses of *Solanum sparsipilum*, *S. chacoense*, and the cultivated diploids *S. phureja* and *S. stenotomum*. Resistant genotypes were selected and retested and resistance was reconfirmed in 82% of the genotypes (Table 5-2). In another test, 26 progenies from these resistant genotypes were crossed with highly selected tetraploid female clones. Two successive backcrosses of resistant selections were made with early heat-tolerant tetraploid material. From these selections, a total of 7,292 genotypes were evaluated for resistance to *M. incognita*. Although 7.9% of the genotypes of 19 progenies showed good resistance, only 5 genotypes of 5 progenies were highly resistant. In studies of 2x-2x and 4x-2x crosses, resistance to *M. incognita* was transferred to an advanced 2x population by crossing resistant genotypes with cultivated 2x clones. Selections were made for resistance, agronomic traits, and production of first-division restitution (FDR) 2n pollen. Seedlings of 3,267 genotypes representing 60 progenies of these crosses were evaluated for resistance. Of the progenies derived from 4x (susceptible) -2x (resistant) crosses, 14% were classified as resistant to *M. incognita*. Approximately 6% of the genotypes were resistant and 7.7% were moderately resistant (Table 5-2). The occurrence of resistant 4x progenies with *S. tuberosum* or *S. demissum* cytoplasm indicates that *S. sparsipilum* cytoplasm is not essential for the expression of resistant genes.

Evaluations for resistance to *M. incognita* were made on more than 7,550 seedlings from 168 progenies of 4x - 4x TPS material. This material was selected initially for agronomic reproduction characteristics, and originated from B.R. clones, breeding pathogen-tested material, and MBN. Of these seedlings, 0.5% of the genotypes were classified as moderately resistant, and 0.2% as resistant. Table 5-2 summarizes the screening tests.

Sweet Potato

Screening for resistance. Reaction to *M. incognita* was evaluated for 486 clones of the cultivated sweet potato germplasm collected from 11 departments of Peru.

Table 5-2. Frequency distribution of resistance and susceptibility of some diploid clones, advanced tetraploid progenies, 4X-2X progenies and 4X TPS progenies to *Meloidogyne incognita*.

		HR	R	MR	MS	S	HS	Total
Diploid clones		231	20	27	23	5	0	306
(selection from 150 progenies)	Percentage	75.6	6.5	8.8	7.5	1.6	0	100
Advanced tetraploids								
(26 progenies)	Seedling	5	572	417	800	5405	98	7297
	Percentage	0.1	7.8	5.7	11.6	74.1	1.3	100
4x-2x crosses								
(60 progenies)	Seedling	27	176	251	408	2405	0	3267
	Percentage	0.8	5.4	7.7	12.5	73.6	0	100
TPS Seedling		0	13	41	582	6790	127	7553
(168 progenies)	Percentage	0	0.2	0.5	7.6	90	1.7	100

HR highly resistant MS moderately susceptible MR moderately resistant HS highly susceptible
R resistant S susceptible

Of the clones from 7 departments, 2.5% were highly resistant, and the largest number of highly resistant clones came from the Department of Lima. This finding reflects the effectiveness of selection pressures applied by farmers in sweet potato cultural practices.

Biological Control

Greenhouse experiments tested the effect of two types of organic matter (chicken and cow manure) on the efficiency of *Paecilomyces lilacinus* in controlling *Meloidogyne incognita* on potatoes. Organic matter applied to the soil at rates to provide final concentrations of 4% to 6% was effective in reducing the damage caused by *M. incognita*. Combinations of organic matter with *P. lilacinus* increased the control efficiency of *P. lilacinus*.

Field experiments examined the role of organic matter alone, and in combination with *P. lilacinus* and aldicarb, in controlling *M. incognita* on potatoes. Covariant analysis showed that potato yields were higher after treatments that combined *P. lilacinus*, aldicarb, and chicken manure. However, yields of potatoes treated with aldicarb and *P. lilacinus* were similar to those of the control, and were significantly lower than yields obtained with other treatments. To determine the residual effects, the same plots will be studied without further applications of chicken manure, aldicarb, or *P. lilacinus*.

Extraction of nematoxic metabolites from selected fungi is a major study interest, and these extracts are being evaluated for biocidal activities and characterization. Preliminary data indicate that the metabolites of these fungi consist primarily of 3 or 4 components with low molecular weights.

Root-Lesion Nematode and False Root-Knot Nematode

Evaluations were made of two root-staining methods used to study penetration, reproduction, and root damage of the root-lesion nematode, *Pratylenchus flakkensis*. With some modifications, the acid fuchsin-sodium hypochlorite and acid fuchsin-lactophenol method proved satisfactory. However, the cold-staining method that uses acetic acid-acid fuchsin and transference to glycerine proved to be more practical. The most effective inoculation was obtained with a rate of 15 nematodes per root tip. The counts of eggs, nematodes, and necrotic lesions were higher at 56 days after inoculation.

Phosphorous and potassium effects on the root-lesion nematode population were examined in four microplot experiments. The increasing amounts of phosphorous did not decrease the nematode damage, but damage was more severe in potassium-deficient plants.

As a basis for a crop-rotation scheme, several crops were studied for *P. flakkensis* host efficiency. At Lima, the least efficient hosts were cotton (cv. ICA-161), beans (cv. Nemasnap), sweet potato (cv. Conchucano Cascajal), and peas (C-59). At Huancayo, the least efficient hosts were wheat (cv. Chumpi), barley (cv. UNA-80), lupines (cv. C-14), and oats (cv. Mantaro).

Of the methods evaluated for the extraction of *Nacobbus aberrans* eggs from infected roots, the Hussey method (1% sodium chloride) proved most effective. Methods for extraction of juveniles from roots and soils also were evaluated.

Screening for Resistance

Six trials were conducted under rustic-store conditions and/or in closed-container tests to identify host-plant resistance. In the first two trials, 9 clones were selected as moderately resistant out of 77 clones. In a third trial, all 25 clones tested from a diploid population proved susceptible. Tests in the fourth trial included 96 hybrids from Australia and 33 clones, with 64 hybrids selected as less damaged. In the fifth trial, 15 clones were selected from a total of 73 clones. The sixth trial tested 43 clones from CIP's pathogen-tested list, and 3 clones were selected as resistant. Results of the tests with selected clones of cycles P-82, P-83, and P-85 are shown in Table 5-3.

In Colombia, seven families with *Solanum berthaultii* ancestors were tested for resistance to PTM and adaptation to the cool conditions in Tibaitata. conditions. All families were obtained from Cornell University and all showed very high levels of resistance to PTM (Fig. 5-1).

At Lima, Peru, in a study of the factors affecting the resistance expression, DTO-33 tubers were equally susceptible when grown in the field and in pots, but the level of susceptibility was associated with tuber age. Freshly-harvested DTO-

Table 5-3. Clones selected for resistance to Potato Tuber Moth, *Phthorimaea operculella*, San Ramon.

	Storage Tests[a]		Lab Test[a]	
Clones	1986	1987	1988	1986
P82119-19	MR	MR	MR	R
P83614-5	S	MR	MR	R
P83693-15	R	MR	MR	R
P83707-6	R	MR	MR	R
P85031-5	–	–	MR	–
P85072-4	–	MR	MR	MR
P85075-2	–	MR	MR	MR
P85112-1	–	MR	MR	MR
P85115-1	–	MR	MR	MR
P85136-1	–	MR	MR	R
P85031-3	–	MR	MR	R

[a]MR = Moderately Resistant; R = Resistant; S = Susceptible

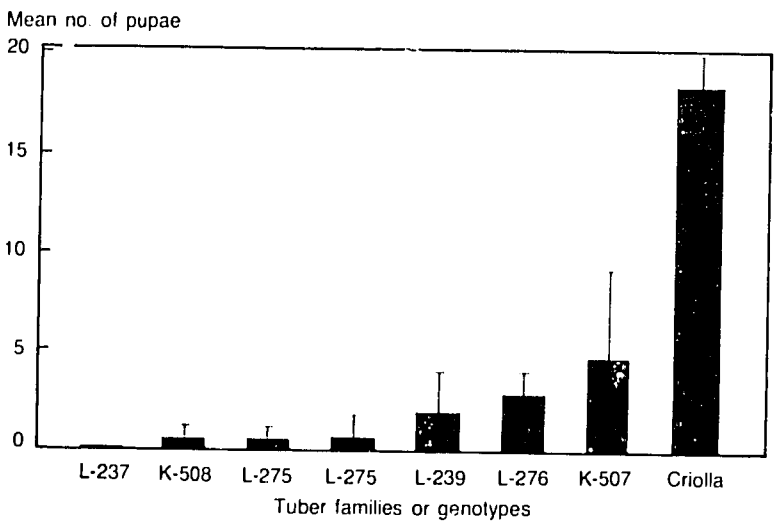


Figure 5-1. Resistance to potato tuber moth larval damage in families generated by Cornell Program, Bogota, Colombia

33 tubers proved susceptible, whereas 30-day-old tubers in cold storage showed resistance.

In Colombia, a study examined the effects of soil types (Toca and San Jorge soils) and of NPK fertilization levels on the resistance expression of cv. Parda Pastusa.

Biological Control

Granulosis virus formulation effects on the potato tuber moth were evaluated in nine trials under store and field conditions, at La Molina and San Ramon, Peru. A dosage of 20 larval equivalents (LE) in 1 liter of water reduced tuber damage in stored tubers. At 45 days after treatment, 70% of the PTM larvae were infected and the PTM population was reduced (12 moths vs 236 moths in check). Dust formulations (using talc as a carrier) protected the tubers effectively. Table 5-4 shows the results of a test evaluating granulosis virus formulations.

The parasitoid *Copidosoma desantisi* (Annecke and Mynhart) was introduced from Peru to Colombia and released in Toca, Boyaca and Tibaitata, Cundinamarca. The parasitoid has established in Tibaitata, where a 30% level of parasitism has been recorded.

In a study of the interaction of *Copidosoma* sp. with the granulosis virus in Peru, the parasitoid failed to develop on GV-infected larvae. A simple methodology was developed for the multiplication of the granulosis virus and the PTM.

Sex pheromone

Sex-pheromone studies continued to examine methods for lowering the cost of the formulations. Two formulations (PTM1, 0.4 mg + PTM2, 0.6 mg; and PTM1, 0.9 mg + PTM2, 0.1 mg) were field-tested for 5 months. Trap captures

Table 5-4. Potato tuber moth damage at 120 days in Storage in Granulosis Virus (GV) Treated and Untreated Tubers, San Ramon, Peru.

Treatments	% Sprout damage	No. of holes tuber	Total[1] PTM Population (L + P + A)[a]
GV (20 L.E. liter)	11.69 a	0.90 a	8.25 a
GV + Talc	1.89 a	0.08 a	4.50 a
Talc	54.07 b	4.39 b	79.25 b
Check	97.22 c	7.75 c	154.00 c

[a]L Larvae; P Pupae; A Adults

1 – Means followed by different letters are significantly different using Duncan's Multiple Range Test (DMRT); P 0.05

did not differ; however, PTM1, 0.9 mg + PTM2, 0.1 mg was the most economical formulation.

In studies of attraction responses of PTM, variations in the ratios of pheromones PTM_1 and PTM_2 produced response differences in two populations from Peru and Colombia. Further tests in Colombia will determine whether these differences might characterize different biotypes or races.

Seasonal Occurrence of PTM

Pheromone traps were used to study the seasonal occurrence of the potato tuber moth in Ethiopia and Burundi. The lowest population levels (fewer than 3 moths/trap/week) were recorded at Holetta Research Center, Ethiopia, during the main season for potato-growing. This season is from July to October and coincides with higher rainfall levels. Medium population levels (2 to 10 moths/trap/week) occurred during the irrigated season, with levels peaking at 19 moths/trap/week at the end of the season.

In Burundi, the higher PTM population levels were recorded in the September-January period at Mahwa and

September-November period at Nykararo.

Store infestations were monitored at four locations in Burundi: Nykararo, Mwokora, Gisozi and Munamira. The highest population levels occurred in Gisozi (2 to 11 moths/trap/month) and the lowest in Munamira (0.1 moth/trap/month).

In Egypt, several tests examined the control of PTM in stores and evaluated the degree of susceptibility of commercial cultivars and other genotypes to this pest. The insecticides fenitrothion and fenvalerate, granulosis virus, and *Bacillus thuringiensis* reduced tuber damage by 50% (in comparisons with the untreated check). In another test, wire-screened stores provided better protection against PTM infestations than did non-screened stores. Light traps collected more adult male and female moths than did pheromone traps that attract only males. The simultaneous use of pheromone and light traps, after two months of storage, protected potato tubers from PTM damage better than did pheromone traps alone.

In another test under store conditions, fenitrotion reduced damage levels to 11% of those recorded for the untreated check. In similar comparisons, a 3-cm layer of *Lantana camara* and a 5-cm layer of straw reduced damage levels to 15% and 30%, respectively.

The level of susceptibility of 14 potato genotypes differed significantly among the tested cultivars (Table 5-5).

Leaf Miner Fly

Field screening for resistance to the leafminer fly *Liriomyza huidobrensis* was conducted at La Molina, Peru. Tests with previously selected material confirmed resistance for varieties Monserrate and Kinigi. Clones with glandular trichomes F728.1 and F743.4 were less damaged

Table 5-5. Relative level of susceptibility of some potato cultivars to the potato tuber moth under laboratory conditions. Kafr El-Zayat, Egypt.

Genotype	% of infested sprouts	Mean no. of tunnels per tuber	% of emergence of adult
1 Atzimba x DTO 28	18.46	0.67	20.00
2 Serrana x DTO 28	23.08	1.30	16.70
3 CFK 69.1 x DTO 33	23.21	1.33	22.00
4 Draga	34.21	2.33	47.00
5 Greta	50.00	2.50	42.00
6 139 (Irish progeny)	58.73	3.00	42.00
7 Claudia	61.54	3.00	48.00
8 Avoundal	63.33	3.80	47.00
9 Escort	66.67	4.00	53.00
10 Désirée	67.74	3.20	55.00
11 Atlanta	72.93	4.50	52.00
12 Morene	74.96	4.30	55.00
13 Jaeria	76.19	4.00	55.00
14 Spunta	78.99	3.70	52.00
L.S.D. 0.05%	1.162	1.216	1.280

during the earlier stages of the crop, but were later damaged as they matured.

Spider Mites

The mite *Tetranychus* sp. was used to screen plants with glandular trichomes. The 738 seedlings from 7 families and 12 clones obtained from Cornell University were evaluated in field cages. Ten clones with less than 50% foliar damage were selected. Some of these clones have combined resistance to PTM and the aphid *Myzus persicae*.

Aphids

Eight clones with high antixenosis were selected in antixenosis tests of 47 glandular-trichome selected clones. The tests were conducted in greenhouses at La Molina, Lima, Peru.

At Holetta Research Station, Ethiopia, yellow-water traps were used to study seasonal occurrence of aphid populations. During the main season, levels of 3.3 aphids/trap/week were recorded. The aphid population was higher during the off season, with an average of 4.7 aphids/trap/week. A peak of 346 aphids/trap/week was reached in November, the driest month of the year, when potatoes had already been harvested. The main species identified was *Myzus persicae* .

In Uruguay, a comprehensive trapping survey was conducted in the rainfed regions for potato production. The lowest population levels of the main aphid vector *M. persicae* were recorded in northeastern Uruguay, suggesting that this is the best region for seed production.

Andean Potato Weevil

In Peru, a total of 469 clones obtained from breeders were evaluated using the closed-container test for tuber resistance. The clones HFF 18.1, UFF 14.3, and 85F 107.9 were selected for resistance to larval damage by the Andean potato weevil *Premnotrypes suturicallus*.

In Colombia, studies examined the correlation between larval population growth and tuber development, and between soil moisture and adult weevil emergence.

Thrips and Mites

Thrips were collected in the Philippines from nine provinces where the lowland potato is grown. *Thrips palmi* (Karni) and *Megalurothrips usinatus* (Bagnall) were identified, with *Thrips palmi* being more prevalent. The predominant species among mites was the microscopic *Polyphagotarsonemus latus* (Banks), known also as broad mite or tea mite.

Natural pest enemies were collected and an anthocorid bug, *Orius tantillus* (Motschulsky), showed promise as a potential predator for *Thrips palmi*. The life cycles of the broad mite and the *Thrips palmi* were studied under laboratory conditions. The broad mite required 51 hours for development. The *Thrips palmi* required 12 days for development and had an adult life of 5 to 8 days.

Sweet Potato Weevil

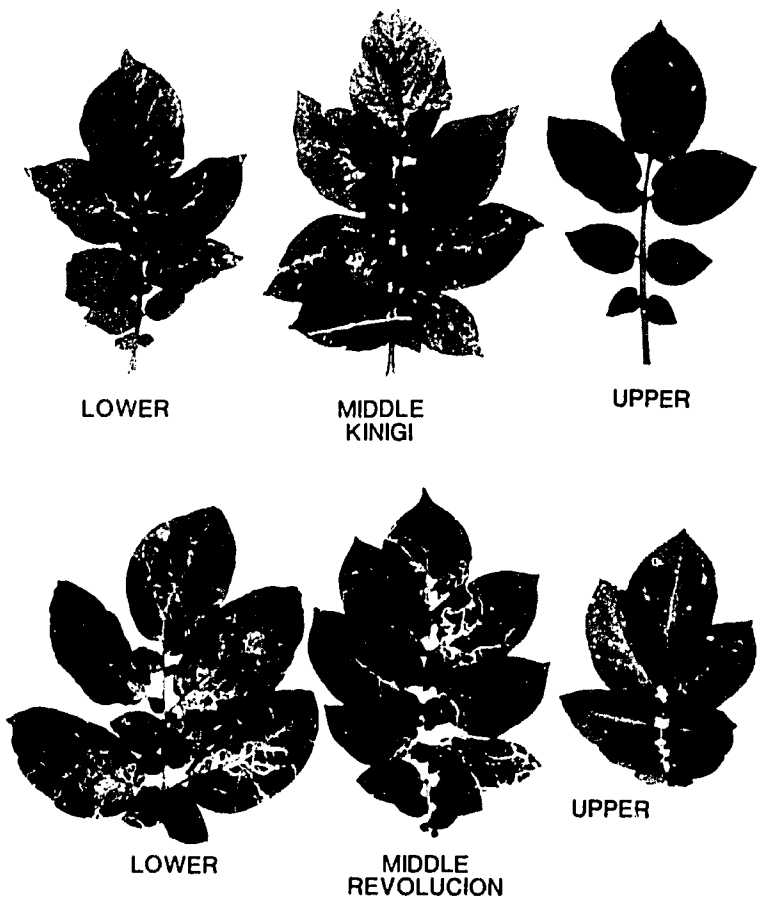
In studies of CIP germplasm to identify resistance and to study the biology of the sweet potato weevil, *Euscepes postfasciatus*, 600 accessions from CIP germplasm were tested using the closed-container test. Selected materials are being subjected to further evaluations. Field screening using previously selected clones was done in Lima. All clones were damaged in stems; however, accessions DLP 103, RCB 16 IN, and ARB 389 were less damaged.

Research Contracts

A research contract with the Universidad Nacional Agraria, La Molina, Lima, Peru yielded abundant information on the collection, identification, and field importance of parasitoids of the most important potato and sweet potato pests in Peru.

These pests include the potato moths *Phthorimaea operculella* and *Scrobipalpula absoluta;* the noctuid *Spodoptera eridania*; the potato aphids, the potato leaf-miner fly, *Liriomyza huidobrensis*; the sweet potato foliage pests, *Pebops* sp., *Trichotaphe* sp., *Microtyris anomalis*, the miner fly *Calycomyza ipomoeae*, the leaf hopper *Empoasca* spp., and the white fly *Bemisia* sp. These pests and their natural enemies were reported to occur seasonally.

Other studies were made of the selective use of insecticides against the potato leaf-miner fly, of the effect of insecticides on the pests, and on beneficial fauna of sweet potato fields.



Leafminer fly (*Linomyza huidobrensis*) damage on resistant (Kinigi) and susceptible (Revolucion) potato cultivars.

Thrust VI

Warm-Climate Potato and Sweet Potato Production

Thrust Profile :1989

Clone LT-7 was the top-yielding entry in studies of the role of nitrogen in warm-climate potato production. This clone showed a greater ability to utilize fertilizer nitrogen, with less reduction in partitioning of dry matter to tubers at high nitrogen levels.

Tuber yield of potato under drought stress was related to the force required to pull plants out of the soil. This potential screening method for drought tolerance is being developed along with others related to root growth, leaf-water potential, stomatal conductance, and leaf appearance. Sweet potato clonal-yield rankings remained about the same under both drought and well-watered conditions. This suggests that simply screening for cropping and yield under non-stress conditions might be sufficient for identifying drought-tolerant clones.

Screening for high growth rates of potato clones and species under controlled-climate conditions identified new sources for heat tolerance, as well as for tolerance to shade, which is important for intercropping.

Relay-cropping potato with maize was an effective method for establishing the potato in a hot-weather, non-traditional, early planting in Egypt. Intercropping maize and potato reduced soil and nutrient erosion in China. Through agronomic modifications of the traditional double-row strip-cropping in Hubei Province, China, yields were increased by 8%, and by 62% in the cane/potato intercropping in Bangladesh.

In China, potato clones are selected for intercropping, and one such selection (802-522) yielded 26% more than the control clone at 460 m, 19% more at 1180 m, and 10% more at 1700 m. Heat-tolerant clones continue to be identified in the breeding programs of Peru, the Philippines, Vietnam, and Bangladesh.

Woman harvesting potatoes from a field intercropped with maize, Burundi.

Agronomic and Physiological Research

Nitrogen Utilization

A series of experiments in Peru to quantify the role of nitrogen (N) fertilization in adaptation of the potato to the warm tropics, ended this year. Yields of the clone LT-7 were greater than those of the cultivars Desiree and Katahdin at all N rates. With no N application (0 kg/ha), the clones showed about the same amount of N in leaves (Fig. 6-1); but at 240 kg/ha N, the clone LT-7 consistently had more leaf N per unit of cropping area. Partitioning of dry matter to tubers was more strongly influenced by the rate of N fertilizer (Fig. 6-2) in the wet season than in previous dry seasons (see Fig. VI.3, Annual Report, 1988). The cultivar Desiree showed a greater decline in partitioning at intermediate N levels than did the clone LT-7. The greater ability of LT-7 to utilize fertilizer N, and the lesser reduction in dry-matter partitioning to tubers at the intermediate N levels, were largely responsible for the overall yield advantage of LT-7. Tubers with this type of yield response to N should prove beneficial to farmers who apply either small or adequate amounts of N to their potato crops.

Drought and Salt Stress

The development of an extensive root system is closely related to the plant's capacity to absorb soil moisture, as well as to avoid dehydration stress. Root-pulling resistance, i.e., the vertical force required to pull a plant out of the soil, is an integrated, quantitative estimate of root development that has been tested by

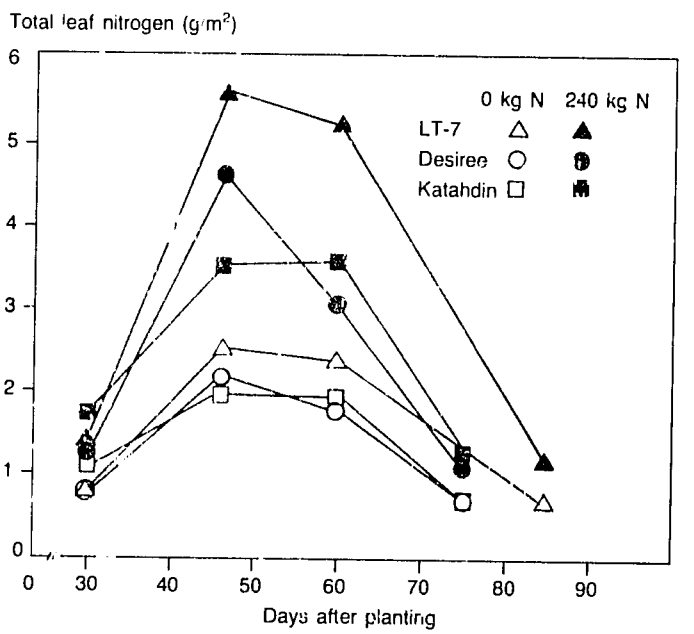


Figure 6-1. Effect of fertilizer N application rates (kg/ha) on weight of N in the leaves in San Ramon, dry season.

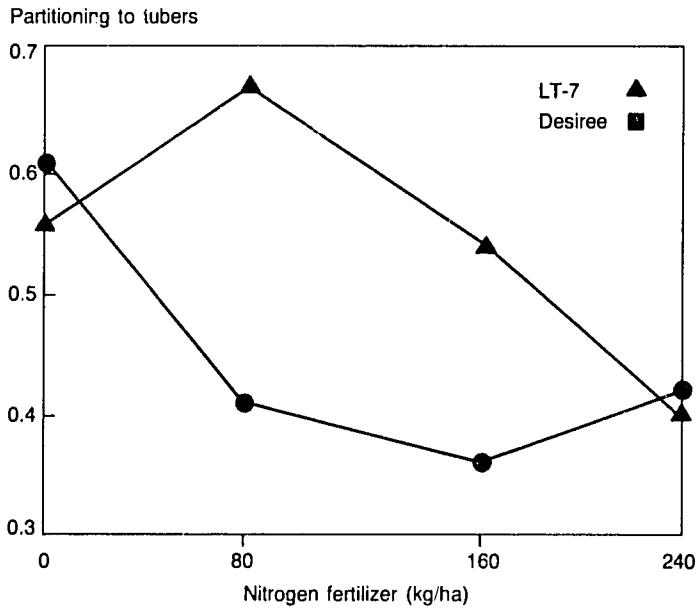


Figure 6-2. Partitioning of dry matter to tubers (70 days after planting) as influenced by genotype and fertilizer N application rates in San Ramon, wet season.

CIP as an indicator of potential drought avoidance.

In a field experiment in which root-pulling resistance was measured at biweekly intervals to determine the optimum time for quantifying this characteristic, a sigmoid curve of resistance on a time axis was observed for the three clones tested, LT-8, Desiree, and Revolucion. The maximum mean separation occurred 45 days after planting, and this date was chosen for subsequent comparisons between clones. A replicated, single-row-plot field experiment was conducted in San Ramon during the dry season with the clones LT-7 and DTO-33 serving as the drought-resistant and moderately-resistant checks, respectively. Sprinkler irrigation was applied after crop establishment to satisfy 50% of the daily evapo-transpirational demand. At 90 days after planting, 22% of the variance in tuber yield was accounted for by variance in root-pulling resistance, and five clones (Cruza 27, I-1039, MS-35-22-R, Huinkel and Mex, 750826) performed as well as or better than did the drought-resistant check in terms of drought-resistance and tuber yield.

The line-source irrigation system was used during the Lima summer season to evaluate clones for drought resistance. The effect of drought stress on leaf-water potential was quantified with the pressure chamber method (Annual Report, 1976). Genotypic and treatment effects were recorded in terms of leaf-water potential measured at midday on the third youngest expanded leaf of the main stem. High leaf-water potential (less negative), indicating a lesser degree of cellular stress than a low (more negative) value, was evident in well-watered,

moderately-stressed plots of the clone LT-7. Under greater drought stress, however, the high leaf-water potential values were not maintained. The cultivar Desiree maintained relatively higher leaf-water potential values than did the others when severely stressed. The leaf appearance of drought-stressed plants was indexed (Table 6-1) and the clones LT-8, B-71-240.2, Mariva, and CGN-69.1, showed the least leaf damage. Leaf-water potential and leaf appearance scores (although measuring different effects) are practical indicators of drought response in the potato. Further data are being collected to confirm their utility, in combination with root-pulling resistance, in the task of identifying parental materials for breeding for drought tolerance.

Preliminary data on stomatal conductance show a good correlation with soil matric potential in one clone, and this relationship will be explored for other clones in the future. Additional methodologies similar to the ones described above will allow for the quantification of plant response to drought stress.

In drought studies in the Philippine lowlands, a 20-day water stress at the early tuberization stage reduced yield more than did stress induced at earlier or later periods. Early-maturing cultivars such as Berolina and Cosima, which cease foliar growth soon after tuberization, were more susceptible to water stress at early tuberization than were indeterminate clones (e.g. P3 or P7) that are characterized by profuse foliage and that have *S. andigena* in their pedigrees. Root growth of water-stressed plants was measured by number, weight, length, diameter, and type. Data indicated that there were major differences in root-growth characteristics as influenced by water stress and genotype. This knowledge will aid in the breeding, screening and selection of drought-tolerant tubers for use by farmers in drought-prone areas.

Table 6-1. Mean drought-stress scores for potatoes under a line-source irrigation system, Lima 1988.

Clone	Distance from the sprinkler line source (m)				
	0.7	2.1	3.5	4.9	6.3
LT-8	1.0	2.0	2.8	3.5	5.0
B.71-240.2	2.0	2.8	3.8	4.5	6.0
P-3	1.8	3.5	3.0	5.5	6.5
Revolucion	2.0	3.3	4.0	5.5	6.5
Ticahuasi	1.0	4.0	3.0	6.5	7.5
G-1	1.0	3.3	3.5	6.0	7.5
LT-7	1.8	2.5	4.3	7.0	7.5
LT-1	2.5	3.8	4.5	5.8	6.5
CGN-69.1	2.3	4.3	5.3	5.5	6.0
Mariva	3.3	3.5	4.5	5.8	6.3
Desiree	2.5	3.5	4.8	6.5	7.0
Rosita	4.0	3.5	5.3	6.0	6.5
DTO-33	3.0	6.0	5.0	5.8	6.5
82PY-19.2	3.3	5.3	7.0	7.5	7.5
Tomasa Condemayta	5.0	6.0	6.3	7.5	8.5
LT-5	4.5	7.0	6.3	8.5	8.3

SED between clonal means = 0.49 and between treatment means = 0.18.

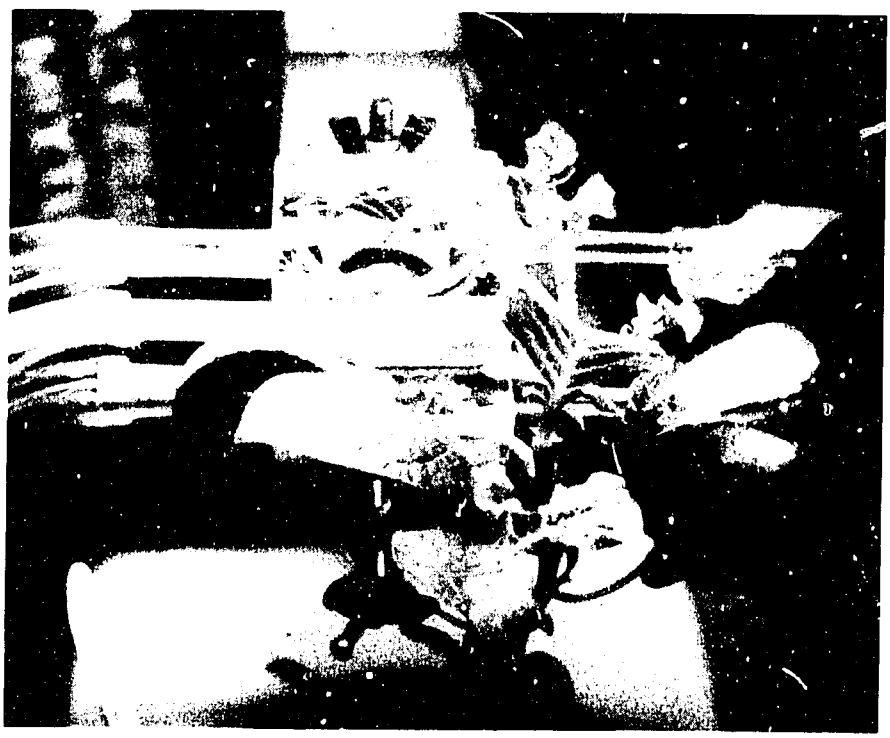
Scores are from 4 replications noted 30 days after the commencement of drought treatments (60 days after planting), obtained based on total plant appearance. Score 1 = no drought effect, 5 = 50% wilting and 9 = complete wilting and necrosis.

Replication, clone, and irrigation effects are highly significant (P = 0.001). C.V. = 30%.

At the Scottish Crop Research Institute (Dundee, Scotland) root characteristics and other factors related to water economy of plants subjected to various levels of drought stress are being studied. These plants are being evaluated in soil "cores" (vertical pipes 10 cm in diameter and 150 cm long) to complement field studies in the lowland tropics.

Field studies with several sweet potato varieties were conducted at Lima and San Ramon to evaluate the effect of drought on yield and water use (using the line-source system, as with potato). Water-use efficiency (WUE) was influenced by genotypes, quantity of water, and site. Under well-watered conditions at both sites, the clones Paramonguino and Ingles showed the highest WUE, and DC-79 and Nemañete showed the lowest WUE. Under drought stress at Lima, high WUE was evident for clones that also showed high WUE under well-watered conditions. At San Ramon, however, some clone/treatment interactions were found. At Lima, the lack of interaction between clones and irrigation treatments for storage-root yield suggests that selection for vigor and high yield under well-watered conditions could allow for simultaneous selection of clones able to yield well under drought conditions. At San Ramon the interaction also was not significant.

Sweet potato clones also were subjected to salt-induced stress, but under in vitro conditions. In an initial test four weeks after treatment, fresh weight and leaf number increased with increasing salt concentration (0 mg to 174 mg NaCl/l).



Measurement of leaf photosynthesis in a plant grown under controlled environment (35°C day, 25°C night).

Heat Stress

Controlled-growth chambers were used to study the potato genetic base for heat tolerance at the Nova Scotia Agricultural College (NSAC), Canada. In vitro-derived plants of a range of cultivars, breeding lines, and species were subjected to a period of heat stress, while tuberization was suppressed. The clones differed significantly in rates of leaf photosynthesis, dark respiration, and growth. Data on chlorophyll fluorescence and leaf anatomy are now being analyzed and indications are that the terminal 'T' value of the chlorophyll induction curve is closely related to dry-matter production under high temperature conditions. Comparative analyses of growth rates of 34 potato genotypes under hot (35°C/25°C day/night) and cool

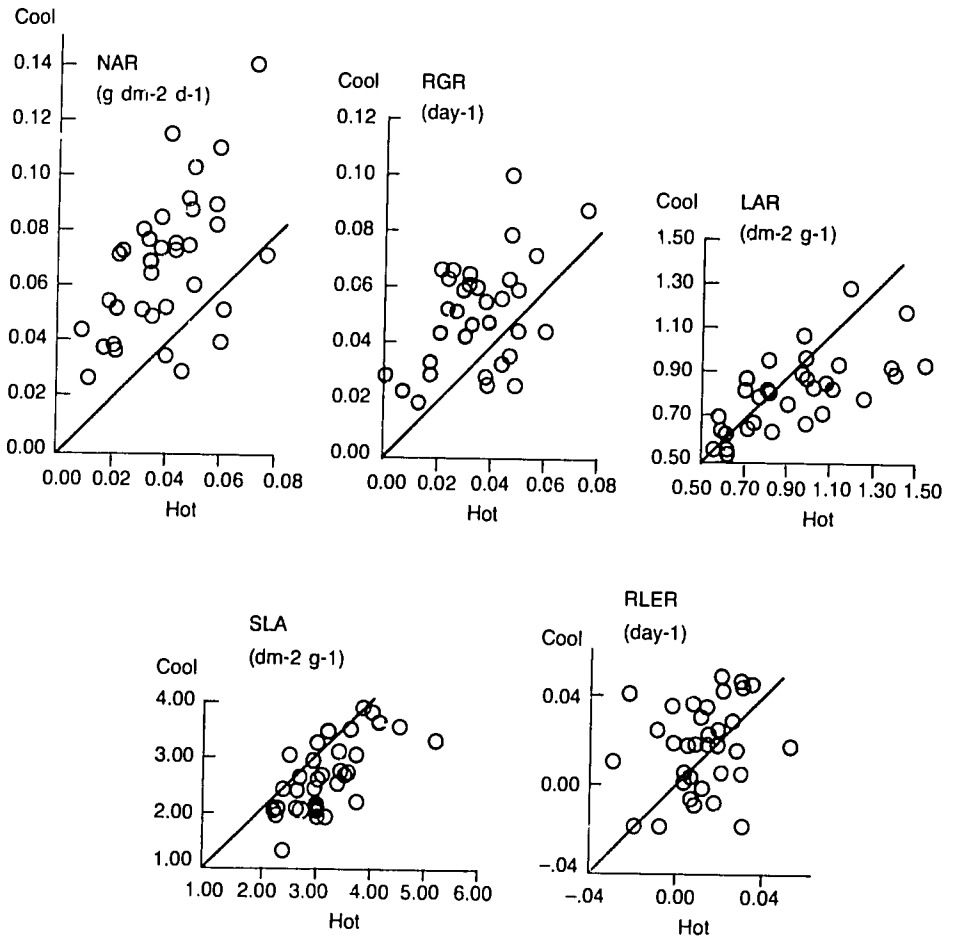


Figure 6-3. Some plant growth analysis parameters as influenced by growing conditions (cool = 20°C day, 10°C night, hot = 35°C day, 25°C night in controlled environments (20 h photoperiod) (NAR - net assimilation rate; RGR - relative growth rate; LAR - leaf area ratio; SLA - specific leaf area; RLER - relative leaf expansion rate).

(20°C/10°C) conditions indicate that, in general, leaves were thinner (a greater specific leaf area) under hot conditions, and net assimilation and relative growth rates were lower under cooler conditions (Fig. 6-3). A number of exceptions were noted, for example, LT-1, LT-5, and accessions of *S. circaefolium* and *S. acaule,* and these and clones with high growth rates are being studied in more detail.

Intercropping and shade tolerance. For relay-cropping or intercropping potato with annual or perennial crops, systems have been designed to avoid competition between associate crops and potato for solar irradiance (Annual Reports, 1981 to 1986-87). To raise total productivity of some intercrop combinations featuring potato, however, a degree of shade tolerance may be desirable, especially if the population of the associate (and oftentimes shading) crop is raised significantly. At the Nova Scotia Agricultural College, Canada, the response of leaf photosynthesis to various levels of irradiance was determined for potato clones and species grown in growth chambers. Differences between genotypes were noted both in values for Pmax (i.e. the light-saturated rate of photosynthesis) and in the quantum efficiency of photosynthesis (i.e. the slope Ø) of the linear response of leaf photosynthesis to irradiance when photosynthesis is light-limited). Clones with a high Pmax should be capable of taking advantage of high-incident irradiance whereas clones with a high Ø should be adapted photosynthetically to less irradiance, such as when shaded.

CIP collaborates with national programs to analyze field performance of intercrop systems. In Egypt, relay-cropping of potato with an existing maize crop is an experimental practice gaining favor among farmers who wish to plant in the hot-season period before the traditional planting date. This practice is especially effective for planting cultivars that do not emerge rapidly under conditions of high soil temperatures, whether due to lack of sprouting or to an inherent aversion of the sprout to growth under high soil temperatures. Yield benefits of the relay-cropping system were greater for the cultivars Alpha and Dragon, which had the least emergence under control conditions. Higher maize-crop yield was an additional benefit from this system.

Under contract with CIP, intercropping research continues at the Southern China Potato Research Center, at Enshi, Hubei Province. Spatial distributions of the maize and potato crops have been evaluated and results show the yield advantage of double potato rows alternating with double rows of maize. Especially at the higher altitudes, this pattern was superior to single potato rows alternated with double rows of maize, or to 4 rows of potato alternated with 4 rows of maize. An experiment at 1,200 m tested closely-spaced single rows of potato and maize (0.5 m between rows of each crop). This combination yielded 88% more harvestable dry matter than the next best combination (double rows of potato and maize). Plastic mulching effectively accelerated the emergence and maturity of the potato (by 10 to 12 days) and also raised maize yields. The extra income did not offset the cost of the plastic mulch, however, and farmers are unlikely to adopt this practice, even if the extra cost is spread over more than one year.

In this part of China, potatoes are usually planted in the autumn, and date of emergence in the spring depends upon the spring temperature regime. Maize

planting and emergence are controllable, after the land is suitably dry and warm. When maize planting was delayed for 10 days beyond the normal planting date to reduce the possible competitive effect on potato, total harvestable dry-matter production (potato plus maize), increased marginally (5%). In contrast, a 40-day delay reduced total dry-matter production by 5%, due largely to the lower maize yield.

The intercropping procedures practiced by farmers in Hubei Province are particularly resilient in that total dry-matter yield is well buffered. In a series of experiments testing a range of agronomic practices, the yield decline for least favorable treatments never exceeded 15% of the best-yielding treatments. Relay-cropping systems such as these could provide sustainable harvests in other subtropical highland potato-growing regions as well.

Scientists at the Yunnan Academy of Agricultural Science at Kunming (24°N, 1,900 m) are working under contract with CIP. They are investigating the benefits of strip-cropping maize and potato, and associated factors including incidence of soil-borne diseases, and the reduction of water, soil, and nutrient losses on sloping soils. Rotational strip-cropping improved the per unit area yields of potato and maize as compared with the yields when they are planted singly. Another advantage was the lowering of the incidence of potato ring rot. Water, soil and nutrient losses on a 21° slope were less in intercropped plots than in maize-only plots, although potato-only plots showed the least loss (Table 6-2). Intercropping, and contour plowing (instead of surface tilling), proved to be an effective combination for reducing runoff from sloping fields.

Experiments in Western Hubei, China, on potato clones adapted to intercropping with maize has resulted in the selection of two locally-based clones as potential cultivars. These emerge 10 days earlier and are 15 cm shorter than the traditional cultivar, Mira. When intercropped with maize, one of the selected clones, 802-522 (Copella x NS78-7), yielded 24% more than did Mira at low elevation (460 m), 19% more at mid-elevation (1,180 m), and 10% more at 1,700 m.

In the collaborative contract involving CIP, the Bangladesh Agricultural Research Institute and the Sugarcane Training and Research Institute in

Table 6-2. Effects of intercropping potato and maize, and contour plowing, on water, soil and nutrient runoff losses on a field with a slope of 21°, Yunnan Province, China.

Treatment	Loss per hectare per season					
	Water (m^3)	Soil (t)	Active nutrients (kg/ha)			
			N	P	K	NPK
Slope - sole maize	563	19.06	29.5	25.5	34.3	89.8
Slope - intercropping	476	8.23	13.6	11.0	18.1	42.7
Contour - sole maize	370	3.65	5.3	4.4	8.4	18.1
Contour - intercropping	216	1.36	2.2	1.8	4.0	7.9
Slope - sole potato	172	2.91	4.8	4.0	6.6	15.4
Contour - sole potato	101	0.62	0.9	0.9	1.8	3.5

Table 6-3. Effect of double-row planting system on potato and cane yields, and net benefit, on farmer and experiment station fields in Bangladesh.

Cropping pattern	Potato Population (plants/m^2)	Farmers' fields			Experiment station		
		Potato (t/ha)	Cane (t/ha)	Net benefit[b] (US$/ha)	Potato (t/ha)	Cane (t/ha)	Net benefit[b] (US$/ha)
Paired row cane at 60 cm + 2 row potato in 120 cm	5.55	4.3	81.0	263	8.3	76.3	360
Paired row cane at 45 cm + 3 row potato in 135 cm	8.33	5.5	83.3	531	10.0	80.6	369
One row cane at 90 cm + 1 row potato in 90 cm	5.55	4.7	82.0	509	6.1	82.0	231
One row cane at 100 cm + 2 row potato in 100 cm	10.00	7.6	85.6	629	12.1	76.3	295
[a]Pure stand potato then cane at 60 cm	11.1	–	–	–	12.7	73.0	239
Pure stand autumn cane at 100 cm	0	–	62.2	0	–	73.3	0
LSD 5%		2.0	10.3	85	2.0	n.s.	208

[a]Potato planted at 60 cm x 15 cm, then transplanted rooted cane settlings in spring.
[b]Extra to that derived from cane alone.

Bangladesh, further data have been collected on the technical and economic performance of potato intercropped with sugarcane. Cane yields were not reduced when the traditional single-row (0.9 m) system for sugarcane planting was changed to a double-row system in which more space was made available for the intercrop. The double-row system facilitated the planting of higher potato-plant populations (Table 6-3). Sugarcane benefited from the residual effects of potassium and phosphorous, (cane yield increases of 4 t/ha to 6 t/ha). To a lesser extent, the crop benefited from the residual effects of N (increases of 2 t/ha to 4 t/ha) applied to but unused by the potato crop. Because most potato and sugarcane are produced using residual soil moisture following the monsoon, practices that conserve soil moisture are of great practical importance. Although planting tubers at a depth of 15 cm did not greatly increase tuber yield, mulching with rice straw raised yields and overall economic returns of both crops (Table 6-4). Current research is focusing on the production of seedling tuberlets as planting materials for intercropping with sugarcane.

In Burundi, studies continue to explore the use of maize and potato intercropping to increase output per unit land area and to control bacterial wilt. Results in 1988 showed that land equivalent ratios (LER, i.e. the land area required for separate crops to equal intercropping production) for all intercropped treatments ranged from 1.12 to 1.27. This indicates a marked yield advantage per unit land area of intercropping, as compared to one-crop-only treatments. Although potato plants ranged from 23% to 45% of the total

Table 6-4. Influence of rice-straw mulch on potato and cane yields on the experiment station and additionally on net benefit on farmers' fields in Bangladesh.

Treatment	Farmers' fields			Experiment station	
	Potato yield (t/ha)	Cane yield (t/ha)	Net benefit[a] (US$/ha)	Potato yield (t/ha)	Cane yield (t/ha)
No mulch	7.2	81.9	560	4.8	79.5
Mulch up to 30 DAP[b]	8.2	86.1	710	5.1	86.4
Mulch up to 45 DAP	8.4	86.1	731	5.3	83.7
Mulch till harvest	8.7	91.1	860	5.2	90.2
Pure cane without mulch	–	80.5	–	–	–
LSD 5%	0.5	1.8	68	n.s.	1.9

[a] Extra to that derived from sole cane without mulch.
[b] Days after planting.

(4.29 plants/m2 to 5.08 plants/m2) plant population, the treatments did not differ in wilt percentages, perhaps because of the high coefficient of variation (77%).

In the Philippine lowlands, experiments continue to explore the association between potato and sweet corn. When potato and maize were planted simultaneously, with populations of 5 to 6 maize plants/m^2 and 2 to 4 potato plants/m^2 (preferably with potato in double-row beds), the resulting LER ranged from 1.22 to 1.41.

Production Strategies and Soil Management.

Systems to reduce crop temperature continue to be studied under farmer conditions. In northern Luzon of the Philippines, the combination of intercropping with maize (planted at one tenth of the maize-only population) plus mulching and irrigation, permitted late (January) planting. This combination produced a 6 t/ha tuber yield increase over that of control plots, with a corresponding increase in net income of US $1,720/ha. Row orientation (Annual Report, 1983) has been manipulated to provide a yield advantage for non-seasonal (late August) potato planting in Egypt, where yields ranged from 10.9 t/ha to 14.6 t/ha. Yields were greater when tubers were planted on the north side of east/west oriented rows.

Clonal Selection

Selection of potato clones suitable for the warm lowland tropics requires evaluation of heat tolerance, yield, earliness, tuber characteristics, and storability (depending on the logistics of production).

Peru

In Peru, a number of clonal selections have been identified that combine high yield and earliness (Table 6-5), although varietal selection is not the prime objective of the breeding program. The clones LT-7, LT-8, 377964.5, and 378015.16 (TS2) continue to demonstrate their abilities as competent parents. Bacterial wilt (BW) at San Ramon reduced plant survival, and studies of resistance to BW will be emphasized. During the dry season at San Ramon, in the routine

screening of the cultivars on CIP's pathogen-tested list, Ballenera, Muruta, and SR-1 (selected in the Philippine lowlands) consistently produced yields greater than 20 t/ha.

At each of CIP's three experiment stations in Peru, and at a southern site at Tacna, 2,000 seedling samples were transplanted from the same sweet potato polycross. The main purpose of this work was to select for earliness, a highly desirable trait to incorporate into CIPs breeding populations. With the exception of Lima, where clones were harvested at 120 days, harvest was at 90 days after planting. Yields of the best four clones ranged from 12 t/ha to 17 t/ha at Lima (winter season); 10 t/ha to 14 t/ha at San Ramon (dry season); 8 t/ha to 12 t/ha at Yurimaguas (dry season); and 17 t/ha to 32 t/ha at Tacna (summer season).

Table 6-5. a) Top-performing first-generation clones, from a sample of 250 evaluated at San Ramon. Summer 1988. Growing period: 90 days. b) Top-performing third-generation clones, from a sample of 45 evaluated at San Ramon. Summer 1988. Growing period: 90 days.

Clone	Plant survival (%)	Yield (t/ha)	Earliness[a]
a)			
(LT-8 x 377964.5)23	80	20.8	7
(C84.580 x C83.119)31	100	20.6	7
(C84.579 x 377964.5)31	70	19.7	5
(C83.331 x C83.119)13	70	16.7	5
(C84.241 x Katahdin)12	80	15.3	9
(MS35.22 x 377964.5)31	100	15.3	7
(C84.436 x Bulk PVY (A))91	70	15.0	7
(Y84.017 x Bulk PVY (A))91	100	15.0	9
(LT-8 x 378015.16)32	70	11.4	7
(C84.579 x 377964.5)71	80	10.6	7
b)			
(B-75-86.8 x C83.551)15	80	23.5	7
(ROPTA D-776 x LT-7)41	70	18.6	7
(377964.5 x 378015.16)31	70	16.5	7
(Atlantic x 378015.16)32	70	13.2	7

[a] Earliness: 1 - very late; 5 - medium; 9 - very early.

The Philippines

A total of 186 clones were selected from 34 tuber families for their adaptation to lowland conditions and for their good tuber characteristics. They were put in diffused-light storage for 9 months prior to replanting. In a previous set of selected clones that were stored for 9 months in situ, the five best clones produced yields of from 27.9 t/ha to 36.7 t/ha, and 53 clones (34% of the total) were selected. Under these conditions, the replanting of tubers stored in diffused light has been effective. Promising clones will be used as parents in the hybridization program.

Early blight remains a problem under lowland tropical conditions, and germplasm with sources of resistance (e.g. Maine 47) is being screened for earliness and early-blight resistance. Lower infection was noted for early-maturing clones, although disease incidence varied among clones having the same maturity ratings. Surprisingly, yield differences among clones or between spray treatments were not related to early-blight infection.

Cooking and processing qualities of lowland potatoes are now being studied to address some of the interests of the fast-food industry. Many clones produced outstanding potato chips or french fries, and three clones, 380584.3, LT-7, and 379693.10, showed capabilities for both forms of preparation.

South Pacific

Cultivars were assessed for yield and disease resistance in 14 variety trials. Even

with second-generation seed tubers, Serrana and B-71-240.2 continued to outyield all other clones. These high yields reflect the excellent virus resistance and good storage characteristics of the two clones. A heat-tolerant, BW-resistant clone, 377850.1 (BR 63.74 x DTO-28), was selected in Fiji and is now being pathogen-tested for distribution to nearby countries.

Vietnam

The clones I-1035 and B-71-240.2 have shown promise for winter planting at Ho Chi Min City (5 m) and are being multiplied for farmer use. Although selections from the cross B-71-240.2 x DTO bulk performed well over three seasons, lack of virus resistance (except to PLRV) is a major limitation.

Bangladesh

Trials at Munshiganj evaluated 3,822 initial introductions from 59 tuber families, 602 second-generation clones, and 91 third-generation clones. The trials were planted in mid-November and run by the national potato program. Some yields were outstanding, as compared with those of standard European check cultivars. Another set of 2,425 genotypes from 38 tuber families was planted late (December, 1987) to expose it to peak levels of virus transmission. Some genotypes (e.g. 382996.1, 384181.46, and 385302.120) yielded more than 500 g/plant. Advanced variety trials with 15 clones were planted at four locations, from Bogra in the north to Chittagong in the south. The sixth-generation clones evaluated in these trials showed minimal degenerative effects, and the yields of several clones surpassed those produced by seed of newly introduced cultivars. Clones awaiting varietal status include: B-71-240.2, 379667.501, 379688.230, 379659.657, 379673.150, 379687.93, 379697.153, 800224, AVRDC 1282-19, and Kufri Lalima.

Late planting (i.e. in December and January) exposes clones to more stress from heat and drought than does traditional planting (mid-October to mid-November). Clones performing well when planted late included Kufri Sindhuri and AVRDC 1282-15 at Munshiganj; LT-2, Cardinal and AVRDC 1284-18 at Joydebpur; and 379697.153 and 380504.110 at Bogra (at 71 days, the latter two yielded 34.3 t/ha and 26.7 t/ha, respectively, compared with 10.3 t/ha for Desiree).

After potato harvest, growers in Bangladesh lack means to store potato inexpensively without deterioration of tuber quality, thus limiting its widespread use as a food crop. Both B-71-240.2 and Kufri Lalima showed excellent storability, and routine screening is now under way for this character.

Training

A total of 20 participants from 8 Asian countries attended a workshop held in China to discuss the status and the future priorities of agronomic research to establish the potato as a major crop in hot climates. The participants cited the need for improved cultivars and development of appropriate methods for managing planting materials. Agronomic research priorities included studies of production under suboptimal growing conditions, including investigations of drought stress and shade tolerance.

Strip-cropping of potato and maize, Yunnan Province, China.

Thrust VII

Cool-Climate Potato and Sweet Potato Production

Thrust Profile: 1989

CIP is developing non-Andean populations for frost tolerance in combination with earliness and immunity to viruses X and Y. Of these, 26,344 seedlings from 108 families were screened in a growth chamber at -3° C. The seedlings that survived the tests (29%) were transplanted to the field for tuber increase and selection. Approximately 500 clones from transplants at harvest were selected for their agronomic value and will be further tested for frost tolerance in the field. Replicated trials of the most advanced selections under both frost and non-frost conditions indicated their high yield potential and high specific gravity (highest tuber yield: 1.89 kg/plant; highest specific gravity: 1.09).

Yields as much as 35% greater than that of the local cultivars were obtained in tests of the adaptability of the cool-environment populations to the longer-day environment of the non-Andean region. These tests were performed in collaboration with the national potato program in southern Chile (lat. 40°5'S).

The national potato program of Peru tested 2,000 clones with resistance to frost and late blight in 59 locations throughout the country. The outstanding clones showing promise as variety releases were 375558.8, 375517.1, and 375608.5, which showed tolerance to frost; and 380481.6, 380493.18, and 377744.1, which exhibited late-blight resistance.

A back-up population, with horizontal resistance to late blight from sources of resistance free of R genes (Population B), is going through a second recombination cycle to increase the frequency of genes for resistance. Preliminary assessment of heritability suggests that rapid progress can be made in improving this character. Of the 65,000 seedlings screened against race "0" of *P. infestans*, 5% showed high levels of resistance.

Harvest of potatoes to be traded for coffee and other foodstuffs, Marcapata, Cuzco.

Breeding for Frost Tolerance

Seedling Screening

Studies emphasized development of populations tolerant to frost, in combination with immunity to viruses X and Y, for the non-Andean region. A total of 26,344 seedlings from 108 families were screened for tolerance to frost in a growth chamber at -3°C. Some 6,000 seedlings (29%) survived the test and were transplanted to the field in Huancayo for multiplication, selection, and further testing for frost tolerance under field conditions. At harvest, 500 clones were selected for their desirable agronomic traits.

Field Testing

Testing in replicated trials. Clones at different stages of selection from both the Andean and non-Andean populations were routinely tested in two replicated trials. One trial was under natural frost conditions at Usibamba (3,800 m), and the other trial was under frost-free conditions at Huancayo Station (3,200 m). During the 1988 season, however, the incidence of frost was not as severe as that experienced during the previous year, when temperatures fell to -1° C to -3° C; thus with only light frost, maximum yield potential was expressed.

Average tuber yields in Huancayo with plant densities of 44,000 plants/ha were 1.1 kg/plant in the randomized complete block design (RCB), and 1.15 kg/plant in the simple 10 x 10 lattice design. The highest tuber yield (1.89 kg/plant) was obtained with the lattice design. The average specific gravities were 1.080 for the RCB and 1.076 for the lattice design.

In the absence of heavy frost, tuber yields at Usibamba also were high, despite irregular rainfall conditions and only medium-level rates of NPK fertilization. Single-plant tuber-weight averages were 1.47 kg for clones in the RCB design and 1.21 kg in the simple lattice design (Figure 7-1), at plant densities of 37,037 plants/ha. Highest tuber yields were 1.68 kg/plant in the RCB design and 1.78 kg/plant in the lattice design.

Adaptability to a Wider Range of Cool Environments

The potato population for the non-Andean region was tested for adaptability to longer-day, cool environments in Osorno, Chile (lat. 40°5'S), in collaboration with the INIA potato program. From the clones introduced and multiplied in the field during 1986/87, 50 clones were selected for their agronomic value under long-day conditions. These clones, including two widely grown local cultivars (Desiree and Ultimus), were further evaluated in the field during 1987/88. Figure 7-2 shows the best-yielding selected clones in the test in Chile.

The data show strong evidence of the increasing adaptability of the potato population to the cooler environments of the non-Andean region.

Utilization of Cool-Environment Populations in Peru

In 1986/87, INIA summarized the results of an evaluation of germplasm throughout Peru and their findings included the following:

A total of 1,197 clones were evaluated at 15 locations (average altitude, 3,398 m) throughout the country. Approximately 90% of these clones came from CIP's research project for frost resistance. Three CIP clones were listed as the most outstanding overall: 375558.8, 375517.1, and 375608.5.

Similarly, 979 clones from CIP's late-blight program were tested for late-blight resistance at 44 locations throughout Peru; and their high levels of resistance were confirmed.

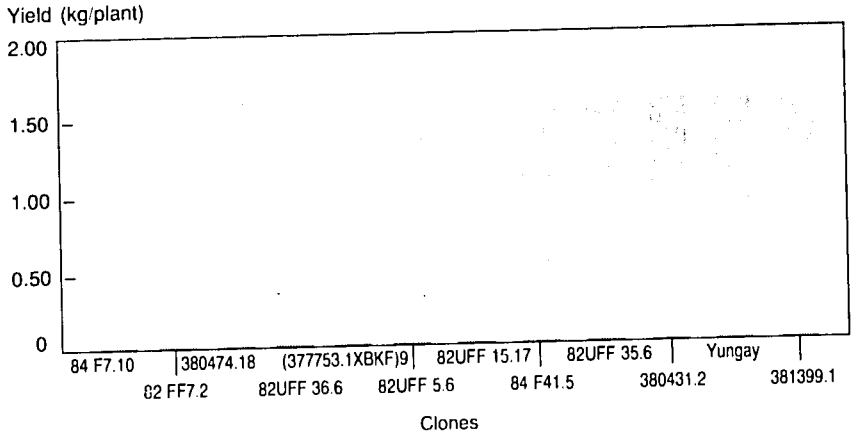


Figure 7-1. Yield performance of clones resistant to frost. (Lattice, 10 x 10) Usibamba 1988.

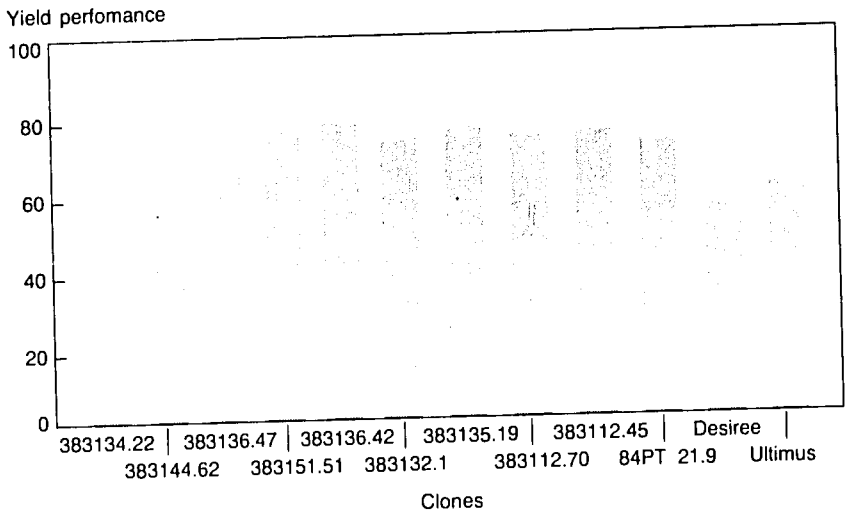


Figure 7-2. Yield performance of best clones under long days (Chile lat. 40°S).

Outstanding clones 380481.6, 380493.18, and 377744.1 showed promise as future varieties. Variety Perricholi (of CIP origin) also showed good late-blight resistance and agronomic value.

Agronomic and physiological studies

Studies on efficient use of nitrogen (N) at traditional potato growing areas. In the Mantaro Valley, Peru three field trials (two on the experiment station and one on-farm) evaluated clones previously selected for their range of yield efficiency under low and high N input. Findings of the on-farm trials indicate negligible response to added N (180 kg/ha) in the absence of applied phosphorous (P) and potassium (K), as compared to the N response in the presence of applied P and K. The lack of response was associated with fewer and smaller tubers.

Three clones (379454.1, Mariva, and Yungay) were particularly responsive to the added N in the presence of applied P and K, but only 379454.1 responded in the absence of P and K. In a similar trial on the experiment station, there was marked response to applied N (in contrast to the previous year's experiment) for all levels of applied P and K, but there was no yield response to applied P and K alone. Apparently, levels of applied P and K on the experiment station soils were sufficient to permit response to N, but additional P and K were needed on the farmer's field. In a field trial at the experiment station with 36 clones grown with or without 180 kg/ha of N (in the presence of applied P and K), those clones that had high yields under low N responded least to additional N. This finding supports results from previous years, and data from four consecutive years are now being processed to determine yield stability and to relate these findings to the response to added N.

Data collected from experiment station trials on leaf-chlorophyll content are being analyzed to identify clones that are efficient in their uptake of N. Early indications show that the semi-quantitative photometric method used is no more accurate than is a visual quantification of green foliage color in the field.

Studies were made of relationships between root morphology and abilities to yield well under low N and to respond to added N. Root-hair number, length, and distribution were quantified on roots of rooted stem cuttings, sprout cuttings, and in vitro- and tuber-derived plants, for genotypes characterized by their yield response to low and high soil N. Simple correlations among these root characteristics were not significant. As a first step in screening clones for their nitrogen-use efficiency, multivariable analyses are now under way to relate clonal root characteristics to field performance.

Control of Fungal Diseases in Cool Environments

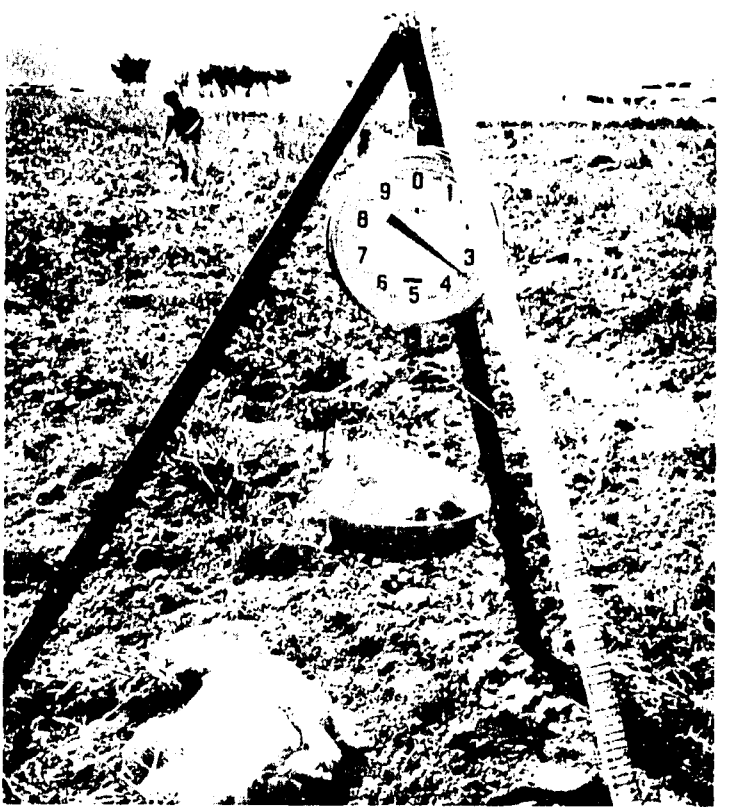
Breeding for late-blight resistance free of R-genes. A back-up population is being developed with resistance to late blight. This work is based initially on native *S. andigena* germplasm, which has no major genes for resistance (Population B). Major objectives are to increase levels of stable horizontal resistance and to improve agronomical attributes.

Preliminary assessment suggests a rather high narrow-sense heritability of horizontal resistance to late blight in this population, indicating that this character can be improved rapidly by using higher inoculum pressure in combination with screening for desirable agronomic attributes.

The correlation between the seedling test and the adult plant test was sig-

nificant (r = 0.58), indicating that the two tests are associated.

A total of 65,000 seedlings was screened against race "0" of *P. infestans* at a concentration of 2,000 zoospores/ml. Approximately 5% of the seedlings were selected for high levels of resistance. These clones currently are being intercrossed to generate a second recombination cycle based only on seedling screening at this preliminary stage. Following the third recombination cycle, selection for agronomic attributes will be made in the field and will be followed by progeny-testing to select parental material.



Weighing clones tested for frost tolerance at 3,800 m (central highlands, Peru).

Thrust VIII

Postharvest Technology

Thrust Profile:1989

Studies of potato storage technology concentrated on storage of consumer potatoes in warm-dry and warm-humid conditions. Special study interests included storage pests and diseases, water loss, and sprouting. Methods to control postharvest losses were studied in Peru, Kenya, India, Pakistan, Thailand and the Philippines, with focus on methodologies that are appropriate to local conditions.

In Peru, technical support was provided for several small processing units in the highlands. The Huancayo plant is now processing several Andean root and tuber crops and operates throughout the year. Products are dehydrated using a combination of solar and artificial drying. A study of integrated control of postharvest potato losses was repeated in rustic consumer-potato stores in San Ramon. The findings supported previous research showing that evaporative cooling reduced the total weight loss of store tubers.

In cooperation with ENEA, in Italy, design work was begun on low-cost solar dryers that are more efficient than solar drying alone. I . Bangkok, a collaborative study with Kasetsart University investigated the demand for potatoes and potato products. Village-level processing and utilization of potatoes were studied by the SOTEC project at Bareilly, India in collaboration with CIP. This work focused on engineering aspects together with product evaluation. A new peeler was developed, the slicing equipment improved, and a blending tank made of stainless steel substituted for the original sheet metal tanks that had rapidly corroded. Many recipes were developed and snack noodles produced.

Low-altitude potato storage trials in Kenya were designed to test household storage methods and box stores. Weight losses were reduced substantially by use of IPC sprout inhibitor in the box stores.

Village-level potato processing (canning), Hapur, India.

Storage of Consumer Potatoes

Research continues to concentrate on storage of consumer potatoes in warm-dry and warm-humid conditions. Methods to control postharvest losses were studied in storage experiments in Peru, Kenya, India, Pakistan, Thailand and the Philippines. Storage pests, storage diseases, water loss and sprouting were special interests.

Peru

A study of integrated control of postharvest potato losses under warm-humid conditions was repeated in rustic consumer-potato stores in San Ramon (see Annual Report 1988). Locally harvested clones and cultivars were cooled by a system that soaked the charcoal-filled store walls with water three times daily. Table 8-1 shows that last year's findings were supported: the evaporative cooling reduced the total weight loss of stored tubers.

The incidence of *Fusarium* dry rot and associated soft rots in untreated tubers was low, as compared with that of previous seasons. Pre-storage dipping in thiabendazole or sodium hypochlorite solutions tended to increase rotting (Table 8-2). The sprout inhibitor CIPC did not increase rotting, as in the previous experiment, probably because the inhibitor was applied one month after harvest, allowing thorough suberization of the tubers prior to treatment. However, sprouting was not effectively inhibited. Covering the tubers with a hessian sack after treatment slightly improved the sprout-suppressing effect of CIPC.

Infestation by the potato tuber moth was higher in stores without evaporative cooling, confirming previous findings. After 180 days of storage, the percentage of larva-damaged tubers was 82.8% in stores without evaporative cooling, as compared with 21.5% in the cooled stores. Pest control was obtained by protecting tubers with barriers of crushed, dried leaves of *Lantana camara*. Tubers treated with CIPC were not damaged (Table 8-2).

Table 8-1. Mean weight loss (% by weight)[a] of potato tubers in San Ramon rustic consumer potato stores, with and without evaporative cooling.

Evaporative cooling	Storage period (days)		
	60	120	180
+	8.8	16.8	37.9
–	10.7	20.8	56.2
CV (%)	36.6	29.1	22.5
LSD	1.2	1.9	4.0

[a] Mean of 5 cultivars with 3 replicate samples of 8 kg each.

Table 8-2. Effect of storage treatments on the incidence of rotting and potato tuber moth (PTM) damage (% tubers affected by weight[a]) after six months in rustic consumer potato stores in San Ramon.

Treatment	Rotting	PTM damage
1) Control (not treated)	12.8	52.2
2) Thiabendazole dip[b]	17.3	47.3
3) Sodium hypochlorite dip[c]	35.0	26.5
4) Lantana camara[d]	19.6	5.7
5) CIPC[e]	11.6	0.0
6) 2 + 3	13.6	40.8
7) 2 + 3 + 4	27.0	1.6
LSD (0.05)	2.2	6.3

[a] Mean of 5 cultivars/clones with 3 x 8 kg per clone.
[b] Tubers dipped for 10 minutes in thiabendazole solution (0.2% active ingredient).
[c] Tubers dipped for 10 minutes in sodium hypochlorite solution (0.5% active chlorine).
[d] Applied as a 5 cm cover of crushed dried leaves.
[e] Isopropyl-N'-(3 chlorophenyl)-carbamate applied as a dust at 1.5 g/kg potatoes, one month after harvest.

When foliage was removed from the mature crop and harvest delayed for one week to stimulate tuber suberization, losses under rustic storage conditions totalled 42.3% after 4 months compared with only 24.3% for tubers harvested immediately after crop maturity. This increased loss probably was due to the longer tuber exposure to disease and insect infestation in the field during the suberization period.

The most effective method for reducing losses was to remove all damaged and diseased tubers prior to storage. Table 8-3 shows that when the highest level of pre-storage selection was used, the weight loss of tubers during rustic storage was comparable with the loss observed for tubers from the same crop stored under refrigeration.

Thailand

In cooperation with the Horticultural Research Institute and the Agricultural Engineering Division of the Department of Agriculture, a farmer survey identified specific postharvest problems in the lowlands of northern Thailand. The survey showed that about half of the potato growers produced less than four tons of potatoes per farm. Potatoes are commonly stored for up to 3 months in heaps 50 cm to 80 cm high, which are covered with straw or dry grass. These heaps are often located in or under farm buildings, much like stores of onion and garlic. Potato tuber moth (PTM) was the most important storage problem. The survey showed that 75% of the farmers would elect to improve their present storage system, if the required investment cost did not exceed US$13.00 per ton of potatoes.

Based on needs assessed in the survey, improved storage methods were developed and tested in on-farm research. The advantages of storage boxes equipped with slatted ventilation ducts placed on the floor were compared with storage methods used by farmers. The boxes had double walls made of bamboo strips, were insulated with rice husks, and came in two sizes – 80 cm and 120 cm Tubers in the boxes were covered with rice husks for protection against the potato tuber moth. During the storage period, minimum outside temperatures ranged from 22° C to 24° C and maximum temperatures from 30° C to 34° C. Temperatures in the potato heap ranged from 26° C to 28° C. Total tuber weight loss after 9 weeks of storage averaged 38.4% in the farmer's method, 7.2% in 80-cm boxes and 8.2% in 120-cm boxes. In the farmer's method, 30% of the tubers were damaged by PTM, whereas no tubers were damaged in the boxes.

During the storage period, potato prices increased by 50%; returns on invested capital (storage structure and potatoes) were negative for the control and +27% for the boxes.

Table 8-3. Effect of pre-storage selection on weight loss (% of initial weight lost) of consumer potato tubers (cv. Desiree) after four months in storage under different conditions.

Selection level[a]	Refrigerated store (4 C)	San Ramon rustic store (23 C)
1	3.2	5.8
2	3.5	8.4
3	4.5	11.2
CV (%)	24.5	
LSD (0.05)	2.9	

[a] 1 All diseased, insect damaged and mechanically damaged tubers removed. 2 Diseased tubers removed but tubers with peeling damage or insect damage (*Diabrotica* spp.) included. 3 Diseased tubers removed but tubers with deep cuts, other mechanical damage, or insect damage included.

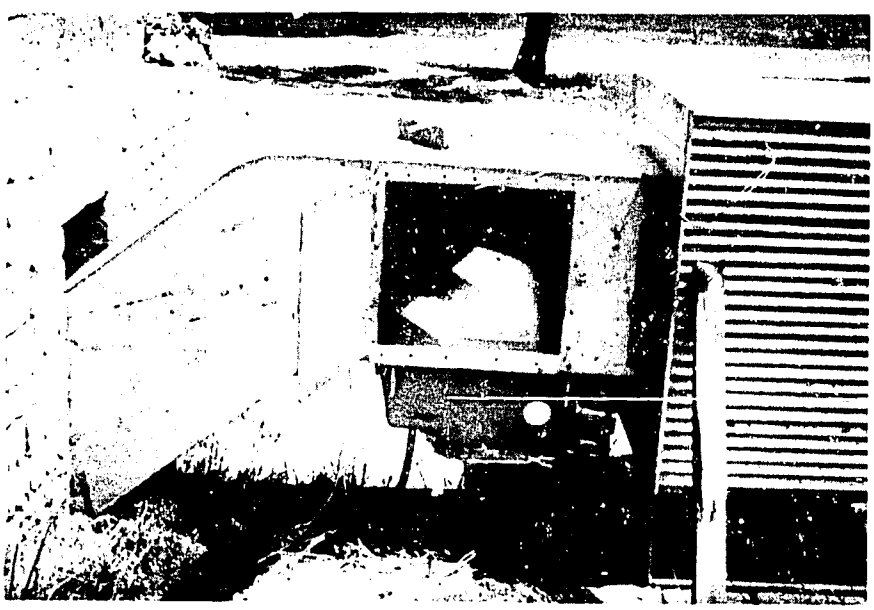
Pakistan

In cooperation with the Pakistan Swiss Potato Development Project, evaluations continued on different designs of evaporative cooling systems for potato stores. A highly efficient air humidifier (water atomizer) was compared with a locally available desert cooler. Both cooling systems were installed on an experimental store equipped with a forced draft ventilation system.

The storage capacity of the experimental store was 20 tons of potatoes for each application. Tubers were treated with the sprout inhibitor CIPC. Total tuber weight loss after 3 months of storage was 6.3% in the store equipped with the desert cooler and 8.8% in the store equipped with the water atomizer. By comparison, tubers stored in the cold store during this period showed a total weight loss of 5.5%. Daily maximum and minimum outside temperatures during the last month of the storage period averaged 40.4° C and 24.4° C, respectively. During this period, the average maximum RH was 46%, and the average minimum RH was 27%.

Kenya

Low-altitude potato storage trials were conducted on the Kenya coast, where stores were loaded on August 31st and unloaded on November 11-12, for a storage period of 70 to 72 days. Comparisons were made of household storage methods and box stores. For the



Experimental evaporative cooled store. Atomizer used as humidifier. Punjab, Pakistan.

household methodology, the potatoes were stored in 1) baskets and 2) traditional heaps on the floor. At unloading, basket storage provided 95% good tubers and the heap method provided 88% good tubers. The losses in the heap method were due mainly to increased moisture loss and to a slight increase in sprouting and rotting.

The box stores methodology was used with and without IPC sprout inhibitor. They were loaded on August 31st and unloaded on December 21st, 112 days later. The results are shown in Table 8-4. Weight losses were considerably reduced by the IPC treatment, which provided 74% good tubers, as compared with 53% in the untreated box.

Table 8-4. Low-altitude storage trials: Mtwpa. Results of trial loaded on August 31 - September 4, 1987. Unloaded on December 21, 1987: 112 days.

Trial results	Box with IPC (%)	Box (%)
Good potatoes	73.88	52.54
Losses		
Sprouts	1.91	1.70
Rotten	8.05	10.74
Rat damage	0.76	0.21
Cockroach damage	0.52	0.27
Moisture loss	14.89	34.54
Total losses	26.19	47.46

Notes: Two nets of small but apparently sound tubers grown from seed stored in naturally ventilated storage and then DLS were placed in the box store for test. Their influence largely obscures a true appraisal of this comparison (control with IPC), because they collapsed due to soft rotting and this affected the complete stores.

Diffused light store, Kenya.

Two kinds of naturally-ventilated stores were tested using controlled ventilation plus evaporative cooling. Aproximately 91% good potatoes were unloaded from each store type, and there were not differences in loss.

Potato Processing

Peru

Transfer of processing technology and training were primary objectives in Peru. Several small processing units are under construction in the highlands of Peru, with technical support from CIP. CIP also continues to give technical support to the work of Centro IDEAS, whose processing plant at Huancayo is based on technology developed at CIP's pilot plant.

The Huancayo plant is now processing a variety of Andean roots and tubers and operates throughout the year. Dehydrated potato products include "crema de papa" (for mashed potatoes), "papa seca", "papa semola" (for soups) and dehydrated potato-based food mixes. Products are dehydrated using a combination of solar and artificial drying. Experiences of processing projects in other countries have indicated a need for low-cost drying systems that are more efficient than solar drying alone.

In cooperation with ENEA, Italy, designs of solar dryers equipped with additional artificial drying systems are being tested at CIP's experimental station in Huancayo.

Thailand

Because of increasing demands for good-quality potato products in many Southeast Asian countries, high priority has been given to the evaluation of clones for processing quality. In cooperation with the Agricultural Chemistry Division of the Department of Agriculture, over 30 clones and cultivars grown at low elevation (500 m) were evaluated for use in processing into chips and french fries. All advanced clones are now routinely tested for processing quality as well as for domestic cooking quality. The cultivars Kennebec and Atlantic showed both good processing characteristics and good field performance. Local factories use locally grown tubers of cv. Kennebec for processing of chips and french fries; thus Kennebec is used as a check in evaluation of clones for processing.

Kasetsart University in Bangkok, in cooperation with the Horticultural Research Institute and CIP, completed a study on the demand for potatoes and potato products in Bangkok. The study showed that about one-third of the total potato production is consumed in the form of processed products. A total of 12 different brand names of potato products were identified in the local market. Most of the products were produced by local processing companies using the Kennebec cultivar.

High-income household consumption of potatoes was twice that of low-income households. High potato prices were identified as one of the main factors limiting potato consumption. Retail price (averaged over three tuber grades) was 190 percent above the average "farm-gate" potato price, suggesting considerable costs related to marketing.

With an estimated increase in consumer income in Bangkok of 10% per year and a population growth of 5% annually, potato demand is expected to increase by 9% yearly. Study recommendations include the establishment of a production and postharvest

program that would gradually reduce potato retail prices, while increasing quality of consumer potatoes.

To meet the expected increase in demand for consumer potatoes, it was recommended that the supply of good quality seed to farmers should be increased and the national seed program expanded.

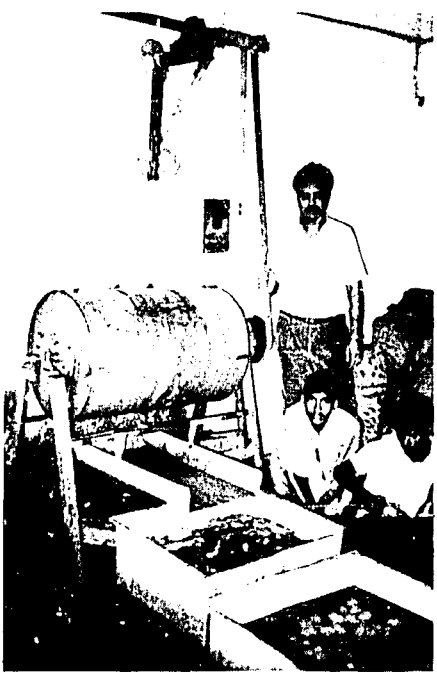
Other recommendations were that high priority be given to selection of high-yielding potato varieties suitable for processing, and that grading and selection practices at the farmer level should be improved to reduce losses during handling and marketing.

A low-cost-potato-processing study is being made as a Ph.D. thesis project. Various driers have been constructed and a number of samples of potato flour produced. Product stability is good and incorporation into bread and other mixes is promising. Additional details will be available when the thesis is published.

India

Village-level processing and utilization of potatoes were studied by the SOTEC project at Bareilly, India in collaboration with CIP. This work has focused on engineering aspects together with product evaluation. A new peeler was developed, the slicing equipment improved, and a blending tank made of stainless steel substituted for the original sheet metal tanks that had rapidly corroded.

Many recipes were developed and snack noodles produced. Some noodles failed to puff after several weeks storage, and this problem is being examined by Compatible Technology Inc. of Minneapolis. Good packaging remains a high-cost input and a constraint on production that requires additional study.



Power-driven peeler (*left*) and slicer (*right*), Chandawsi, India.

Seed Technology

Thrust Profile: 1989

CIP now produces hybrid TPS from new hybrid combinations, using a large-volume production unit in Lima. This seed is distributed to countries participating in the international TPS trials. Improved devices and methods were developed for pollen extraction, storage, and pollination for large-scale hybrid TPS production. Studies were made of the use of TPS in producing table potatoes on subsistence-level farms. A low-cost method showed promise in use of locally available substrates, which were solarized to control soil-borne pathogens and irrigated from local streams using a simple, gravity system. Other studies examined TPS germination and early seedling vigor responses, as well as parental effects on the rooting capacity and early-field establishment of potato seedlings.

The influences of location, seed maturity and supplemental N during production of the TPS were examined as an aid in the selection of more vigorous clones during early seedling emergence and development .The performance of planting materials from similar genetic backgrounds was evaluated for effects of tuber origin, single-sprout seedling tubers, stem cuttings and apical cuttings. The results suggested that physiological factors, rather than genetic factors, influence tuber number and size distribution.

To help plant breeders plan effective crossing blocks, studies were made of flowering induction in sweet potato, and 1,460 accessions from the CIP sweet potato germplasm collection were grouped into categories of high-, moderate-, and low-flowering capacity. Only 3% of the accessions were rated as high-flowering; 88% as moderate-flowering; and 9% as low-flowering. Sweet potatoes were grown continuously for 12 months without being harvested in order to obtain an uninterrupted record of the developmental responses of 150 varieties. They were grown in Peru at latitudes from 5°S to 17°S under a wide range of environmental conditions, at locations including coastal desert, cool highlands, and mid- and low-elevation humid tropics. The results indicate that the traditional biannual harvest has a negative effect on flowering.

A case study of Ecuador's seed potato system has been completed. It was part of a series exploring the strengths and weaknesses of seed systems.

Farmers harvesting tubers grown from TPS seedlings, Egypt.

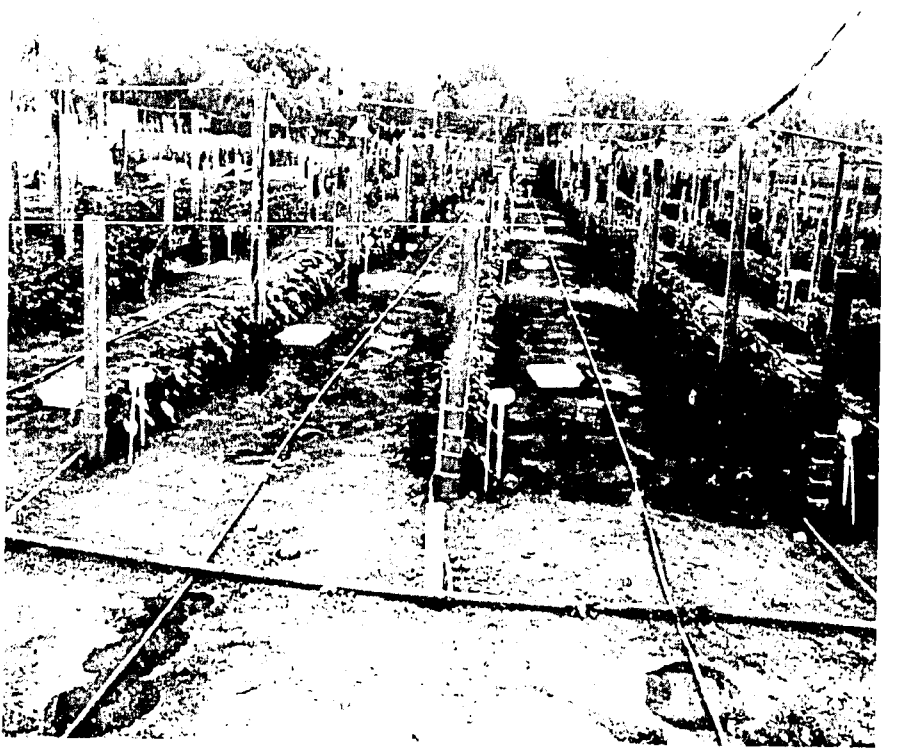
True-Potato-Seed Breeding

International TPS Progeny Evaluation Trials

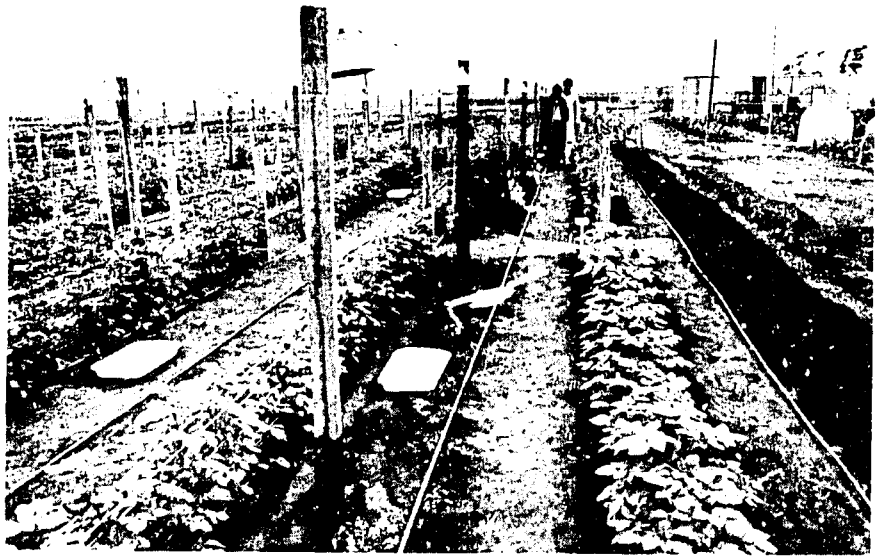
The International TPS Progeny Evaluation trials continued to produce new high-performing progenies. In 1988, 26 families were included in trials at San Ramon, Peru, in the summer and winter seasons. Yields generally varied between the two seasons, except for four progenies that had relatively stable yields: 377887.25 x LT7; Atlantic x LT7; C83.119 x Santo Amor; and LT-8 x AVRDC-1287.19. LT8 x AVRDC-1287.19 also had good stability in the 1986 international trials for long-day performance.

Production of Hybrid TPS

A relatively large-scale production unit has been established in Lima to produce new hybrid combinations of TPS for distributing to countries participating in the international trials. Most of these plants were grown from in vitro propagated plantlets, and then transplanted to the field on two consecutive planting dates (Photo 9-1). For each planting date, the female clones were transplanted about 20 days after the males. Management practices to enhance flowering included training of plants; proper irrigation methods; pest control; use of night breaks of three hours scheduled according to seasons;



Hybrid TPS production in Lima of 36 new progenies for regional evaluation.



Management practices and field devices for optimizing flowering in selected parents.

additional side-dressing of nitrogen every 8 days; and occasional use of growth regulators for flower induction in some clones (Photo 9-2). The ratio of female to male plants was 1:1, with a plant spacing of 1.5 m x 0.4 m. Field establishment of the in vitro plants was enhanced by a drip irrigation system. The parental clones used as females in the crossing block were LT-8, I-1035, Atlantic, CFK69.1, B71.240.2, Serrana, and Atzimba. The male clones were TS1, TS2, LT7, 7XY.1, AVRDC 1287.19, and R128.6. The pollen was collected daily and stored at -12° C. Characteristics of the male progenitors varied greatly (Table 9-1).

Table 9-1. Flowering and pollen characteristics of different male progenitors used in Lima (May July) for hybrid TPS production.

Male progenitor	Flower initiation days after planting	Flowering period (wks)	No. flowers per plant	Pollen fertility %	Pollen per 25 flowers (mg)
TS-1	54	2	2.8	5	8.4
TS-2	30	3	5.5	23	14.4
LT-7	48	4	13.0	25	18.4
7XY.1	46	6	83.0	45	60.6
AVRDC1287.19	40	8	16.0	38	51.1
R128.6	70	·10	78.0	48	63.1

Three male parents (7XY.1, R128.6, and AVRDC 1287.19) were evaluated to determine the effect of post-storage temperatures on their pollen viability. Seed-setting in flowers pollinated at six different developmental stages is being analyzed to define the best pollinating time and to minimize the probabilities of selfing. Improved devices and methods were developed and tested with promising results for pollen extraction, storage, and pollination suitable for large-scale hybrid TPS production.

South America

To meet the strong local demand for reducing costly imports of seed, trials were begun in Paraguay to investigate the potential for a TPS, tuber-based seed system. Annual seeding of botanical seed during the winter season (June-July) is thought to be capable of providing healthy planting material that can be stored during the summer (December-February). This material then could be utilized the following year in several plantings.

Fourteen progenies were sown in a nursery in July 1987 and later transplanted to seedbeds (total transplanted area: 50 m^2). The seedling tubers were harvested in December, then graded and stored under diffused-light conditions. High summer temperatures promoted fast sprouting.

In related trials:

- Seedling tubers of 9 g to 20 g were planted in seedbeds in March to study the potential of a second multiplication for the 1988 planting season.
- Seedling tubers larger than 20 g also were planted in the field in March to evaluate the production of consumer potatoes and healthy seed for the planting season.

Seed emergence was uneven in these trials, except in sections of the field that were occasionally shaded by nearby plants. Later in the season, all progenies grew well with fast canopy development and satisfactory yield performance.

For the fourth consecutive year, large quantities of TPS were produced in the south of Chile as a part of the collaborative project between INIA and CIP (Table 9-2). So far, a total of 56.7 kg of hybrid seed has been produced and distributed worldwide. The conditions for TPS production during 1988 were by far the best in four years.

Table 9-2. Summary of TPS produced in Osorno (Chile) during four seasons (1984-88) under the Collaborative Project INIA/CIP. INIA, Osorno, 1988.

Season	Net area[a] (m^2)	Number of plants Female	Male	Total fresh fruit weight (kg)	Total dry seed weight (kg)
1984/1985	698	781	383	372.4	5.39
1985/1986	2341	2411	1420	1140.3	13.16
1986/1987	2266	2414	1215	481.2	5.78
1987/1988	3131	2870	2610	2635.2	32.40
Total	8436	8476	5628	4628.8	56.70

[a] Net area: Does not include borders, areas to separate block progenies, or blocks of males or females.

Africa

In April, 1988, potatoes were produced from TPS at three locations in Cameroon. The main constraints in testing this technology were insect damage (cut worms mostly) after transplant, and climatological factors, especially heavy rains (up to 700 mm in one week).

TPS from 22 progenies were sown in early April in a large seed nursery (10 m^2). Soil was not sterilized and only Furadan was applied two days before sowing. Germination was 80% for most progenies although two progenies had germination rates lower than 25%. After 40 days, seedlings were transplanted to nurseries and fields for seedling tuber production.

Asia

Approximately 735,000 seeds have been produced from 152 hybrid combinations at the Canlubang and Santa Lucia stations in the Philippines. An extended day length (18 hrs) and heavy (800 kg/ha) fertilizer applications (split, applied weekly) resulted in profuse flowering for most of the parents, especially for 381064.3, 381064.7, 381064.10, and 381064.12.

Research focuses on identification of TPS progenies (hybrids and open pollinated) with high-yield potential as transplants, as well as on tuber generations with resistance to bacterial wilt and viruses.

China

Improved TPS progenies are being developed for various environments of China. During 1988, 25 kg of high-quality OP seed was collected at Wumeny and 5 kg of hybrid seed was collected at Humeny for distribution to farmers in southwest China. Improved coordination between research and extension, high-quality seed, and establishment of TPS collection procedures helped boost the area planted with TPS transplants from 33 ha in 1987 to 110 ha in 1988.

TPS Physiology

Seed Density

Low-density TPS from ten crosses produced seedlings that had lower percentages of emergence and/or dry weight than did seedlings of medium- or high-density seed, except for TPS of Atzimba x R128.6. The differences between high- and medium-density seed effects generally were less important than the differences when they were compared with effects of low-density seed. The female-parent genotype had a stronger effect on seedling performance than did the pollen source genotypes (Atzimba vs CFK69.1 crosses). However, the results also may suggest that the specific combining effect of the pollen parent could influence early seedling performances (Serrana x LT7 vs other crosses x LT7).

Radical Elongation

The effects of TPS crosses on early radical development were studied in 23 different crosses, and mother-plant influences were found to be significant. The most vigorous cross, Atlantic x LT7, was used to demonstrate the importance in TPS production of location, seed maturity, and supplemental N for effective selection of more vigorous crosses during early seedling emergence and development. Two other selected crosses (Atzimba x R1286.6 or Atzimba x DTO28) were used to show that high levels of supplemental N during seed

production and proper seed development at harvest are both essential for enhancing seed vigor and preserving vigor during long-term storage.

Supplemental Nitrogen

Supplemental N applied at regular intervals (10 days) during seed development has been shown to increase seedling vigor of TPS, when seed is tested after storage of more than 12 months. This improvement was clearly shown in TPS tested under high (> 25° C) temperatures after 20 months of storage. However, supplemental-N has also been shown to lower seedling performance in tests of newly-harvested TPS. Thus, supplemental N effects are associated with both increased seed vigor and increased seed dormancy.

Under favorable temperatures (20° C to 25° C), supplemental N, applied at the rate of 540 kg/h and divided into 6 applications, produced TPS that emerged at a much faster rate than did the control or other N treatments. The N treatments had similar effects on the percentage of emergence and seedling dry weight. However, emergence under favorable temperatures was 90% for all treatments, and dry weights varied by a maximum of only 0.7 mg/plant. Thus, supplemental N influences on TPS vigor are more evident under supra-optimal temperatures.

Early Vigor

Studies were made of TPS germination, early seedling vigor, and finalizing parental effects on the rooting capacity and early-field establishment of potato seedlings. The TPS vigor studies used seed of six selected hybrid combinations produced at Huancayo. The seed was obtained by pollinating flowers of only one influorescence per plant on the same day for each hybrid, leaving only four berries to develop per plant. The seed was harvested 50 days after pollination. Standard procedures were used for seed extraction, drying, and storage. The seed was germinated under light or dark conditions at 2 to 6 months after extraction

Screening for resistance to transplant shock, CIP-Lima.

and the corresponding rates for each progeny and environment were calculated for a germinating period of 15 days. Although the experiment is still at a preliminary stage, progenies were shown to differ in response.

Pollen Selection

Previous studies of seedling characteristics suggested that pollen-selection techniques may be an effective tool for increasing the uniformity of progeny performance in some TPS crosses. Findings indicated that the tolerance of pollen grains to high-temperature exposure may not be associated with a higher adaptation in the clonal pollen parents for producing tubers under tropical conditions Similarly, such tolerance may not influence the performance of the resulting TPS cross during emergence at supra-optimal temperature. These experiments were repeated and expanded in 1988 to include a wider variety of genotypes.

The study findings also suggest that pollen grains of different sizes may produce TPS progenies that differ in sporophytic characteristics, at the seedling stage. That is, the proportion of pollen sizes and their viability may differ among clones, which suggests that such differences also may occur in pollen lots of a given clone when harvested at different stages of plant maturity. In preliminary experiments, several new crosses were produced using pollen of various sizes. The TPS will be tested for the effects of pollen size on the resulting seedling and tuber characters.

The work on pollen selection is expected to produce results that can be applied to large-scale TPS production.

TPS Agronomy

South America

In Peru, advanced TPS progenies from CIP's breeding program, included in the international TPS trials, were evaluated for performance as transplanted seedlings or as seedling tubers. The seedling tubers were produced during the off-season in protected nursery beds. Because the region is a basic seed-producing area, virus build-up is important; therefore, the seed-sized tubers (3.5 cm) are being evaluated for virus contamination over three successive generations.

At San Ramon, another experiment evaluated a TPS utilization system for small farms in hot-humid areas.

Use of TPS to grow table potatoes in beds might offer an attractive production alternative, especially in subsistence-level farming areas. In San Ramon, a low-cost method using locally available substrates has shown promise. The substrates are solarized to control soil-borne pathogens, and a simple irrigation system is used to apply water from streams, which are commonly found on tropical farms. The usefulness of this system for household production will be assessed under farmer-management conditions on three different farms in the San Ramon area.

Four TPS progenies of Atlantic x LT-7, Serrana x LT7, CFK69.1 x DTO-33, and Atzimba x 7XY.1 were evaluated in Paraguay. In cooperation with national institutions, 200 m^2 of seedlings were grown in seedbeds and 100 m^2 in farmers' fields. Agronomic performance was evaluated and both groups of collaborators agreed that Atlantic x LT7 and Serrana x LT7 showed fewer problems

during transplanting and produced fewer and larger tubers.

Africa

Spring- and fall-season experiments in Egypt examined the feasibility of using seedling tubers as an alternative source of planting materials. Different sizes and generations of seedling tuber progenies were used, with imported and local varieties used as checks. Some of the findings are listed below.

Imported seed and physiologically-old seedling tubers had better emergence rates and more stems per hill than did local physiologically young tubers.

Imported varieties and seedling tubers from the spring crop had higher yields than did those from the fall crop.

For the spring crops, the amount of consumer tubers produced from seed obtained from imported seed and from seedling tubers was greater than that produced from the fall-crop seedling tubers.

Seven tons of first- and second-generation seedling tubers produced at CIP-Kafr El-Zayat Experimental Station in the spring were distributed to 40 farmers. The performance of these farmers' plots (100 m^2 to 200 m^2) during the fall was evaluated and compared with farmers' plots sown with seed of European varieties. The seedling tuber yields were generally higher than those of farmers' seed, and farmers' responses were positive about the prospect of using seedling tubers.

In Cameroon, TPS feasibility trials examined the use of TPS to produce potatoes. They were planted in three locations in unsterilized field soil; yield and numbers of tubers were only average, although some progeny produced more than 250 mini-tubers/m^2. Transplants were unsuccessful because of severe attacks by crickets and large ants.

Asia

Multilocational trials of the All-India Coordinated Potato Improvement Project over two seasons confirmed that hybrid TPS-family yields equaled or surpassed those of standard cultivars when used as transplants or first-generation tuberlets (Table 9-3). In other comparisons with local cultivars in India and Sri Lanka, trials over two seasons showed that selected TPS hybrid progenies maintained better yield potential for at least two generations of tuber production. The best-yielding hybrid progenies have been

Table 9-3. Evaluation of TPS families: on-farm trials with F_1 C_1 tubers in Meerut District (U.P.) India during 1987-88 season

Families	Yield (t/ha)				
	Site I	Site II	Site III	Site IV	Mean
HPS-1 III	20.8	26.3	28.0	28.3	25.9
HPS -2 III	19.8	25.3	20.2		21.8
HPS-I III	20.4	27.3	27.8	27.9	25.8
PS-II III	25.0	29.3	31.6	28.5	28.6
Kufri Badshah (cv)	21.9	25.6	25.3	25.4	24.5

NPK fertilizer applied: 150:80:100 kg/ha
Crop duration: 90-110 days

distributed to Bangladesh, Nepal, Sri Lanka, and the Philippines.

In Vietnam, 20 kg of OP TPS of CFK69.1 and Atzimba was collected from farmers in Dalat. This seed was distributed to 45 cooperators, who harvested 48 ha of transplants in 1988.

In China, two CIP TPS progenies (CFK69.1 x 7XY.1 and 379303.37 x 7XY.1) have yielded 40 t/ha in the seedling tuber generation. One of these progenies will be selected for potato production of seedling tubers in southwest China using hybrid seed produced in China.

Propagation

To validate previous experiments, random comparisons were made among single-sprout seedling tubers, stem cuttings (mother plants from seedling tubers), apical cuttings (from seedlings) and seedlings. These materials were all from the same progenies and were compared in nursery beds and in the field (San Ramon and Lima) at constant main-stem densities.

The seedlings had the lowest survival rate in nursery beds (Table 9-4). Yields from stem cuttings were significantly better than those from either seedlings or apical cuttings. Seedlings had the highest tuber number per plant and percentages of small tubers (10 g) whereas these measures were intermediate in seedling tubers and apical cuttings, and lowest in stem cuttings. As a result of these findings, more emphasis will be placed on seedling tuber production and use.

At Lima, seedling survival rates in the field were lower than those for seedling tubers and stem cuttings. At San Ramon, field survival rates among planting materials did not differ statistically (Table 9-5). Yields among propagation methods for each progeny did not differ, except for Atzimba x R-128.6 at Lima, where the difference between seedling tubers and stem cuttings was significant. As in the findings with nursery beds, tuber numbers per plant were highest in

Table 9-4 Yield and yield components of planting materials from TPS progenies in nursery beds (Means of Lima winter and San Ramon dry season experiments, 1988).

	Plants harvested %	Tuber number Per plant	Tuber number %< 10 g	Yield kg per m²
CEX-69 1 x DTO-28				
Seedling tubers	84	6.2	63	5.5
Stem cuttings	87	2.4	30	5.7
Apical cuttings	83	5.8	66	3.9
Seedlings	62	12.0	87	4.0
Atzimba x DTO-28				
Seedling tubers	79	3.6	60	3.4
Stem cuttings	80	2.9	35	6.0
Apical cuttings	78	5.1	56	4.7
Seedlings	54	11.3	80	4.1
LSD 5%	11	1.0	12	1.2

Table 9-5. Yield and yield components of single-stem planting materials from TPS progenies in the field (San Ramon dry season, 1988).

Harvested	Plants tubers (%)	Yield per hill	t/ha
CFX-69.1 x DTO-28			
Seedling tubers	64	8.1	11.2
Stem cuttings	73	5.7	12.4
Apical cuttings	80	12.2	11.7
Seedlings	75	15.8	13.4
Atzimba x DTO-28			
Seedling tubers	62	7.5	13.4
Stem cuttings	75	7.4	17.5
Apical cuttings	76	11.7	18.9
Seedlings	66	12.9	14.5
LSD 5%	ns	3.3	5.6

seedlings and lowest in stem cuttings. In comparisons between seedlings and apical cuttings, and between seedling tubers and stem cuttings, the differences in tuber numbers recorded in the field were less than those in nursery beds.

In previous studies of the effects of tuber origin on seed production, seed tubers from warm climates have yielded significantly less than their counterparts from cool climates, irrespective of the production method used. Table 9-6 shows the results when mother plants were raised from seed tubers of warm- and cool-climate origins. Stem cuttings were then compared under warm-climate field conditions. Tuber-origin effects were not reflected in cutting and survival rates or in total and marketable yield (Table 9-6). Thus, seed tubers produced in warm climates may be a suitable source of mother plants in potato-production systems based on cuttings.

South America

In vitro propagation techniques have been improved and approximately 6,000 mini-tubers are being produced twice a year in greenhouses in Uruguay. Results from the fall of 1988 showed that these mini-tubers had a multiplication rate of 20 t/ha. Three locally selected clones are being multiplied with this method, to be used as substitutes for some imported seed.

Africa

At Nairobi, in work with the National Potato Research Program in Tigoni, special-project funding was used to rehabilitate the facilities and reorganize the basic seed program. The production cycle was begun with carefully selected tubers of five standard Kenyan varieties produced at ADC Molo. Five tubers of each variety were sent to Lima to under-

Table 9-6 Effect of tuber origin to produce mother plants on performance of cuttings in the field (Lima, summer 1988).

Variety	Climate during seed production	Survival %	Yield Total g/m²	Yield Marketable (%)
Desiree	warm	87	1670	91
	cool	90	1630	93
LT-5	warm	86	1570	92
	cool	85	1470	89
		ns	ns	ns

go virus clean up. The number of cuttings harvested per mother plant was low, except for Kenya Baraka, which yielded 36 cuttings/plant. The low rates were attributed to high soil and air temperatures in the screenhouses. A new, larger screenhouse is now under construction, with a capacity of 10,000 tuberlets per season.

Asia

On-farm trials in the Philippines have shown the feasibility of growing potatoes from apical cuttings. In 64 trials, cuttings from I-1085, I-1039, P-7, and I-1035 yielded over 21 t/ha and produced higher economic returns than did the control grown from tuber seed, although overall yields of the cuttings were lower.

Evaluation of CIP germplasm for suitability as cuttings for consumer potato production has revealed several areas for exploitation. In Vietnam, farmers continue to use sprouts to rapidly multiply limited amounts of seed tubers.

Again, major genetic differences have been detected. The clone CIP 380584.3 is an outstanding performer for sprout utilization.

China

In vitro tuber production experiments were extremely successful in using standard procedures for growing shoots in shallow M.S. substrate media for 2 to 3 weeks; then tuber-inducing regulators were used or else the flasks were put in the dark. Micro-tubers were harvested at 3 to 4 weeks. This technique will now be incorporated into the pre-basic seed-production program.

Case Studies on Seed - Tuber Systems

A case study of the seed-potato system in Ecuador was completed as part of a series designed to identify strengths and weaknesses of the seed systems. The series includes similar reports on the Philippines (Annual Report, 1988), Kenya (upcoming) and a combined report on Canada, the Netherlands and the United Kingdom (Annual Report 1988:157).

In Ecuador, where potatoes have been cultivated for thousands of years, small highland farmers produce most of the crop. The government has been involved officially in potato research and extension for 25 years, and in potato-seed production and promotion for 15 years. However, seed production in the official program remains at a relatively low level. Apart from the introduction of new varieties, the basic technology of seed production, selection, storage, management, and marketing in the informal small-farm sector has changed little in recent decades.

Among the major technical innovations in potato production, modern seed production appears to have had less of an impact than have other innovations.

New varieties have made the greatest impact on the seed potato system, and most of these have been diffused and adopted within informal systems. This finding highlights an important weakness in the formal seed system: the lack of an effective seed distribution model. The potato-growing areas of Ecuador have distinct large- and small-farm sectors, with separate seed-potato systems. Generally, these two systems have little contact.

A principal conclusion of the study is that institutional and coordination problems – rather than technical pro-

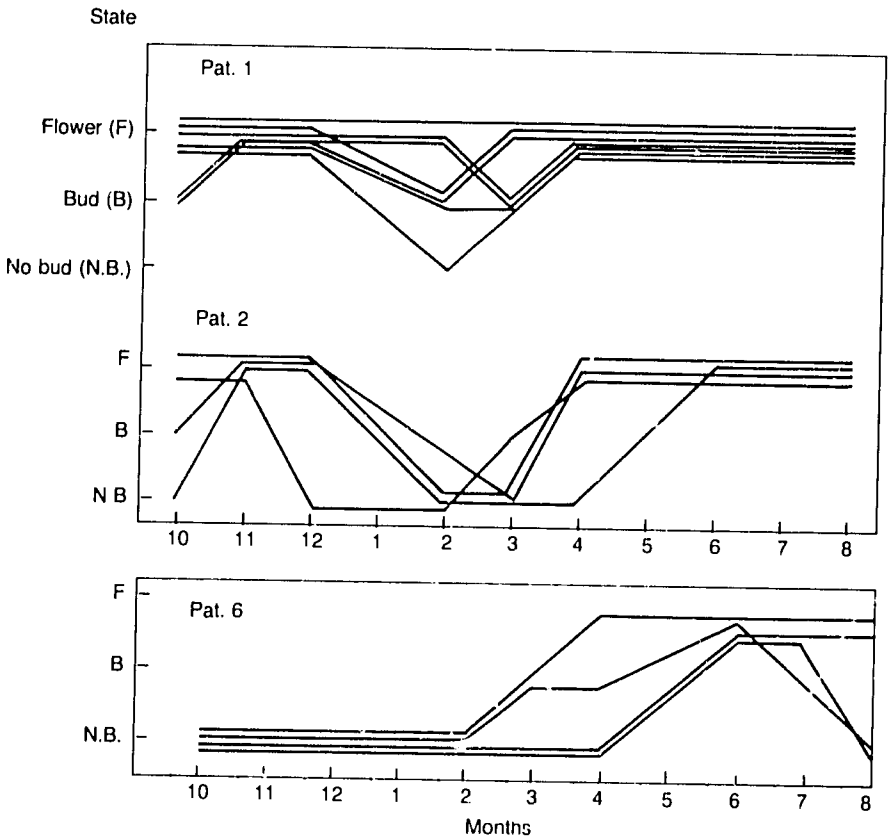
blems—are limiting the effectiveness of the seed program in Ecuador. The seed program is part of the broader task of extending research results to the appr priate users.

Sweet Potato

To help breeders make better crossing blocks for sweet potato and to improve seed production, studies were made to categorize or regroup sv. eet potato germplasm available at CIP.

Based on the number of flower buds and flowers on vines, 1,460 accessions of sweet potato were grouped into categories of high-, moderate- and lov flowering capacity. Of the total acce. sions, 3% were in the high-flowerir category, 88% in the moderate, and 9 in the low.

The selected accessions of the thre categories have shown eight patterns c flowering habit. Patterns designated 1, :



Remarks: Plants were grown in open field at CIP-Lima. Planting date, July 20, 1986.

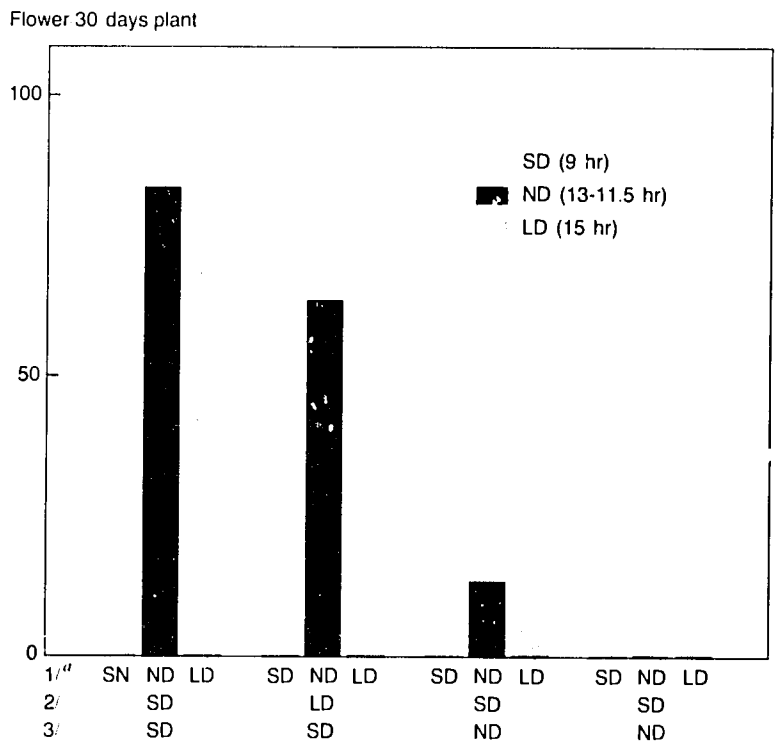
Figure 9-1. Flowering pattern of sweet potato.

and 6 are shown in Fig. 9-1. The majority of accessions with high-flowering capacity follow pattern 1. Patterns 1 and 2 described the habits of most of the moderate-flowering accessions, while pattern 6 included 30% of the low-flowering accessions. The flowering pattern seems to be determined by the juvenile period of an accession and by its response to photoperiod and temperature.

A study of short-day treatment and grafting effects on flower induction indicated that the high- and moderate-flowering accessions are easily induced to flower by grafting and/or a short-day treatment (9 hr).

The findings on short-day treatment effects on flower induction of scion and root stock in grafted plants clarified the principles of flower-induction capacity of a stock. Figure 9-2 shows the effects of photoperiodic pretreatment on scions and root stocks.

The flower-induction capacity of the stocks (*I. nil, purpurea*, and *setosa*) were studied and varietal differences were determined for flower-induction



Root stock, c. c. j. (*I. purpurea*). SD, ND, and LD stand for short, natural, and long day.
a1 photoperiodic pretreatment on root stock; 2 photoperiodic pretreatment on scion; 3 photoperiodic during growing period; 4 var. RCB 195 of Cat. II.

Figure 9-2 Effect of pretreatment of scion and root stock on flowering under different day lengths.

capacity of the stocks, positive effects of short-day treatment of the stock (*I. nil*), and for the effects of age of the stock (*I.nil*) on flower induction of the grafted plant. The techniques useful for improving flower induction in sweet potato included selection of competent stock of high compatibility, conditioning of stock by short-day treatment, taking of scions from mature mother plants, and growing of the grafted plant under short-day conditions (Fig 9-2).

I. purpurea with white flowers is recommended as an elite root stock for open-field growing, and for its high compatibility for grafting with scions, adaptability to rather heavy soil, tolerance to nematodes, and high-flowering induction capacity. *I. nil* also is recommended as elite stock, especially when grown in pots. It has a high flowering capacity and its root system is adapted to porous soil.

To facilitate short-day treatments and seed collection, grafted and non-grafted plants were trained to a single vine and tied stakes were posted around the plants. The findings indicate that the traditional biannual harvesting of sweet potatoes was also associated with an approximate 2-month interval without flowers. In further studies in 1988, sweet potatoes were grown continuously for 12 months without an intervening harvest.

This research provided an uninterrupted record of the developmental responses of 150 varieties under a wide diversity of environmental conditions throughout Peru at locations including coastal desert, cool highlands, and mid- and low-elevation humid tropics (from latitudes 5°S to 17°S). Preliminary analysis of selected varieties indicates that the flowering of a given variety of sweet potato can vary considerably from one location to another. Thus, environmental requirements for the various developmental responses may differ widely among sweet potatoes and other *Ipomoea* species.

After experiments in 1986-87 and 1987-88, 14 varieties were selected that perform well in cool environments. Three of the 1[illegible] vari[illegible] proved to be exceptionally resis[illegible] to cold weather, showed no damage from numerous hail storms, and produced the best harvest weight in tubers.

Following extensive tests of cultivation methods, a CIP research guide is being prepared to help in training and demonstration of a system of reliable, efficient regimens for propagation and post-planting maintenance of sweet potato plants. It also includes information on the handling of post-in-vitro-propagated plantlets.

Training

South America

The International Seed Production Course was organized by CIP-UNA in Lima, Peru and attended by 18 participants from Bolivia, Brazil, Colombia, Ecuador, Guatemala, Honduras, Paraguay, Peru, Uruguay, and Venezuela. Beginning in 1989, the course will be held in Chile.

In other training activities in Peru, more than 40 visitors and trainees from all over the world visited CIP facilities in Lima to gain practical experience in in vitro and rapid multiplication techniques. Huancayo had 30 visitors from outside Peru. They were given information on seed-production technology, seed-program development, and on-farm research.

A formal seed production course at Cuzco was attended by 68 participants from the national program and various rural development projects.

In January, workshops on basic seed distribution were organized in the southern region (Cuzco), and in the central region (Huancayo).

In September, at Lima, 22 seed specialists attended a two-day meeting on basic seed production.

Africa

A two-week seed production course in Rwanda focused on use of TPS as an alternative to traditional seed schemes. A CIP regional scientist participated in a seed-production course held in Holetta, Ethiopia in August, presenting a lecture on rapid multiplication techniques and their integration into a seed program.

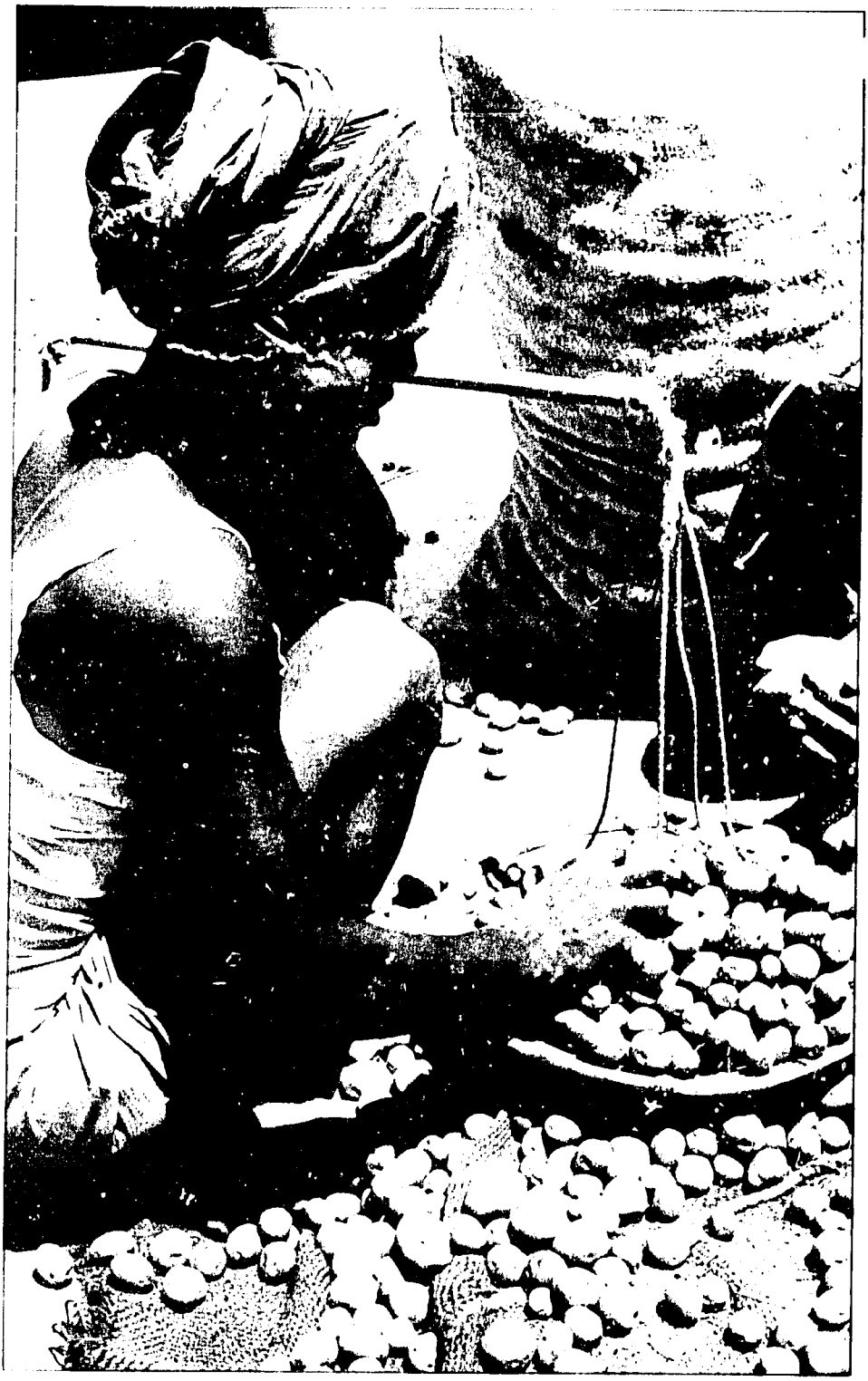
Asia

In Bangladesh, 99 participants attended a one-week course at BARI on use of TPS as transplants, seedling tubers, and tuberlets.

In CIP Region VII, innovative and low-cost appropriate technology was a major topic for training farmers and scientists.

The emphasis was on rapid propagation techniques, including in vitro propagation; establishment and maintenance of mother plants; and transplanting and management of cuttings in the field as well as TPS. Trainees at Sta. Lucia represented Bhutan (1), the Philippines (4), and Vietnam (3). In China, farmers and scientists worked together in a course to demonstrate new technologies.

Seedling tuber production at CIP station, KAFR, El Zayat, Egypt.



Food-Systems Research

Thrust Profile: 1989

Food-systems research analyzes patterns and trends of potato and sweet potato production, and assesses the needs of potato producers, market agents, and consumers. An overall aim is to evaluate the process of technological change and the impact of crop-improvement programs in developing countries. In 1988, research focused on constraints to potato and sweet potato production and use, farmer experimentation and technological change, marketing and demand, impact of potato improvement programs, prospects for Andean crops, and patterns and trends in root-crop production and use.

A survey of national program leaders indicated that the principal constraints to production and use of potatoes and sweet potatoes were concentrated in the post-harvest phase of food production. Studies in Kenya and Peru revealed that farmers' criteria for evaluating new potato varieties often differ sharply from breeders' and agronomists' criteria. Farmers generally look for varieties that meet several broad criteria, rather than varieties that meet only one or a few criteria, such as yield or disease resistance.

On-farm research in Indonesia provided a mechanism for farmers to contribute directly to the development of TPS technology. A study in Peru's southern highlands revealed that the potato is the only native Andean food that is eaten frequently in both rural and urban areas. These studies suggest that the future of Andean food crops will depend on the extent to which agricultural research and development activities address the needs of these crops and of their producers. Other major considerations include future economic policies, which in the past have favored the subsidized importation of wheat and rice to the detriment of domestic food production.

Marketing work emphasized backstopping studies conducted by NARS scientists. Surveys of national leaders indicated that CIP has contributed significantly to increasing the national programs' capacity for training, seed production, storage, and breeding. Benefits at the farm level had been achieved principally through improvements in seed quality, and also through the supply of better varieties.

Farmer weighing seed for potato tuber moth evaluation trials, Bangladesh.

Assessment of Production and Use Constraints

To help set research priorities, CIP has begun to systematically assess the needs of the National Agricultural Research Systems (NARS) and of potato and sweet potato farmers, market agents, and consumers.

Workshops

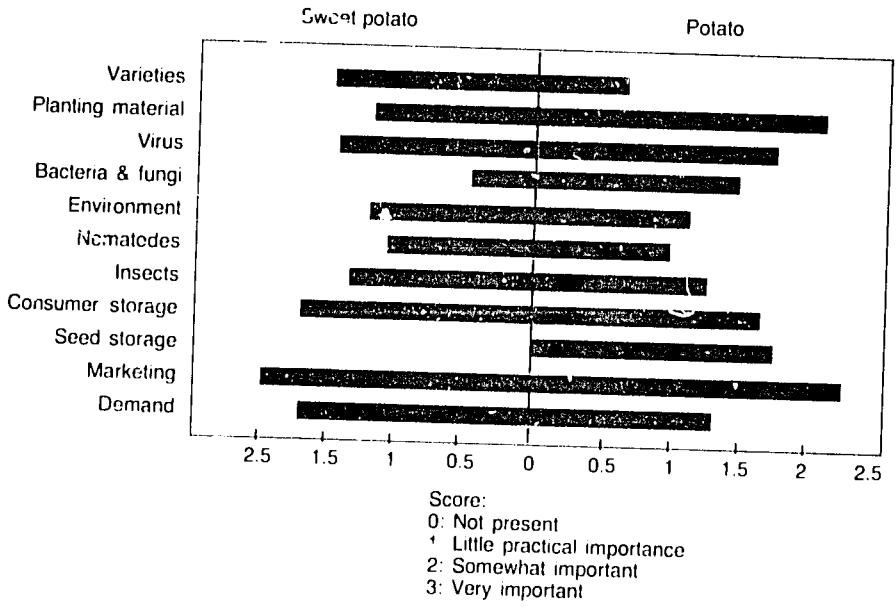
In Argentina and Uruguay, special workshops were organized in 1988 to bring together sweet potato researchers, extension agents, processors, and farmers. After formal presentations and discussion, working groups formulated conclusions and recommendations for future sweet potato research and development.

Diagnostic surveys and marketing studies figure prominently in the research activities recommended by the working groups.

NARS Survey

In 1987 and 1988, questionnaires were mailed to a total of 117 potato and sweet potato researchers in developing countries, requesting detailed information on pre-planting, field-production, and postharvest problems. Figure 10-1 shows that for both crops, constraints to production and use were concentrated principally in the postharvest phase, while constraints in the pre-planting phase ranked next.

For sweet potatoes, postharvest problems of storage, marketing, and limited demand were considered to be particularly important. In the pre-planting phase, two problems were highlighted: the lack of early varieties that meet consumers' and processors' requirements, and scarcity of planting material. The principal field-production



Source: CIP 1987 constraints survey.

Figure 10-1. Scores indicating relative importance of constraints to production and use of potato (121 regions in 38 countries) and sweet potatoes (34 regions in 14 countries).

problems were caused by the sweet potato weevil (*Cylas formicarius*), drought, poor soils, and weeds.

For potatoes, the most important constraints cited were unstable supplies and prices, and high marketing margins. The scarcity and high cost of planting material also were noted. In the field-production phase, late blight, potato leaf roll virus (PLRV), and tuber moth were the most frequently noted problems.

Responses from an expanded survey are being analyzed to determine the main constraints reported by researchers in different agro-ecological zones. A survey report will be published in late 1989.

In-depth studies of crop production, marketing, and use are needed to complement survey findings and to provide reliable information. These studies would serve as a basis for setting research priorities at CIP and NARS.

Field Studies

Peru. A multidisciplinary team from CIP and Peru's National Research Institute (INIAA), conducted a field survey in the coastal valley of Cañete, which produces about one-quarter of the country's sweet potatoes.

Sweet potato was found to be principally a commercial, dual-purpose crop: most roots are sold for human consumption and the foliage is commonly used for feeding dairy cows. Although many varieties are grown, only a few have desirable agronomic traits and good market acceptance. Hence, farmers are eager to obtain early-maturing, dual-purpose varieties. Most sweet potato farmers have relatively little management experience with sweet potato. Generally, these farmers have been laborers on cooperatives that only recently have been divided into individual parcels. Thus, applied on-farm research and extension methods show promise for increasing yields and farm incomes.

China. Approximately 80% of the world's sweet potatoes are grown in China and extensive biological research has been conducted on the crop here. However, socioeconomic data is scarce, particularly that related to marketing and utilization. CIP contracted the International Food Policy Research Institute (IFPRI) to conduct an extensive review of available publications, unpublished reports, and statistical data.

This literature review produced little information on potato or sweet potato marketing and utilization; therefore, the IFPRI is now conducting field studies that focus on these topics.

Total root-crop production in China has fallen about 20% during the last decade. Three major factors account for this decrease: 1) in recent years, the government has sharply reduced purchases of root crops throughout the country, 2) a poor transport and communications infrastructure retards private-market integration and discourages market agents from handling perishable root crops, and 3) a decentralized fertilizer-allocation system provides little incentive for farmers to apply fertilizer to root crops. These findings highlight the important roles played by policies and infrastructure in determining sweet potato production trends.

Farmer Experimentation and Technological Change

Involving farmers more effectively in the formal, science-based research and development system offers great potential for improving the generation and diffusion of new technologies that will be used on a large scale. In 1988, field

studies were conducted in Kenya, Peru, and Indonesia.

Evaluation and Choice of New Varieties

Kenya. Potatoes are attractive to many highland farmers because of their dual use as both a food and cash crop. This double purpose gives farmers, most of whom are women, flexibility in the disposal of their harvest. The distribution of potato varieties varies greatly because farmers change varieties rapidly. When production levels fall,they often use new varieties to recover previous yield levels, instead of renovating seed of the same variety. Because of the proximity, convenience, and low cost of local seed tubers, the farmers' own communities are usually the primary source of seed when they decide to renovate or change varieties. Because the gene pool is delineated at this local level, the community serves as a seed bank for individual farmers. This customary reliance on neighbors for seed often leads to communities of farmers who grow much the same varieties.

Certified seed is used by less than 5% of Kenyan farmers. There is little correlation between the varieties provided by the seed certification program and those that farmers grow. For example, the popular local variety Nyayo is grown by half the farmers, but no certified seed is produced. Little or no certified seed is produced for several of the more popular varieties. Study findings reflect the high price of certified seed, lack of timely distribution, and farmers' skepticism about its value. These findings also suggest that public officials and farmers differ widely in their perceptions of farmers' needs. Cost-benefit analysis of certified seed use on small farms is needed to assess the economic merit of using local seed as compared with certified seed.

A possible source of confusion about variety preferences may stem from the

Sweet potato farmer, China

different processes of evaluation and choice of varieties. Potato breeders and farmers often concur on the relative agronomic merits of a variety. However, additional considerations such as trader preferences, availability of seed, information flows, and local environment, influence a farmer's choice of variety. Special concerns are that varieties be resistant to late blight and that they yield well.

Farmers who produce primarily for home consumption are concerned that a variety taste good; commercially-oriented farmers are more concerned with a variety's marketability. Because some communities or localities develop reputations among traders as sources of particular varieties, trader demand may effectively limit the choice of variety for commercially-oriented farmers.

Peru. Andean farmers are hardworking and pragmatic plant breeders. The farmers' careful evaluation and selection of naturally occurring crosses account for hundreds of native Andean potato varieties with a wide range of agronomic and culinary characteristics.

Field studies in the Andes indicate that farmers seldom seek to grow a single ideal potato variety, preferring instead to choose a range of varieties that can fulfill broader needs. Moreover, when farmers are evaluating potential new varieties, they tend to select a variety that meets several needs, rather than a variety that may be excellent for a single or limited purpose. Thus, Andean farmers manage a range of varieties that fulfills their total food system's needs. Individual variety selections are based on their fit within diverse ecological conditions and are generally evaluated in terms of their value as both a cash crop and as a household food. Farmers look for "friendly varieties" that offer the farmer flexibility in use for sale as well as for household consumption.

In the 1987/88 season, 17 potential new varieties were evaluated in five central-highland locations in Peru. Farmer group evaluations resulted in the selection of two "friendly potato" candidates. One selection was based mainly on the potato's ability to meet market requirements. Although it was relatively late-emerging, it performed well in the area. Hail storms did not seriously affect it, and it produced a reasonable number of large tubers and several smaller tubers for seed. It had an attractive color and shape, and was better for use in soups than for boiling.

The farmers' second potato selection was based on its ability to meet household needs. It matured quickly, and emerged rapidly in a strong stand with many stems. It withstood light frost, but was somewhat susceptible to hail. It produced plenty of good-sized tubers that were nicely shaped, white-skinned, and similar in appearance to a native variety. This variety cooked quickly and tasted good.

Although the farmers appreciated these clones, they were not ready to endorse their release as varieties. The farmers take a long-term view of variety selection based on a detailed knowledge of ecological and climatic variations, and they wanted to see how the clones performed in different soils under diverse weather conditions. Although Andean farmers do not lay out experiments with several side-by-side replications, they do replicate their "trials" over a period of time in different seasons.

The complexity of the local ecology and of household needs is reflected in the farmers' use of 39 criteria to evaluate the varieties. Although breeders using statis-

tical models cannot manage such diverse criteria, the farmers' perspectives could be incorporated into the breeders' selection process by involving farmers directly in the evaluation of potential new varieties.

These studies on potato varieties are continuing in the highlands, and similar work on sweet potato varieties is beginning on the Peruvian coast.

Experiments in a Non-traditional Environment

Research in San Ramon and Oxapampa, on the eastern slopes of the Peruvian Andes, has shown that many in-migrant farmers experiment extensively with potato cultivation practices.

These experiments are primarily "adaptive" in the sense that they 1) seek to adapt previous cultivation practices to new environments, and 2) address varietal testing, planting dates, agro-chemical application, and plant shading. Such experiments differ from the farmers' "problem-solving" experiments that address a specific difficulty, such as a new disease arising in a relatively stable environment. They also differ from the "curiosity" experiments that may stem from the farmers' interest in potential agronomic relationships.

Although the methods used in such experiments are not as rigorous as those of formal science, this farm-level research presents clear evidence of the farmers' acute observation of the environment, of their ability to respond to changes, and of their crucial role in the process of technological change.

Farmer experimentation provides both a human resource and a body of knowledge; thus, it should be stimulated to foster local adaptations of technologies and to provide insights for more formal research.

Farmer Experimentation with TPS in Indonesia

On-farm research is often preceived and planned as an adjunct to experiment station research that will facilitate technology transfer. In Indonesia, however, an entirely different approach is being used to involve farmers closely in all stages of the TPS experiments. The purpose is to enlist farmers' active collaboration in the development of systems for producing seed and consumer potatoes from TPS, which potentially may be used throughout Southeast Asia.

Farmers and researchers interacted during informal group meetings held every 15 days. The use of TPS under Indonesian conditions was clearly defined as a "learning experience" for everyone, with all farmers and scientists involved as equal partners. No "recipes," "blueprints," or "packages" were specified or sought. Rather, the researchers contributed their previous experience, and the farmers contributed their knowledge of local vegetable production and conditions. The farmers received no financial assistance, other than the provision of TPS. As this approach became understood, and as farmers and researchers became familiar with one another, discussions became frank and mutually productive.

At the initial meeting in February 1988, researchers outlined several methods for growing TPS and the merits of each method were discussed. The farmers readily understood the topics under discussion and several important considerations were identified. They were more concerned about agronomic characteristics, such as maturity or disease resistance, than about yield per se. They preferred to transplant seedlings directly to the field, as they do for cabbage or tomato, rather than to produce

tuberlets. They indicated a preference for producing consumer potatoes from TPS, as they were not accustomed to producing and storing seed tubers. The farmers also were concerned about having a reliable supply of TPS.

The 11 farmers attending the first meeting insisted that a packet of (old) TPS used for demonstration be left with them. This seed was sown in a nursery bed and served as a useful point of discussion.

In the first season (February-July 1988), farmers were encouraged to produce tuberlets and to learn about the technique. It was feared that this technique would be neglected, because of the farmers' professed preference for transplanting. In the second season, (October 1988-January 1989), several possible experiments were discussed and 20 farmers were asked to participate. All farmers elected to test the performance of TPS as a source of direct transplants.

Eleven of the 20 farmers were given approximately 500 seeds of one of three progenies: Atzimba x DTO-28, Atzimba x R 128.6, or Serrana x DTO-28. As a group, they prepared one demonstration plot, generally following CIP's recommendations. Discussions continued, however, and farmers clearly had their own ideas. The other nine farmers then sowed their beds according to their own ideas. No two beds were prepared the same: there were variations in substratum media, shading, watering, and in the use of mulch and pesticides. Emergence and vigor varied considerably due to the age of the seed (too old) and the media used. Farmers having poor results were given more seed and several new farmers joined the group.

When fresh seed was received from Lima, some farmers requested samples. By this time, farmers were more confident and the group was more adept at informal interaction. Feeling more at liberty to experiment, they radically changed nursery management. During a visit to the Lembang Horticultural Research Institute (LEHRI), some farmers were impressed by the use of stem cuttings: one even began his own program of cuttings.

Yields and the number of tubers per m^2 varied considerably but progeny performances did not differ widely. Yields increased with later plantings, presumably as a result of improved seed quality and farmer techniques. Analysis and discussion are still required to identify factors that may have contributed consistently to yield differences.

The continuing discussions revealed these important considerations:

- Farmers still prefer to transplant seedlings to the field rather than to produce tuberlets.
- They prefer to produce seedlings in small trays and to transplant to nursery beds for tuberlet production or to banana-leaf pots for direct transplanting to the field.
- They were unconcerned with shape, size and color of tubers during this early stage.
- All farmers said that they would keep their produce from the next season as seed, and they showed concern about seed storage.

The potential for introducing rapid multiplication techniques has been explored, and five farmers have requested mother plants and training in this area.

Marketing and Demand

Thrust X has two marketing goals: to develop an information base that other institutions and researchers can draw upon, and to help strengthen NARS' capabilities in conducting marketing and demand studies.

Backstopping NARS Research. To help backstop marketing studies conducted by NARS, support was provided in planning, reviewing, and financing collaborative projects and research contracts. A study in Thailand examined marketing, consumption, and demand for potato products. Draft reports of potato marketing studies were prepared by researchers from Indonesia, Zaire, the Dominican Republic, and Bangladesh.

A central finding of the *Thailand Study* was that potato consumption is discouraged by high potato prices and the low income of many urban consumers. The *Indonesian Study* revealed that potatoes produced in mid-elevation areas of this country were of relatively poor quality and were difficult to market. The *Zaire Study* concluded that potato marketing in Zaire's capital, Kinshasa, was both risky and costly because of the irregularity of supply and the perishability of potatoes produced in the Kivu area. Exploration of the economic feasibility of simple processing was suggested as a step toward lower marketing costs and risks. The *Dominican Republic Study* indicated that many commonly held beliefs about the "exploitative" practices of middlemen may overlook the essential functions that marketing agents perform, such as assembly, transportation and bulk breaking. The *Bangladesh marketing Study* found that, despite periodic market surpluses and price declines, potato production is still profitable for most farmers, irrespective of the size of their farms. The study found that, contrary to popular belief, large growers who sell their harvest on the farm received lower prices than do growers who sell their potatoes in the marketplace. The findings also indicated that in some parts of the country, traditional potato storage is more profitable than is cold storage. This helps explain why cold-storage facilities are seldom used in areas such as Tongibari.

PRACIPA — Commercialization Thrust X activities also backstop marketing studies conducted by national collaborators in the Andean Cooperative Potato Research Program (PRACIPA). Under this program, which completed its first year of activities in March 1988, marketing studies have been conducted by local researchers in five Andean countries: Bolivia, institutional marketing of seed potatoes; Colombia, marketing of processed potatoes; Ecuador, marketing of seed potatoes; Peru, developing a market information system for consumer potatoes; and Venezuela, marketing of consumer potatoes in the western highlands.

Bolivia. PRACIPA-Bolivia surveyed more than 15 institutions (public, private, and combined) that distribute seed potatoes in the Cochabamba region. In 1986 and 1987, two of these organizations handled over 75% of the seed in the country. Most of the seed consisted of Dutch varieties such as Alpha, Cardinal, and Diamant. The survey results and other findings were presented in a workshop organized by the Instituto Boliviano de Technologia Apropecuaria (IBTA) in September 1988; a second survey is under way to assess farmers' participation in, and opinions of, the various seed-potato distribution programs.

Colombia. Colombia has few traditional potato processing facilities. To assess the economic feasibility of village-level processing, surveys were made of 81 growers, 133 urban consumers, and operators of 20 eating establishments in the Pamplona region in 1987 and 1988. Nearly all of the farmers were interested in simple potato processing facilities, preferably in cooperative units. Consumers and restaurant owners expressed an interest in the various products processed from potato flour they were shown, but disliked their color (grey) and hardness. In addition to continued backstopping of the technical work in the Pamplona area, PRACIPA-Colombia is now conducting an informal survey in the Pasto-Ipiales region to assess the feasibility of using processed potatoes to feed guinea pigs.

Ecuador. The national potato program in Ecuador has recently upgraded its technical capability to produce improved seed. To determine the demand for this seed, surveys were made of multipliers, users, and non-users of improved seed in central Ecuador. The results show that, contrary to the widely-held belief, most multipliers do *not* sell seed to other producers. Instead, they keep most of it for their own use. Preliminary results of a survey in northern Ecuador show a similar pattern.

Peru. Work during 1987 and 1988 included helping prepare a regular market bulletin for potatoes in central Peru; setting up a computerized database covering monthly market statistics for the past 25 years; and surveying government personnel and growers in the central highlands who receive the bulletin. Government personnel felt the bulletin was useful and requested that it appear bimonthly. The National Farmers Organization has expressed an interest in reproducing copies of the bulletin for distribution through its local chapters. INIAA has initiated new research on the marketing of seed and processed potato products.

Venezuela. More than 100 potato growers were surveyed in the Tachira region of Venezuela. Findings emphasize the highly commercial orientation of producers, the predominance of traditional sources of market information, and the need for improved availability of seed and access to transportation from farm to marketplace.

Impact Assessment

NARS Survey

In 1987, a questionnaire was mailed to the leaders of national potato programs in Africa, Asia, and Latin America to assess the status of national potato programs, their research problems, and the impact of CIP and NARS activities to date. Responses were received from 41 national leaders.

Status of National Programs. The data indicate that three-quarters of the countries surveyed now have potato-breeding programs. Thirteen countries have comprehensive breeding programs and gene banks. Their activities include crossing, screening, clonal evaluations, and varietal releases. Eight countries have intermediate-level breeding programs that utilize germplasm populations bred elsewhere. Ten countries have variety-testing programs that depend on imported advanced clones or varieties. All of the countries polled can receive and utilize tubers, 32 can handle TPS, and 28 can handle in vitro materials.

More than half of the countries have selected and released new varieties from genetic materials provided by CIP. Three-quarters of the countries are currently conducting research on TPS and diffused-light seed storage (DLS). The new DLS technology has reached more countries than the other storage techniques.

Impact of Collaboration. National leaders indicate that collaboration with CIP has had a positive impact in several areas, most notably in improving links with other programs; expanding training; improving planning, coordination, and management; and, in releasing of new varieties. Most respondents felt that collaboration with CIP had helped the program to increase its staff and budget.

The survey findings suggest that national program/CIP collaboration has helped farmers obtain better quality seed,improve seed storage and obtain better varieties.

Impact of CIP Research Contracts. CIP contracts research on priority topics at institutions around the world. A questionnaire was mailed to the leaders of all such contracts, requesting their views on the benefits of their contract in terms of improvements in training (amount, quality), research facilities, theses, publications, and varieties released. The questionnaire also solicited information on the use of new research techniques or methods in seed production, in extension, and by farmers.

Benefits. The survey respondents indicated that the principal benefits had come through expanded training and publications (Table 10-1). In developed countries, significant benefits of research contracts accrued to developing-country nationals who prepared theses or worked as research assistants. In both developed and developing countries, most breeding contracts helped support student thesis work. In developing countries, many research contracts helped to improve research facilities.

Use of New Techniques. Most research contracts have led to the development of

Table 10-1 Principal benefits of research contracts and users of new techniques and methods (% respondents indicating each answer).

Breeding	Developed countries		Developing countries	
	Other contracts	Breeding contracts	Other contracts	contracts
Principal benefits:				
Number of people trained	9	5	7	7
Quality of training	8	3	6	7
Research facilities	5	3	6	5
Number of theses	9	2	5	4
Number of publications	10	4	6	6
New varieties released	4	2	4	1
Principal users				
Researchers	10	4	7	6
Seed programs	5	2	3	4
Extension	2	2	3	5
Farmers	2	2	3	4
No observations	10	5	7	7

Source: CIP survey of research contracts 1986-87.

new methodologies; fewer have resulted in new production methods. In developed countries, relatively few new technologies have been used by seed programs, in agricultural extension activities, or by farmers.

In contrast, in developing countries, new techniques have been used more frequently in seed programs, and by extension agents and farmers.

Research contracts have improved ties between CIP and research institutes around the world; they also have promoted an information and technology exchange among countries. For example, Argentina's National Research Institute (INTA), under contract with CIP, released a new potato variety, "Serrana." It has been distributed to many other countries, and is now grown in Argentina, Brazil, the Republic of Korea, Peru, the Philippines, Thailand, and Vietnam.

The Plant Research Institute in Australia has a contract with CIP to provide pathogen-free germplasm for regional trials in Southeast Asia. In addition to benefiting developing countries in the region, the experience has allowed the Institute to become the center for importation of potato germplasm into Australia.

A similar project with sweet potatoes is now under way.

Prospects for Andean Crops

Over 40 food crops were domesticated in the Andes of South America in pre-Columbian times. These include the potato, as well as:

- oca (*Oxalis tuberosa*)
- mashua (*Tropaeolum tuberosum*)
- quinoa (*Chenopodium quinoa*)
- cañihua (*Chenopodium pallidicaule*)
- kiwicha (*Amaranthus caudatus*)
- lupines (*Lupinus mutabilis*)

These crops are potentially valuable food resources, but with the exception of the potato, production and consumption of these crops are declining in the Andean regions.

The Peruvian government and many non-governmental organizations have initiated programs to promote the production and consumption of these crops. To provide a solid knowledge base to help in the planning of improvement programs, a study was conducted in the department of Cuzco, in the Peruvian highlands. Study objectives were to identify 1) the role these crops play in local farming systems, and in rural and urban diets, and 2) the principal constraints to greater production and utilization. Native An-

Table 10-2. Crops grown in two communities of Cuzco Department, Peru.

Crop	% of farmers growing the crop	Average area planted with in the crop (m^2)
Potato	100	9,354
Olluco	76	1,943
Barley	63	3,203
Broad bean	59	1,340
Mashua	43	1,163
Oca	27	1,321
Oat	25	4,505
Lupine	24	1,008
Quinoa	20	745
Oca/Olluco	12	2,000
Broad bean/quinoa	4	1,300
Others	12	136

Source: Cuzco farm survey 1987.

dean crops generally were found to grow at between 3,500 and 4,000 m, usually in complex farming systems that include both crops and livestock. In the five communities surveyed in the districts of Ccatcca and Colquepata, potato is the most commonly grown crop, followed by olluco, barley, and broad bean (Table 10-2). Rotations generally include relatively long periods of fallow (up to 7 years) and the total cultivated area averages between 1 and 2 ha per family.

Rural respondents indicated that low yield and the scarcity of good crop land are two principal barriers to expanding the production of native Andean crops.

Table 10-3. Farmers' perceptions of the principal factors limiting production of Andean crops in the two communities of Cuzco Department, Peru (% farmers reporting each factor).

	Quinoa[a]	Lupines[b]	Olluca[c]	Oca[c]	Mashua[c]
Low yield	61	22	11	16	17
Scarcity of good land	21	38	48	32	28
Climate problems	12	37	11	4	8
Scarcity of seed	7	–	4	8	17
Pests and diseases	–	–	15	20	–
Storage problems	–	–	6	4	8
Other problems	–	4	4	16	28
Total	100	100	100	100	100

[a] A cereal. [b] A pulse. [c] Root crops.

Source: Cuzco farm survey 1987.

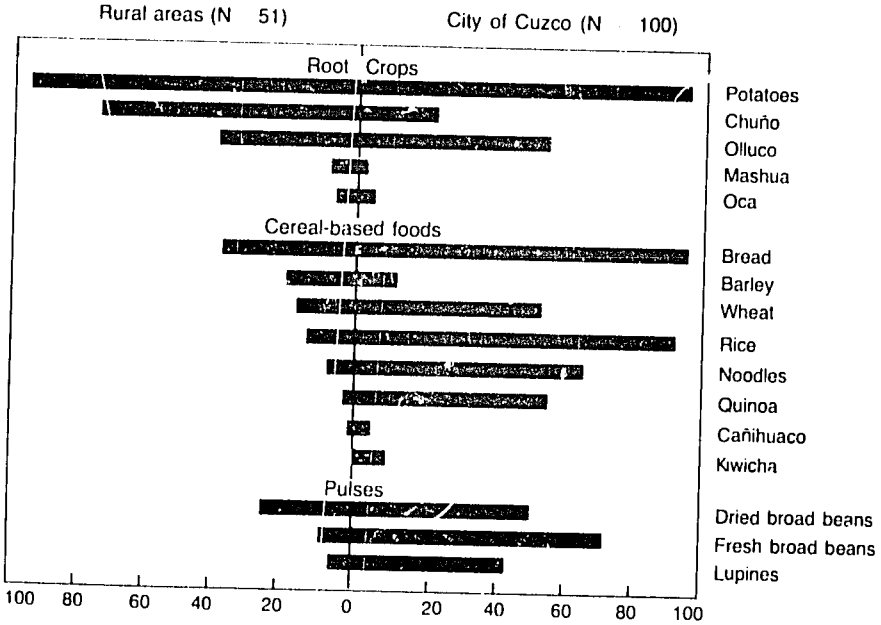


Figure 10-2. Consumption of selected foods: percentage of respondents reporting "frequent" consumption in the Department of Cuzco, Peru.

(Table 10-3). Climatic problems were also noted, particularly for quinoa and lupines. Seed scarcity, insects, diseases, and storage were also mentioned as problems for root crops.

Consumption patterns in rural areas reflect production patterns. Rural diets are heavily dependent on tubers (Fig. 10-2). Because of the relatively good storage properties of potatoes, and particularly those of chuño (dried potatoes), the crop plays a particularly significant role in the rural food system. Virtually all rural families eat potatoes frequently; three-quarters eat chuño, and approximately half eat olluco. Bread is the only cereal-based food that is eaten frequently in rural areas.

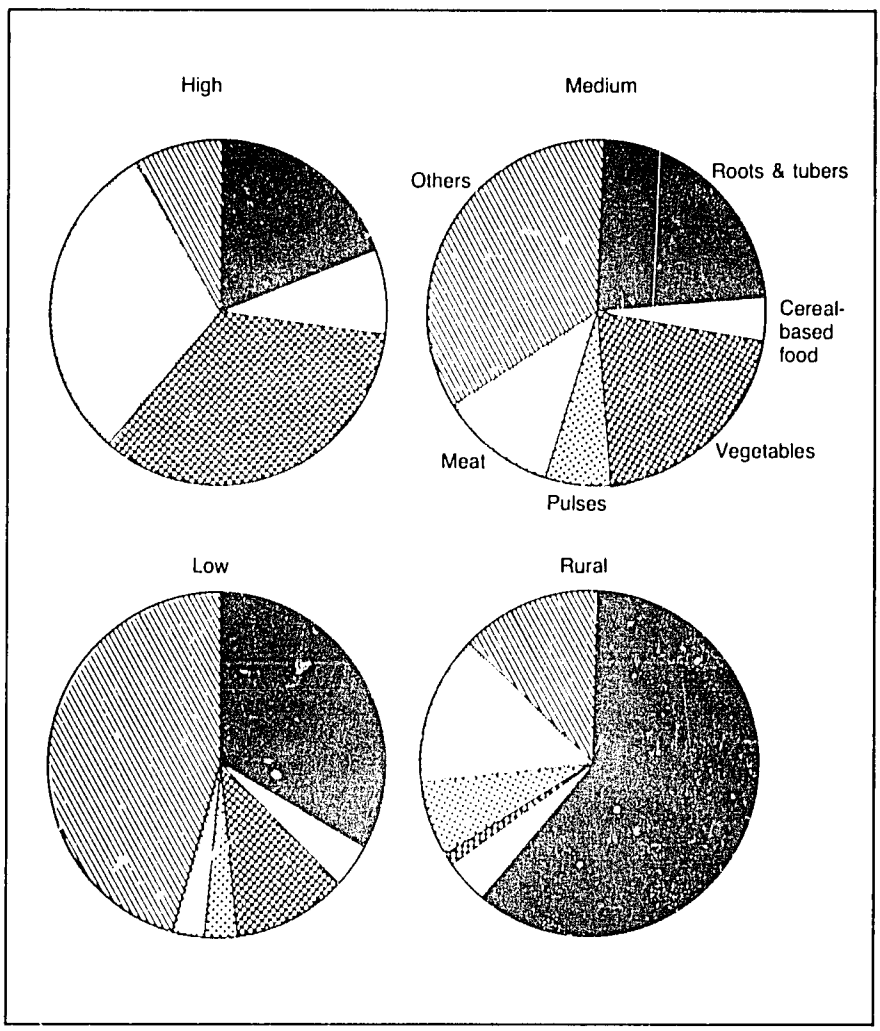


Figure 10-3. Foods consumed at lunchtime in rural areas and in the city of Cuzco, by socioeconomic strata (% respondents).

Aside from the technical constraints, cropping patterns reflect the increasing degree of commercialization of agriculture. When farmers require more money, for example, to pay for school fees and consumer goods, they plant a larger proportion of their land with cash crops, principally potatoes, barley, and oats.

The survey revealed that diets in the city of Cuzco are much more diverse than those in rural areas, and are closely linked to socioeconomic status. Consumption of tubers and cereal-based foods tends to decline sharply as incomes rise, whereas consumption of meat and vegetables increases significantly.

Consumption of wheat-based products, e.g., bread and noodles, and of rice is increasing in both rural and urban areas (Figure 10-3). This can be attributed to long-term governmental subsidies for the importation of wheat and rice. Other factors influencing consumption patterns in the city of Cuzco are price and availability. Some tubers, such as olluco, oca, and mashua, are available in city markets for only a short time each year after harvest. Cereals such as kiwicha and cañihua are scarce and costly throughout the year. The high prices of chuño and quinoa sometimes discourage use by urban residents.

Few agricultural research and extension activities have addressed the needs of farmers who grow native Andean crops. As rotations have intensified and as new pests, diseases, and fertility problems have developed, the national agricultural research systems have not been able to offer farmers adequate solutions. Consequently, both production and consumption of native Andean crops have declined in rural areas. In urban areas, the decreasing availability of Andean crops has increased their price and discouraged consumption. Additionally, for several years, economic policies have tended to raise the relative price of native Andean crops by subsidizing the importation of cereals, particularly rice and wheat.

Future production and use of Andean crops will depend largely on government price and trade policies and on the degree of commitment to crop research and extension built around the needs of Andean farm families.

Analysis of Patterns and Trends

Worldwide, there is little systematic information on potato and sweet potato production and use and on the needs of producers and consumers. Thrust X activities help generate and disseminate needed information.

Statistical Database

CIP maintains a computerized database that contains country-level estimates of root-crop production and use, as well as major economic and demographic indicators. This information is used to generate comprehensive statistical publications and to provide an information service for personnel at CIP and collaborating institutions. The database is updated annually by incorporating recent FAO and World Bank estimates.

Publications

The book *Underground Crops* (Winrock International, 1988) represents the first comprehensive use of the entire database to produce a reference book on global root-crop production and use. An initial narrative section outlines the salient characteristics of root crops, discusses accuracy of available statistics, and summarizes the highlights of the book's 31

tables. A special commentary is included on African root-crop data. The tables list national statistics for the years 1961 to 1985, including information on total production, area, and yields of cassava, edible aroids, potato, sweet potato, yam, and unspecified root crops. Recent estimates also are provided for per capita root-crop production; availability for consumption; supply of dietary energy and protein; root-crop trading, and farm-gate prices.

A volume titled *World Geography of the Potato* (in progress) will synthesize the mass of country-specific data available at CIP and in NARS. The book includes country and world maps of potato production zones. It identifies, describes, and classifies farming systems in developing countries where the potato plays, or potentially could play, an important role. It also describes the ecology, climate, population patterns, and cropping systems of each production zone.

Country-level Research

A graduate student at the Universidad Nacional Federico Villareal has mapped out Peru's principal agro-ecological zones of potato production. This map significantly contributes to understanding potato production patterns in the extremely diverse ecology of the Andes, where the potato originated. Peru's national potato program will use the map in planning and targeting potato-improvement efforts.

The government of Indonesia, via CRIFC, is expanding its research on both potatoes and sweet potatoes. As a contribution to the decision-making process, provincial- and district-level data on potato and sweet potato production from the Central Bureau of Statistics, the Office of Statistics, and district offices in Java were compiled in 1988.

These data were assembled in a computerized database, and a report containing statistical tables, figures, and maps is scheduled for publication in 1989.

Potato storage in Egypt.

Human Resources Development

Profile: 1989

The Training and Communications Department coordinated CIP's human resource development efforts in 1988, providing backup assistance for research administrative programs at headquarters, in all CIP regions, and in collaborative NARS projects. The closely associated units of Training, Communications Support, and Information Services provided technical and professional support that ranged from field demonstrations and evaluations with farm families to electronic, machine-to-machine communications.

A total of 302 national research and education collaborators from 57 countries participated in 16 specialized activities. The 16 production activities involved 353 national researchers, extension, and education collaborators and farmers from 55 countries. CIP scientists at headquarters worked alongside 57 visiting scientists from 29 countries, for a total of 221 weeks. And 94 graduate students and national collaborators from 14 countries did their research at headquarters, regional sites, or universities overseas. CIP was also host to the workshop "Human Resource Development Through Training," with participants from 13 CGIAR centers and 4 non-associated centers.

CIP's administrative and research staff were assisted in designing and planning print, photographic, and electronic media. Media production in support of administration included the annual report, self-study, budget documents, a public-awareness brochure. and an audio-visual presentation for visitors. CIP's research-based publications include 9 works in Spanish, 18 in English, and 7 in French.

Co-publishing efforts included contracts to translate CIP technical media into French and Chinese. To enhance skills in applied communications technology and related training skills in human resource development, the Department provided informal learning sessions and on-the-job experiences for visiting scientists at headquarters, as well as in regional and in-country settings including Chile, Ecuador, and Colombia. Media developed for this work included technical information bulletins and complementary slide sets, plus research guides and course lecture materials and handouts.

In addition, advisory support was provided to national programs and networks, and included assistance to PROCIANDINO. RICA, COTESU, SEINPA, and ALAP. Collaboration was begun with other Centers to exchange information on policies and to share experiences and tools. These included sharing a bibliography of reference documents used at CIP for translation. CIAT was contacted for collaboration on machine-assisted language translations from English into Spanish.

Hands-on practice for trainees at an international production course, Shimla, India.

The Information Services unit developed a CIP Bibliographic Database of more than 25,000 references for conventional and non-conventional literature in CIP's library. Other new services include access to potato and sweet potato references from CABI and AGRIS magnetic tapes, via a computer at CIP headquarters. Databases such as AGRIS in Vienna and DIALOG also can be accessed via satellite. A specialized bibliography on TPS has been prepared. Other activities to encourage exchange among the Centers include a database on publishing procedures, training in scientific writing and consultancy support to the Latin American Potato Journal.

Developing Human Resources

CIP's global human resource development program builds upon a regional and national network of farmers, agricultural researchers, extensionists, educators, and businessmen.

The Training and Communication Department coordinates these efforts within three closely associated units: Training, Communication Support, and Information Services. Communication roles are central to this process, and CIP staff activities range from traditional field work with farm families to electronic, machine-to-machine communication. They provide both direct technical services and professional consultancies to support research and administrative programs at headquarters, in all CIP regions, and in collaborative NARS projects.

Training

The training support strategy for human resource development is based on the premise that communication skills should be learned in conjunction with crop-improvement skills. CIP training objectives are classified as 1) production-oriented, to help participants respond to farm-level problems, and 2) specialized, to enhance research capabilities (Table 11-1).

Highlights of 1988 activities include:

- 302 national research and education collaborators from 57 countries participated in 16 specialized group training activities.
- 353 national researchers, extension agents, education collaborators and farmers from 55 countries participated in 16 production group training activities.
- 57 visiting scientists from 29 countries worked with CIP scientists at headquarters in Peru for a total of 221 weeks.
- 94 students and national collaborators from 14 countries carried out their thesis research at headquarters, regional sites, or at collaborating universities.

Other training included informal sessions and on-the-job experiences at headquarters in Peru to help visiting scientists communicate their research findings more effectively; training of selected national scientists and com-

Table 11-1. Training activities of CIP and the collaborative research networks, 1988.

Region	Activity	No. of participants	No. of countries
Headquarters-Peru			
	Production with special[a] emphasis on seed production	18	10
	Workshop on marketing (PRACIPA)	12	7
	Visiting scientists	57	29
	Scholarships	24	10
	Student assistantships	17	1
	Preprofessional practice[b]	53	5
Region I			
Argentina	Workshop on advancements in potato breeding	29	6
Colombia	Workshop on field-level diagnostic skills (CIP/CIAT)	16	10
Colombia	Potato tuber moth	19	6
Region II			
Mexico	Potato germplasm management (PRECODEPA)	13	8
Region III			
Zimbabwe	Workshop on improvement in seed production and distribution	15	10
Kenya	Postharvest technology	16	10
Rwanda	Seed production	6	2
Ethiopia	Seed production	35	1
Rwanda	Workshop on late blight (PRAPAC)	34	5
Zaire	Production	31	1
Region IV			
Egypt	Production	27	1
Morocco	Production	15	1
Turkey	Production	12	1
Tunisia	Seed production and storage	18	1
Region V			
Cameroon	Workshop on potato production and constraints in West and Central Africa	11	10
Cameroon	Production[a]	16	1
Nigeria	Vegetative seed production[a]	27	14
Region VI			
India	Modern methods in potato production	23	4
India	Sweet potato production	16	4
India	Workshop on sweet potato improvement	32	15
India	Workshop on marketing and processing	18	9
Sri Lanka	Workshop on TPS, extension and on-farm technology transfer	18	6
Region VII			
Burma	Production	24	1
Fiji	Production	16	9
Philippines	Production[a]	17	1
Region VIII			
China	Workshop on potato production	33	11
China	True potato seed	12	1
China	Workshop on postharvest	37	14
China	Sweet potato virology	8	1
China	English language	9	1
China	Sweet potato in vitro germplasm management	12	1

[a] United Nations Development Program (UNDP)

[b] 45 trainees from Peru, 8 from developed countries

municators on course organization, management, and evaluation (e.g., national staff from Chile); development of communications-related learning experiences in regional and in-country courses, e.g., Ecuador and Colombia; and preparation of training materials, including technical information bulletins and complementary slide sets, and other media such as research guides, lecture materials and handouts.

CIP was host to a workshop for all international agricultural research centers on "Human Resource Development Through Training." Participants from 13 CGIAR centers and 4 non-associated centers made recommendations that were subsequently approved by the Center directors. A working group was named to further evaluate the recommendations and prepare viable plans of action, and joint efforts began immediately following the workshop.

Communication Support

Unit functions included planning and design for print, photographic, and electronic media for research and administrative programs. The media products ranged from photos of field and laboratory experiments to editorial help with journal articles and co-published books (Table 11-1). Technical and professional communications services included writing and editing, audience analysis, language translation, graphics and illustration, printing and audiovisual production, and distribution. CIP's publications and learning materials now include co-publishing efforts and other contracts to translate CIP technical media and the CIP circular into the the French and Chinese languages.

Media production in support of administration included the annual report, a self-study and budget documents, a public-awareness brochure, and an audio-visual presentation for visitors to CIP.

Support to National Programs and Networks

National program collaborators, mainly in Latin America, were assisted in identifying communications problems and in seeking solutions.

Accessing database, Information Service Unit

This assistance included support to:

- PROCIANDINO to help develop communication strategies for transfer of technology to their audiences.
- Red Interamericana de Comunicadores Agricolas (RICA) to help generate an informal flow of information among communicators in agricultural research institutions in Latin America.
- Country-level projects in Peru, e.g., COTESU and SEINPA, as well as ALAP.

Information Services

Development of Databases. A CIP Bibliographic Database has been developed, containing conventional and non-conventional literature from CIP's library that is related to potatoes and sweet potatoes. The database now has more than 25,000 references; it includes bibliographical data, keywords, and abstracts in the English, Spanish, and French languages, if available in the original document.

Potato and sweet potato references are accessed from CABI and AGRIS magnetic tapes maintained by a computer at CIP headquarters in Lima. Other databases (for example, AGRIS in Vienna and DIALOG in the USA) are accessed via satellite.

A database on publishing p rocedures has also been designed and procedures are available that provide instructions for submission of articles to more than 100 journals.

Services. ISU services directly support CIP headquarters and regional staff and are free-of-charge to qualified users in national and regional programs, including researchers, university professors, and students.

Retrospective Searches. A total of 1,260 retrospective searches have been conducted for 152 CIP staff and 329 national researchers.

Selective Dissemination of Information. This quarterly service is available to recommended users who have a continuing need for up-to-date information on specific topics. Over 200 profiles have been developed and 114 users are being serviced.

Specialized Bibliographies. Users other than CIP staff may require specialized bibliographies prepared from CIP's priority research areas; three such bibliographies have been prepared from the CIP database.

Training demonstrations: All visiting scientists at headquarters in Lima were given an orientation on how to use the CIP information services. Participants in group training exercises received instruction on how to access information, and a slide set was prepared for use by regional staff in in-country and regional activities.

Cooperation International Agricultural Research Centers: As a result of the first CGIAR Documentation and Information Services Meeting held at CIP in 1985 and a subsequent meeting was held at ICRISAT . ISU staff have been instrumental in developing action plans for inter-center collaboration.

List of Abbreviations and Acronyms

AGRIS	International Information System for Agricultural Sciences and Technology (Italy)
AID	Agency for International Development
ALAP	Asociacion Latinoamericana de Papa
AMV	alfalfa mosaic virus
ANOVA	analysis of variance
APLV	Andean potato latent virus
APMV	Andean potato mottle virus
ARARI	Aegean Regional Research Institute (Turkey)
AVRDC	Asian Vegetable Research & Development Center (Taiwan)
a.i.	active ingredient
avg	average
BARI	Bangladesh Agricultural Research Institute
BPI	Bureau of Plant Industries (Philippines)
BW	bacterial wilt
CAAS	Chinese Academy for Agricultural Sciences
CABI	Commonwealth Agricultural Bureau International (CAB International)
CDH	Centre pour le Developpment de l'Horticulture (Senegal)
CGA	general combining ability
CGIAR	Consultative Group on International Agricultural Research
CIAAB	Centro de Investigaciones Agricolas "A-Boerger" (Uruguay)
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIP	Centro Internacional de la Papa (Peru)
CIPC	isopropyl-N-3-chlorophenyl-carbamate
CMS	cytoplasmic male sterility
CNPH	Centro Nacional de Pesquisa de Hortaliças (Brazil)
COTESU	Cooperacion Tecnica Suiza
CPRA	Centre de Perfectionnement et de Recyclage de Pratiques Agricoles de Saïda (Tunisia)
CPRI	Central Potato Research Institute (India)
cm	centimeter
cv	coefficient of variation
cv.	cultivar
DLS	diffused-light store
DMRT	Duncan's multiple range test
DNA	deoxyribonucleic acid
d	day
EB	early blight
EBN	endosperm balance number
EDTA	ethylenediaminetetraacetic acid
ELISA	enzyme-linked immunosorbent assay

EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria (Brazil)
ENEA	Energia Nucleare e delle Energie Alternative (Italy)
ERSO	Consorzio "Mario Neri" (Imola, Italy)
FAO	Food and Agriculture Organization of the United Nations
FDR	first division restitution
FONAIAP	Fondo Nacional de Investigaciones Agropecuarias (Venezuela)
GA	gibberellic acid
GAAS	Guandong Academy of Agricultural Sciences
g	gram
h	hour
ha	hectare
hrp	hypersensitive response
IAO	Istituto Agronomico per l'Oltremase, Italy
IBPGR	International Board for Plant Genetic Resources
IBTA	Instituto Boliviano de Tecnologia Agropecuaria
ICA	Instituto Colombiano Agropecuario (Colombia)
ICAR	Indian Council for Agricultural Research
ICRISAT	International Crop Research Institute for Semi-Arid Tropics
ICTA	Instituto de Ciencia y Tecnologia Agricolas (Guatemala)
IDEAS	The Venezuelan International Institute of Higher Studies
IDRC	International Development Research Centre (Canada)
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture (Nigeria)
INIA	Instituto Nacional de Investigaciones Agropecuarias (Chile)
INIAA	Instituto Nacional de Investigacion Agraria y Agroindustrial (Peru)
INIAP	Instituto Nacional de Investigaciones Agropecuarias (Ecuador)
INIFAP	Instituto Nacional de Investigaciones Forestales y Agropecuarias (Mexico)
INIPA	Instituto Nacional de Investigacion y Promocion Agropecuaria (Peru)
INIVIT	National Institute for Research in Tropical Roots and Tubers (Cuba)
INPT	Institut National de la Pomme de Terre (Togo)
INRA	Institut National de la Recherche Agricole (Senegal)
INRAT	Institut National de la Recherche Agronomique de la Tunisie
INTA	Instituto Nacional de Tecnologia Agropecuaria (Argentina)
IPO	Research Institute for Plant Protection (Netherlands)
ISABU	Institut des Sciences Agronomiques du Burundi
kb	kilobar
L	liter
LAR	leaf area ratio
LB	late blight
LEHRI	Lembang Horticultural Research Institute, Indonesia
LER	land equivalent ratio

LSD	least significant difference
LUE	light use efficiency
lat.	latitude
long.	longitude
MA	monoclonal antibody
MBN	Meloidogyne bacterial wilt nematode resistant material
MJ	megajoule
m	meter
meq	milieequivalent
min	minute
ml	milliliter
mm	millimeter
mo	month
NAR	net assimilation rate
NARS	National Agricultural Research Systems
NASH	nucleic acid spot hybridization test
ND	not determined
NS	not studied
NSAC	Nova Scotia Agricultural College
nm	nanometer
ns	not significant
OP	open-pollinated
PBI	Plant Breeding Institute (Cambridge, UK)
PCARRD	Philippine Council for Agriculture and Resources Research and Development
PCN	potato cyst nematode
PIPA	Programa de Investigacion en Papa (Peru)
PLRV	potato leafroll virus
PNAP	Programme National de l'Amelioration de la Pomme de Terre (Rwanda)
PRACIPA	Programa Andino Cooperativo de Investigacion en Papa (Andean region)
PRAPAC	Programme Regional d'Amelioration de la Culture de Pomme de Terre en Afrique Centrale (Central Africa)
PRECODEPA	Programa Regional Cooperativo de Papa (Central America-Caribbean)
PRI	Plant Research Institute
PROCIANDINO	Programa Cooperativo de Investigacion Agricola para la Subregion Andina
PROCIPA	Programa Cooperativo de Investigaciones en Papa (southeast region of South America)
PSTV	potato spindle tuber viroid
PTM	potato tuber moth
PTV	Peru tomato virus
PVA	potato virus A

PVM	potato virus M
PVS	potato virus S
PVV	potato virus V
PVX	potato virus X
PVY	potato virus Y
ppm	parts per million
RCB	randomized complete block design
RGR	relative growth rate
RH	relative humidity
RICA	Red Interamericana de Comunicadores Agricolas
RLER	relative leaf expansion rate
RNA	ribonucleic acid
SAPPRAD	Southeast Asian Program for Potato Research and Development
SCRI	Scottish Crops Research Institute (Scotland)
SD	standard deviation
SED	standard error or difference
SEINPA	Semilla e Investigacion en Papa (Peru)
SLA	special leaf area
SPCV	sweet potato caulimo-like virus
SPFMV	sweet potato feathery mottle virus
SPLV	sweet potato latent virus
SPMMV	sweet potato mild mottle virus
sec	second
TPS	true potato seed
t	ton
UNA	Universidad Nacional Agraria - La Molina (Peru)
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
var.	variety
vol	volume
vs.	versus
WUE	water use efficiency
wk	week
wt	weight
yr	year

Papers Published in Scientific Journals

Aley, P., and E. R. French. 1987. Capacidad de biovares I y II de *Pseudomonas solanacearum* para causar infeccion latente en tuberculos de papa. Fitopatologia 22(2):48. (Abstr.)

Antle, J. M., and C. C. Crissman. 1988. The market for innovations and short run technological change: evidence from Egypt. Economic Development and Cultural Change 36(4):669-690.

Atlin, G. N., and S. G. Wiersema. 1988. Selection against inbred seedlings in mixtures of inbred and hybrid true potato seed. Potato Research 31:105-112.

Bartolini, I., and P. Jatala. 1988. Separacion de componentes del medio de cultivo de hongos y nematoxinas producidas por hongos con tres tipos de Sephadex. [Separation of components of fungal media and nematoxins produced by fungi with three types of Sephadex.] Nematropica 18(1):2. (Abstr.)

Baulcombe, D. C., and E. N. Fernandez-Northcote. 1988. Detection of strains of potato virus X and of a broad spectrum of potato virus Y isolates by nucleic acid spot hybridization (NASH). Plant Disease 72:307-309.

Bryan, J. E. 1988. Implementation of rapid multiplication and tissue culture methods in third world countries. Am. Potato J. 65:199-207.

Canto-Saenz, M., R. Anguiz, and H. Torres. 1988. Interaccion entre *Verticillium dahliae* y *Pratylenchus flakkensis* in Potato. [Interaction between *Verticillium dahliae* and *Pratylenchus flakkensis*.] Fitopatologia 22:64. (Abstr.)

Canto-Saenz, M., N. Chacon, and P. Jatala. 1988. Damage threshold density of *Globodera pallida* on potatoes in Pomamanta, Peru. *In* Abstracts of the E.S.N. XIXth International Nematology Symposium, Uppsala, Sweden. August 7-13. p. 20.

Caringal, E. M., and P. Vander Zaag. 1987. On-farm evaluation of rapid multiplication of potatoes (*Solanum* spp.) in Benguet. Phil. Agr. 70:101-107.

Chandra, R., J. H. Dodds, and P. Tovar. 1988. In vitro tuberization in potato. IAPTC Newsletter 55:10-20.

Chavez, G. L., and K. V. Raman. 1987. Evaluation of trapping and trap types to reduce damage to potatoes by the leaf miner *Liriomyza huidobrensis* (Diptera: Agromyzidae) Insect Sci. Applic. 8(3):369-372.

Chavez, R., C. R. Brown, and M. Iwanaga. 1988. Transfer of resistance to PLRV titer buildup from *Solanum tuberosum* to a tuber-bearing *Solanum* gene pool. Theor. Appl. Genet. 76:129-135.

Chavez, R., M. T. Jackson, P. E. Schmiediche, and J. Franco. 1988. The importance of wild potato species resistant to the potato cyst nematode, *Globodera pallida*, Pathotypes P_4A and P_5A, in potato breeding. I. Resistance studies. Euphytica 37:9-14.

Chavez, R., M. T. Jackson, P. E. Schmiediche, and J. Franco. 1988. The importance of wild potato species resistant to the potato cyst nematode, *Globodera pallida*, Pathotypes P_4A and P_5A, in potato breeding. II. The crossability of resistant species. Euphytica 37:15-22.

Chavez, R., P. E. Schmiediche, M.T. Jackson, and K.V. Raman. 1988. The breeding potential of wild potato species resistant to the potato tuber moth, *Phthorimaea operculella* (Zeller) Euphytica. 39:123-132.

Delgado de la Flor, R., P. Jatala, and A. Gonzalez. 1988. Distribucion del nematodo quiste de la papa (*Globodera* spp.) en Cuzco, Peru. [Distribution of the potato cyst nematode (*Globodera* spp.) in Cuzco, Peru.] Nematropica 18(1):4. (Abstr.)

Delgado de la Flor, R., P. Jatala, and A. Gonzalez. 1988. Efectos de algunos extractos de plantas sobre la actividad de *Caenorhabditis elegens*. [Effects of some plant extracts on the activity of *Caenorhabditis elegans*.] Nematropica 28(2):4. (Abstr.)

Demagante, A. L., and P. Vander Zaag. 1988. Potato (*Solanum* spp.) growth and yield under isohyperthermic conditions as influenced by weed control treatment. Phil. Agr. 70(1-2):91-99.

Demagante, A. L., and P. Vander Zaag. 1988. The response of potato (*Solanum* spp.) to photoperiod and light intensity under high temperatures. Potato Res. 31:73-83.

Dodds. J. H. 1988. Tissue culture technology. Practical application of sophisticated methods. Amer. Pot. J. 65:167-180.

Dodds, J. H., and J. M. Jaynes. 1987. Crop plant genetic engineering. Science fiction to science fact. Outlook on Agriculture 16:11-115.

Ekanayake, I. J., S. K. De Datta, and P. L. Steponkus. 1989. Spikelet sterility and flowering response of rice to water stress at anthesis. Annals of Botany 63:257-264.

Ekanayake, I. J., P. Malagamba, and D. Midmore. 1988. Effect of water stress on yield indices of sweet potatoes. *In* Abstracts of Eighth Symposium of International Society for Tropical Root Crops. pp. 31-32. (Abstr.)

Ekanayake, I. J., and D. J. Midmore. 1988. Drought response of potatoes in warm tropical areas. *In* Abstracts of International Conference on Dry Land Farming, Amarillo/Bushland, Texas, U.S.A., August 15-19. 1988. p. 8. (Abstr.)

Ekanayake, I. J., and P. L. Steponkus. 1988. Water stress induced female floral defects anthesis, and grain sterility in upland rice. Plant Physiology 84(4):141.

Escobar, V., and P. Vander Zaag. 1988. Field performance of potato (*Solanum* spp.) cuttings in the warm tropics: influence of planting system, hilling, density and pruning. Am. Potato J. 65:1-10.

Estrada, N., and L. Valencia. 1988. Desarrollo de cultivares de papa resistentes a la palomilla *Phthorimaea operculella* (Zeller) en Colombia. Revista Latinoamericana de Papa 1 (1):64-73.

Fabian, O., and E. N. Fernandez-Northcote. 1988. Evaluacion de germoplasma de *Lycopersicon* spp. y *Capsicum* spp. para resistencia al virus peruano del tomate. Fitopatologia 23:32-36.

Fernandez-Northcote, E. N., and Charlotte Lizarraga. 1988. Detection of potato viruses X and Y serotypes in potato leaf extracts by enzyme-linked immunosorbent assay on nitrocellulose membranes (NCM-ELISA). *In* Fifth International Congress of Plant Pathology, Kyoto, Japan, 1988, p. 48. (Abstr.)

Fernandez-Northcote, E. N., J. Saldamando, B. Casana, and O. Fabian. 1987. Contact transmission and synergism of Peru tomato virus (PTV) and tobacco mosaic virus in tomato. Evaluation of *Lycopersicon* spp. and *Capsicum* spp. germplasm for resistance to PTV. Fitopatologia 22:42-43. (Abstr.)

Franco, J., and A. Matos. 1987. Effect of sodium hypochlorite treatment on *Globodera pallida*. Nematropica Vol. 18 (in press, Abstr.)

Franco, J., A. Matos, and A. Gonzalez. 1987. La fertilizacion inorganica en el manejo integrado del nematodo del quiste de la papa. Fitopatologia (Peru) 22:64. (Abstr.)

Franco, J., A. Matos, and A. Gonzalez. 1987. La fertilizacion inorganica en el manejo integrado del nematodo del quiste de la papa. Nematropica Vol. 18. (in press, Abstr.)

Franco J., A. Gonzalez, A. Matos, and R. Salas. 1987. Efecto de clones resistentes a la multiplicacion de *Globodera pallida*. Fitopatologia (Peru) 22:62-63. (Abstr.)

Golmirzaie, A. M. 1988. Comparison of hybrids with different open-pollinated (OP) generations of true potato seeds (TPS) for agronomical characters. Amer. Potato J. 65:480. (Abstr.)

Gonzalez, A., J. Franco, and A. Matos. 1987. Metodos para la evaluacion de resistencia a *Globodera pallida* en plantulas individuales de papa. Fitopatologia (Peru) 22:64. (Abstr.)

Gonzalez,, A., J. Franco, and A. Matos. 1987. Metodos para la evaluacion de resistencia a *Globodera pallida* en plantulas individuales de papa. Nematropica Vol. 18. (in press, Abstr.)

Hidalgo, O. A. 1988. Progresos en la produccion de tuberculos semilla de papa en Latinoamerica. Revista Latinoamericana de la Papa, 2:(1), 1989.

Hidalgo, O. A., A. A. Fedalto, and J. A. M. Telles. 1988. Comportamento em campo de batata-semente armazenadas sob luz difusa e/ou frio no Distrito Federal. Hort. Bras. 6(1):58. (Abstr.)

Ho, T. V., N. T. Hoa, T. T. Loan, L. T. Tuyet, and P. Vander Zaag. 1988. Techniques for using sprouts for potato production in the tropics. Potato Res. 31:379-383.

Ho, T. V., and P. Vander Zaag. 1987. Sweet potato in Vietnam. Agriculture International 39(7-8):221-223.

Horton, D. E. 1988. Las papas en los paises en desarrollo. Revista Latinoamericana de la Papa 1(1):9-17.

Horton, D. E. 1988. Potatoes: truly a world crop. Span. 30(3):116-118.

Horton, D. E. 1988. The nutritional and economic value of potatoes in developing countries. LIFE Newsletter 20(4):2.

Horton, D. E. 1988. World patterns and trends in sweet potato production. Tropical Agriculture 65(3):268-270.

Horton, D., and G. Prain. 1988. The International Potato Center's experiences with farmer participation in on-farm research. Culture and Agriculture 34:1-4.

Horton D., and R. L. Sawyer. 1988. On-farm research: experiences with potatoes. Entwicklung + Landlicher Raum 3:19-21.

Huaman, Z., A. Baltazar, and J. Espinoza. 1988. Studies on the effect of stigma exertion in true potato seed production. Am. Potato J. 65(8):484. (Abstr.)

Iwanaga, M., and R. Ortiz. 1988. Comparison of the parental value of FDR 2x and of 4x progenitors in two locations. Amer. Potato J. 65:491. (Abstr.)

Jatala, P., I. Bartolini, and M. Zegarra. 1988. Determinacion selectiva de carbohidratos y minerales en las extracciones de nematoxinas exogenas de hongos. [Selective determination of carbohydrates and minerals in exogenous nematoxin extractions of fungi.] Nematropica 18(1):11. (Abstr.)

Jatala, P., and A. Gonzalez. 1988. Un nuevo nematodo que ataca la papa en Peru [A new nematode attacking potato in Peru.] Nematropica 18(1):11. (Abstr.)

Jatala, P., and E. Guevara. 1988. Efecto de varias poblaciones de *Meloidogyne incognita* sobre la expresion de resistencia y susceptibilidad de papa generado de semilla botanica. [Effects of various populations of *Meloidogyne incognita* on the expression of resistance and susceptibility of potatoes generated from true potato seeds.] Nematropica 18(1):12. (Abstr.)

Jatala, P., and E. Guevara. 1988. Reaccion de germoplasma de camote a *Meloidogyne incognita*. [Reaction of sweet potato germplasm to *Meloidogyne incognita*.] Nematropica 18(1):12. (Abstr.)

Jatala, P., E. Guevara, and R. Salas. 1988. Eficiencia de *Paecilomyces lilacinus* y algunos nematicidas en el control de *Meloidogyne incognita* en raices de olivos. [Efficiency of *Paecilomyces lilacinus* and some nematicides in controlling *Meloidogyne incognita* in roots of olive trees.] Nematropica 18(1):12. (Abstr.)

Jaynes, J. M., and J. H. Dodds. 1987. Synthetic genes make better potatoes. New Scientist 1578:62-64.

Kadian, M. S., P. K. Patel, K. C. Thakur, and M. D. Upadhya. 1988. Comparative yield potential of seedlings and seedling tubers from true seed in Deesa (Gujarat). J. Indian P. Assoc. 15 (1 and 2):115-128.

Kadian, M. S., P. K. Patel, M. D. Upadhya, and K. C. Thakur. 1987. Evaluation of TPS families for potato production in Deesa (Gujarat). J. Indian P. Assoc. 14 (1 and 2):57-59.

Lamberti, F., P. Jatala, and A. Agostinelli. 1988. Un informe de algunas especies de *Xiphinema* presentes en Peru. [A report on some *Xiphinema* species occurring in Peru.] Nematropica 18(1):13. (Abstr.)

Lindo, L. de, E. R. French, and J. Elphinstone. 1987. Influencia del nivel de calcio en la susceptibilidad a Erwinia en plantas de papa provenientes de semilla botanica. Fitopatologia 22:49. (Abstr.)

Lizarraga, C., and E. N. Fernandez-Northcote. 1989. Detection of potato viruses X and Y in sap extracts by a modified indirect enzyme-linked immunosorbent assay in nitrocellulose membranes (NCM-ELISA). Plant Disease 73:11-14.

Lizarraga, C., and E. N. Fernandez-Northcote. 1987. Detection of potato viruses X and Y in sap extracts by enzyme-linked immunosorbent assay on nitrocellulose membranes (NCM-ELISA). Fitopatologia 22:43. (Abstr.)

Llerena, R., L. Mattos, and E. French. 1987. La punta morada en papa. Fitopatologia 22:49. (Abstr.)

Llontop, J., and J. Franco. 1988. El nematodo del quiste de la papa (*Globodera* spp.) en la region andina de La Libertad, Peru. I. Distribucion e identificacion de especies. Fitopatologia 23(2):49-58.

Llontop, J., and J. Franco. 1988. El nematodo del quiste de la papa (*Globodera* spp.) en la region andina de La Libertad, Peru. II. Razas de *Globodera pallida*. Fitopatologia 23(2):59-64.

Llontop, J. A., J. Franco, and M. Scurrah. 1987. Identificacion de especies y razas del nematodo quiste de la papa *Globodera* spp. en la zona papera de La Libertad, Peru. Fitopatologia (Peru) 22:63. (Abstr.)

Llontop, J. A., J. Franco, and M. Scurrah. 1987. Identificacion de especies y razas del nematodo quiste de la papa *Globodera* spp. en la zona papera de La Libertad, Peru. Nematropica Vol. 18. (in press, Abstr.)

Llontop, J. A., M. Scurrah, and J. Franco. 1987. Maria Huanca, new potato variety resistant to potato cyst nematode. Nematropica Vol. 18. (in press, Abstr.)

Lopes, C.A., J. A. Buso, and O. Hidalgo. 1988. Comportamento de genotipos de batata para resistencia a murcha bacteriana causada por *Pseudomonas solanacearum*. Fitopatol. Bras. 13(2):97. (Abstr.)

Malagamba, P. 1988. Potato production from true seed in tropical climates. HortScience 23(3):495-500.

Martin, C., and H. Torres. 1987. Control de tizon temprano de la papa (*Alternaria solani*) en condiciones de selva alta en Peru [Control of early potato blight (*Alternaria solani*) under highland jungle conditions in Peru.] Fitopatologia 22:58. (Abstr.)

Mendoza, H. A., C. Martin, and A. Brandolini. 1987. Miglioramento della patata per resistenza ad *Alternaria solani* in ambiente tropicale. Revista di Agricoltura Subtropicale e Tropicale. Firenze LXXXI (1-2):53-71.

Midmore, D. J. 1988. Potato (*Solanum* spp.) in the hot tropics. VI. Plant population effects on soil temperature, plant development and tuber yield. Field Crops Res. 19:183-200.

Midmore, D. J., D. Berrios, and J. Roca. 1988. Potato (*Solanum* spp.) in the hot tropics. V. Intercropping with maize and the influence of shade on tuber yields. Field Crops Res. 18:159-176.

Midmore, D. J., and R. E. Rhoades. 1987. Applications of agrometeorology to the production of potato in the warm tropics. *In* C.J. Stigter (ed.), Agrometeorology of the Potato. Symposium held in Wageningen, April 9-10, 1987. Actae Horticulturae 215:103-136.

Midmore, D. J., J. Roca, and D. Berrios. 1988. Potato (*Solanum*: spp.) in the hot tropics. IV. Intercropping with maize and the influence of shade on potato microenvironment and crop growth. Field Crops Res. 18:141-157.

Nakashima, J., and E. N. Fernandez-Northcote. 1987. Purification of potato virus A (PVA) and its serological detection. Fitopatologia 22:42-43. (Abstr.)

Ochoa, C. 1988. New Bolivian taxa of *Solanum* (Sect. Petota). Phytologia 65(2):103-113.

Ochoa, C. 1989. *Solanum amayanum*: a new wild Peruvian potato species. Amer. Potato J. 66(1):1-4.

Ochoa, C. 1988. *Solanum bill-hookeri*: new wild potato species from Peru. Amer. Potato J. 65(12):737-740.

Ochoa, C. 1989. *Solanum salasianum*: new wild tuber-bearing species from Peru. Amer. Potato J. (in press).

Ochoa, C. 1989. *Solanum* ser. Simplicissima, nueva serie tuberifera de la Sect. Petota (*Solanaceae*). Revista Academia Colombiana de Ciencias Exactas, Fisicas y Naturales, Bogota, Colombia (in press).

Pallais, N., and N. Fong. 1988. Influence of dormancy on the effectiveness of priming true potato seed. *In* Abstracts of 85th Annual Meeting of the Amer. Soc. of Hort. Sci. and 33rd Annual Meeting of Canad. Soc. Hort. Sci., Michigan State Univ. HortScience 23:796. (Abstr. # 552).

Pizarro, A., M. Canto-Saenz, and J. Cepeda. 1988. Cost-benefit relation of aldicarb 15G on potatoes in Huasahuasi, Peru. *In* Abstracts of the XX Congreso Anual de Nematologia de la ONTA, San Jose, Costa Rica, November 7-11. p. 8.

Potts, M. J. 1987. Dialogue underlies success of potato in Burundi. International Agricultural Development 7(5):9-10.

Potts, M. J., and E. Biranguza. 1989. The evaluation of alternative fodder crops under African highland conditions. Expl. Agric. 25:99-107.

Potts, M. J., E. Biranguza, and C. Bweyo. 1989. Evaluation of alternative legumes for green manure and grain under African highland conditions. Expl. Agric. 25:109-118.

Potts, M. J., and S. Nikura. Developing a seed potato farm spurs introduction of new ideas. Agriculture International 39(9/10):266-270.

Quispe, C., and J. Franco. 1987. Efecto de tres densidades de inoculo, tres metodos de desarrollo radicular y tres criterios de evaluacion en la determinacion de resistencia de papa a *G. pallida*. Fitopatologia (Peru) 22:61. (Abstr.)

Quispe, C., and J. Franco. 1987. Three inoculum densities, three methods of root propagation and three criteria to evaluate potato resistance to *Globodera pallida*. Matropica Vol. 18. (in press, Abstr.)

Raman, K. V., R. H. Booth, and M. Palacios. 1987. Control of potato tuber moth *Phthorimaea operculella* (Zeller) in rustic potato stores. Trop. Sci. 27:175-194.

Raman, K. V. 1988. Control of potato tuber moth with sex pheromones in Peru. Agric. Ecosystems Environ. 21:85-99.

Raman, K. V. 1988. Insecticide toxicity to three strains of green peach aphid (*Myzus persicae* Sulzer) reared on resistant and susceptible potato cultivars. Crop Protection 7:62-65.

Rhoades, R. E. 1988. Thinking like a mountain. ILEIA 4(1):3-5.

Rhoades, R. E. 1988. When the honeymoon is over: managerial reality after technology generation and acceptance. *In* David Groenfeldt and Joyce Moock (eds.), Social Science Perspectives on Managing Agricultural Technology. pp. 169-178.

Romero, J., and K. V. Raman. 1988. Evaluation of ten *solanum* potato cultivars for major insect pests, natural enemies, and pest resistance in the highlands of Peru. Trop. Agric. 65(1):34-36.

Salazar, L. F. 1988. The plant viruses. *In* R. G. Milde (ed.), The Filamentous Plant Viruses. Vol. IV, South America. New York and London, Plenum Press, p. 343-347.

Salazar, L. F., I. Balbo, and R. A. Owens. 1988. Comparison of four radioactive probes for the diagnosis of potato

spindle tuber viroid by nucleic acid spot hybridization. Potato Research 31:431-442.

Salazar, L. F., R. W. Hammond, T. W. Diener, and R. A. Owens. 1988. Analysis of viroid replication following agrobacterium-mediated inoculation of non-host species with potato spindle tuber viroid cDNA. J. Gen. Virol. 69:879-889.

Santos, A. B. de los, O. K. Bautista, and M. J. Potts. 1986. Table potato storage in the Philippine highlands: a survey of current practices. Philippine Agriculturist, 69:365-384.

Scott, G. J. 1988. Improving peasant marketing practices: the case of potato producers in Peru. Culture and Agriculture 34:4-8.

Scott, G. J., and C. Gutierrez. 1987. La comercializacion de alimentos y los campesinos: el caso de la papa en la sierra central del Peru. Cuadernos de Agro-Industria y Economia Rural. Bogota: Pontificia Universidad Javeriana. 18:9-19.

Scurrah, M., and J. Franco. 1987. Contribution of *S. andigenum* and *S. vernei-S. tuberosum* in potato cyst nematode resistance for the Andean region. American Potato J. 64:456-457.

Scurrah, M., and J. Franco. 1987. Fourth cycle of selection for resistance to two pathotypes of *Globodera pallida*. *In* 10th Triennial Conference of the European Association for Potato Research, Aalbory, Denmark. p. 259. (Abstr.)

Scurrah, M., J. Franco, and M. Lazaro. 1987. Seleccion de clones resistentes a *Globodera pallida* en dos ambientes. Fitopatologia (Peru) 22:61-62.

Scurrah, M., J. Franco, and M. Lazaro. 1987. Selection of resistant clones to *Globodera pallida* in two environments. Nematropica Vol. 18 (in press, Abstr.)

Song, Bo Fu, Qu Dong Yu, and P. Vander Zaag. 1987. True potato seed in China: past, present and future. Am. Potato J. 64:321-327.

Stegemann, H., S. Majino, and P.E. Schmiedichc. 1988. Biochemical differentiation of clones of oca (*Oxalis tuberosa*, Oxalidaceae) by their tuber proteins and the properties of these proteins. Economic Botany 42(1):37-44.

Tivoli, B., H. Torres, and E. R. French. 1988. Inventaire, distribution et agressivité des espèces ou variétés de *Fusarium* rencontrées sur la pomme de terre ou dans son environnement dans differentes zones agroécologiques du Pérou. Potato Research 31:681-690.

Torres, H., and D. Gamarra. 1988. Identificacion y control de microorganismos contaminantes de semilla botanica de papa. Fitopatologia 23:26-31.

Vander Zaag, P., and A. L. Demagante. 1987. The potato (*Solanum* spp.) in an isohyperthermic environment. I. Agronomic Management. Field Crops Res. 17:199-217.

Vu Tuyen Hoang, Pham Xuan Liem, Vu Bich Dan, Ngo Doam Dam, Nguyen Xuan Linh, Nguyen van Viet, Pham Xuan Tung, and P. Vander Zaag. 1988. True potato seed research and development in Vietnam. American Potato J. 65:295-300.

Wiersema, S. G., and R. Cabello. 1987. A comparison of variability in storage behaviour of seed tubers from true potato seed and clonal tubers. Potato Research 30:485-489.

Wiersema, S. G., R. Cabello, P. Tovar, and J. H. Dodds. 1987. Rapid seed multiplication by planting into beds micro tubers and in vitro plants. Potato Research 30:117-120.

Xinagling, G., C. Tianqing, Z. Mingkai, S. Bo Fu, and W. Shaoyan. 1988. Potato Anther Culture. Bulletin of Agricultural Science and Technology 7:18-19.

Recent CIP Publications

Von Arx, P. T. Ewell et al. Management on the potato tuber moth by Tunisian farmers: a report of on-farm monitoring and a socioeconomic survey. 1988. 30 p.

Aguilar, J., and C. Vittorelli. Disinfest planting substrate using methyl bromide to produce basic potato seed tubers in greenhouses. 1988. 11 p.

Bebbington, A. Farmer strategies in regional agricultural change. The case of commercial potato production in Oxapampa. Working Paper 1988-1. 1988. 17 p.

CIP and ICAR. Potato Research in India. Report of the 1988 External Review 1989. 69 p.

CIP Informe Anual, 1986-87. 1988. 232 p.

CIP. Annual Report 1988. 1988. 210 p.

CIP. Bacterial diseases of the potato. Planning Conference Report 1987-1988. 233 p.

CIP. Catalogo de publicaciones y materiales visuales. 1988. 64 p.

CIP. Exploration, maintenance, and utilization of sweet potato genetic resources. Report of the First Sweet Potato Planning Conference 1987. 1988. 369 p.

CIP. Informe Anual 1988. 226 p.

CIP. International Potato Center 1988. 24 p. Illus.

CIP. Mejoramiento de la batata (*Ipomoea batatas*) en Latinoamerica. 1988. 277 p.

CIP. Publications Catalog. 1988. 59 p.

CIP. Publications of the Social Science Department and its Staff. 1988. 22 p.

CIP. Strategies for the conservation of potato genetic resources IV. Report of the Planning Conference, February 9-13, 1987.

CIP. The social sciences at CIP. Report of the Third Social Science Planning Conference, September 7-10, 1987. 1988. 72 p.

Cortbaoui, R. and R. Booth. Evaluation en champs d'agriculteurs des entrepots pour la conservation de la semence. 1988. 10 p.

Cortbaoui, R. Siembra de papa. 1988. 17 p. 20 ed. revisada.

Cortbaoui, R. Optimisation de la productivite de la pomme de terre evaluation et utilisation des resultats des essais en champs d'agriculteurs. 1988. 13 p.

Cortbaoui, R. Recherche en champs d'agriculteurs en vue de l'optimisation de la productivite de la pomme de terre 1988. 9 p.

Cortbaoui, R. Optimisation de la productivite de la pomme de terre planification et mise en oeuvre des essais en champs d'agriculteurs. 1988. 15 p.

Cortbaoui, R. Optimisation de la productivite de la pomme de terre evaluation et utilisation des resultats des essais en champs d'agriculteurs. 1988. 13 p.

Ezeta, F. N. Collaborative country research networks. 1988. 12 p.

Franco, J., and Rincon, H. (eds) Investigaciones nematologicas en programas latinoamericanos de papa. Reimpresion 1988. 2 volumenes, p. 189

Gregory J. Scott. La pomme de terre en Afrique Centrale; Une etude sur le Burundi, le Rwanda et le Zaire. 1988. 248 p.

Horton, D. Analyse de budget partiel pour les essais de pommes de terre en champ d'agriculteurs. 1988. 12 p.

Horton, D. Underground crops: long-term trends in production of roots and tubers 1988

Lizarraga, R., P. Tovar, U. Jayasinghe, and J. Dodds. Cultivo de tejidos para la eliminacion de patogenos 1988. 23 p. (Guia de Investigacion CIP 3)

Malagamba, P., and A. Monares. True Potato Seed: Past and present uses. 1988. 40 p.

Midmore, D. J. Fisiologia de la planta de papa bajo condiciones de clima calido. Guia de Investigacion CIP 24. 1988. 15 p.

Monares, A., et al. Economia de la industria de semillas en el Peru con enfasis en los cultivos de papa y hortalizas. 1988. 72 p.

Monares, A. La papa en Chile: tuberculos-semilla de categoria certificada 1988. 85 p.

Monares, A., and A. Achata. Costos de produccion de la semilla (Sexual) hibrida de papa. Metodo agroeconomico de estimacion basado en muestreos. Serie de Evaluacion de Tecnologia No. 8. 1988. 25 p.

Monares, A., and Achata, A. Produccion de semilla (Sexual) hibrida de papa en Chile: Factibilidad economica. 1988. 37 p.

Rhoades, R. and Bidegaray, P. Los agricultures de Yurimaguas; uso de la tierra y estrategias de cultivo en la selva peruana. 1988. 136 p.

Rhoades, R., M. Benavides, J. Recharte, E. Schmidt, and R. Booth. Traditional potato storage in Peru: Farmers' knowledge and practices. Food Systems Research Series No. 4. 1988. 67 p.

Rhoades, R. E. Comprendre les petits agriculteurs: perspectives socioculturales des essais en champ d'agriculteurs. 1988. 9 p.

Scott, G. Marketing Bangladesh's potatoes: present patterns and future prospects. 1988. 107 p.

Scott, G. Potatoes in Central Africa: A study of Burundi, Rwanda and Zaire. 1988. p. 159.

The American Phytopathological Society. Compendium of sweet potato diseases. 1988. 74 p.

Wissar, R., and R. Ortiz. Mejoramiento de papa en el CIP por adaptacion a climas calidos tropicales. Guia de Investigacion CIP 22. 1988. 51 p.

Articles Published in CIP Planning Conferences

Accatino, P. 1988. The role of the social sciences in meeting farmer and national program needs. *In* Proceedings of the Third Social Sciences Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 95-101.

Beaufort-Murphy, H. 1988. A review of strategies for overcoming sterility and incompatibilities of sweet potatoes. *In* Proceedings of the First Sweet Potato Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources, International Potato Center, Lima, Peru, February 23-27, 1987. pp. 175-184.

Crissman, C. 1988. Identifying strengths and weaknesses in seed programs. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September, 7-10, 1987. pp. 262-272.

De la Puente, F. 1988. Progress in explorations and collections of sweet potato genetic resources, the IBPGR/CIP Project. *In* Proceedings of the First Sweet Potato Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources, International Potato Center, Lima, Peru, February 23-27, 1987. pp.75-100.

Dodds, J. H. 1988. Review of in vitro propagation and maintenance of sweet potato germplasm. *In* Proceedings of the First Sweet Potato Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources, International Potato Center, Lima, Peru, February 23-27, 1987. pp. 185-192.

Dodds, J. H. 1988. Status of the in vitro potato collection at CIP and new approaches for long term conservation. *In* Proceedings of the XXIX Planning Conference on Strategies for the Conservation of Potato Genetic Resources IV, International Potato Center, Lima, Peru, February 9-13, 1987. pp. 75-87.

Dodds, J. H. and S. Y. C. Ng. 1988. In vitro methods for pathogen elimination and international distribution of sweet potato germplasm. *In* Proceedings of the First Sweet Potato Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources, International Potato Center, Lima, Peru, February 23-27, 1987. pp. 323-329.

Elphinstone, J. 1988. Methods of control of Erwinia diseases of the potato. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 187-192.

Elphinstone, J., L. de Lindo, and E. R. French. 1988. Control of Erwinia diseases in San Ramon. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 193-201.

French, E. R. 1988. Field evaluation of clones bred for resistance to *Pseudomonas solanacearum*. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 109-112.

French, E.R., and L. Sequeira. 1988. Additional sources of resistance to bacterial wilt. *In* Proceedings of the

Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 29-33.

French, E. R., and U. Nydegger. 1988. Mass screening procedures for resistance to *Pseudomonas solanacearum*. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 15-17.

Gregory, P. 1988. Sweet potato research at CIP. *In* Proceedings of the First Sweet Potato Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources, International Potato Center, Lima, Peru. February 23-27, 1987. pp. 11-16.

Hidalgo, O. 1988. Soft rot and blackleg (*Erwinia* spp.) in warm climates. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center Lima, Peru, March 16-20, 1987. pp. 179-186.

Horton, D. E. 1988. Assessing impact: the general framework. *In* Proceedings of the Third Social Sciences Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 231-246.

Horton, D. E. 1988. The Social Sciences at CIP. *In* Proceedings of the Third Social Sciences Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10 , 1987. pp. 31-79.

Horton, D. E. 1988. World patterns and trends in sweet potato production and use. *In* Proceedings of the First Sweet Potato Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources, International Potato Center, Lima, Peru, February 23-27, 1987. pp. 17-25.

Horton, D. E., W. Collings, M. Iwanaga, H. Mendoza, and M. Collins. 1988. Constraints to production and utilization of potatoes and sweet potatoes. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 129-133.

Horton, D. E., N. Puican, and R. Rhoades. 1988. Root crop database. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 111-117.

Huaman, Z. 1988. CIP's role in the development of an Inter-Gene Bank Cooperation for potato genetic resources conservation. *In* Proceedings of the XXIX Planning Conference on Strategies for the Conservation of Potato Genetic Resources IV, International Potato Center, Lima, Peru, February 9-13, 1987. pp. 97-100.

Huaman, Z. 1988. Current status on the maintenance of sweet potato genetic resources at CIP. *In* Proceedings of the First Sweet Potato Planning Conference on Exploration, Maintenance, and Utilization of Sweet Potato Genetic Resources, International Potato Center, Lima, Peru, February 23-27, 1987. pp. 101-120.

Huaman, Z. 1988. Descriptors for the characterization and evaluation of sweet potato genetic resources. *In* Proceedings of the First Sweet Potato Planning Conference on Exploration, Maintenance and Utilization of

Sweet Potato Genetic Resources, International Potato Center, Lima, Peru, February 23-27, 1987. pp. 331-355.

Huaman, Z. 1988. Status of the native Andean cultivated potato collection maintained at CIP. *In* Proceedings of the XXIX Planning Conference on Strategies for the Conservation of Potato Genetic Resources IV, International Potato Center, Lima, Peru, February 9-13, 1987. pp. 27-44.

Huaman, Z., L. de Lindo, and J. Elphinstone. 1988. Resistance to blackleg and soft rot and its potential use in breeding. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 215-228.

Iwanaga, M. 1988. Use of wild germplasm for sweet potato breeding. *In* Proceedings of the First Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources, International Potato Center, Lima, Peru, February 23-27, 1987. pp. 199-210.

Jatala, P., C. Martin, and H. A. Mendoza. 1988. Role of nematodes in disease expression by *Pseudomonas solanacearum* and strategies for screening and breeding for combined resistance. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 35-37.

Jatala, P., and K. V. Raman. 1988. Major insect and nematode pests of sweet potatoes and recommendations for transfer of pest free germplasm. *In* Proceedings of the First Sweet Potato Planning Conference on Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources, International Potato Center, Lima, Peru, February 23-27, 1987. pp. 319-321.

Mendoza, H. A. 1988. Progress in resistance breeding in potatoes as a function of efficiency of screening procedures. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 39-64.

Monares, A. 1988. Analytical framework for design and assessment of potato seed programs in developing countries. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 247-261.

Monares, A., and P. Malagamba. 1988. Design of a client-oriented technology: the case of true potato seed. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 173-181.

Ochoa, C. and P. Schmiediche. 1988. Status of the collection at CIP: wild species. *In* Proceedings of the XXIX Planning Conference on Strategies for the Conservation of Potato Genetic Resources IV, International Potato Center, Lima, Peru, February 9-13, 1987. pp. 19-26.

Otazu, V., J. Elphinstone, and H. Torres. 1988. Erwinias and other pathogens and pests: possible interactions in the warm climate of San Ramon. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 203-214.

Piña, M. 1988. Assessing results of training and communication. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 273-286.

Prain, G., and U. Scheidegger. 1988. User friendly seed program. *In* Proceedings of the Third Social Science Planning Conference on the Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 182-203.

Rhoades, R. 1988. CIP's philosophy on farmer participatory research. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 159-172.

Rhoades, R. 1988, Food systems research. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 89-94.

Rhoades, R. 1988. The reference file method: an eclectic approach for improving agro-ecological and crop data of developing countries. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 118-128.

Scott, G. 1988. Potato marketing and demand in developing countries. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 134-153.

Scott, G. 1988. Training through marketing research: the CIP experience. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 317-333.

Schmiediche, P. 1988. Breeding for Resistance to *Pseudomonas solanacearum*. Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, 16-20 March, 1987, Lima, Peru. pp. 19-27.

Schmiediche, P. 1988. The utilization of wild potato species in breeding. *In* Proceedings of the XXIX Planning Conference on Strategies for the Conservation of Potato Genetic Resources IV, International Potato Center, Lima, Peru, February 9-13, 1987. pp. 135-149.

Schmiediche, P., J. Jaynes, and J. H. Dodds. 1988. Genetic engineering for bacterial disease resistance in potatoes. *In* Proceedings of the Planning Conference on Bacterial Diseases of the Potato, International Potato Center, Lima, Peru, March 16-20, 1987. pp. 123-132.

Zachmann, R. and G. Robertson. 1988. Social Science training: past experience and needs expressed by national programs. *In* Proceedings of the Third Social Science Planning Conference on The Social Sciences at CIP, International Potato Center, Lima, Peru, September 7-10, 1987. pp. 334-343.

Research and Consultancy Contracts in 1988

Research and consultancy contracts and special projects facilitate research on priority problems and provide funds for potato and sweet potato work in both developing and developed countries. The contracts greatly increase CIP's flexibility to meet changing needs and have proved to be both effective and low cost. In budgetary terms, collaboration with other institutions through contract research is advantageous because facilities and personnel needed for a specific research activity are already in place. Thus, CIP conserves resources, and such savings are especially important as CIP moves further into biotechnological research with its high-cost implications. The returns on investments have been worldwide, both in terms of research data and in building valuable relations with the contractees who frequently play an important role in CIP's research-planning conferences and other planning and assessment activities.

Thrust I

Collection, Maintenance, and Utilization of Unexploited Genetic Resources

1. Guangdong Academy of Agricultural Sciences (GAAS), **China** – Development of sweet potato germplasm for the tropics. *Feng Zu-Xia*
2. Zhuzhou Institue of Sweet Potato (XISP), **China** – Evaluation of sweet potato germplasm. *Sheng Jia Lian*
3. Instituto Nacional di Investigaciones Agropecuarias (INIAP), **Ecuador** – Maintenance of the potato germplasm in vitro collection. *F. Muñoz*
4. Rothamsted Experimental Station, **England** – Stability/variability of potato in culture and storage. *M. G. K. Jones*
5. Ente Nazionale delle Energie Alternative (ENEA), **Italy** – Development of potato varieties resistant to insect pests by means of conventional innovative breeding technologies. *A. Sonnino and, L. Bacchetta*
6. Universita degli Studi della Tuscia Viterbo, **Italy** – Use of genetic engineering methods to confer fungal disease resistance to potatoes. *C. Di Pace*

Thrust II

Production and Distribution of Advanced Breeding Material

7. Instituto Nacional de Tecnologia Agropecuaria (INTA), Balcarce, **Argentina** – Programa de utilizacion de mayor variabilidad genetica en el plan de mejoramiento de papa. *A. Mendiburu*
8. Centro Nacional de Pesquisas de Hortalicas (CNPH/EMBRAPA), **Brazil** – Evaluacion de germoplasma de papa (*Solanum tuberosum* L.) con relacion a resistencia a *Alternaria solani*. *F. J. B. Reifschneider*
9. Centro Nacional de Pesquisas de Hortaliças (CNPH/EMBRAPA), **Brazil** – Selection of TPS progenies adapted to the northeast and center west of Brazil. *Jose A. Buso*
10. Agriculture Canada, **Canada** – Nutritional and chipping evaluation of selected parental clones in Peru, the Philippines and Canada. *T. R. Tam*
11. Consorzio "Mario Neri" (ERSO), Imola, **Italy** – Selection of potato clones with high starch content. *L. Concilio*
12. Instituto Nacional de Investigacion Agraria (INIAA), **Peru** – Evaluación de clones avanzados del CIP para el Programa Nacional de Papa del Peru. *D. Untiveros*

13. University of Tacna, **Peru** – Evaluation of sweet potato germplasm for tolerance to certain abiotic stresses under arid conditions. *N. Arevalo*
14. Aegean Regional Agricultural Research Institute (ARARI), **Turkey** – Potato germplasm evaluation and multiplication. *N. Kuzman*
15. Cornell University, Ithaca, New York, **U.S.A.** – The utilization of *Solanum tuberosum* spp. *andigena* germplasm in potato improvement and adaptation. *R. L. Plaisted, H. D. Thurston, W. M. Tingey, B. B. Brodie, E. E. Ewing, and D. Ave*
16. North Carolina State University, **U.S.A.** – Breeding and adaptation of cultivated diploid potato species. *W. W. Collins*
17. North Carolina State University, **U.S.A.** – Breeding early-yielding, and disease-resistant sweet potatoes with enhanced food quality and nutritional value. *W. W. Collins*
18. University of Wisconsin, Madison, **U.S.A.** – Potato breeding methods with species, haploids and 2n gametes. *S. J. Peloquin*

Thrust III

Control of Bacterial and Fungal Diseases

19. University of Queensland, Brisbane, **Australia** – Taxonomy of *Pseudomonas solanacearum*. *A. C. Hayward*
20. Centro Nacional de Pesquisas de Hortaliças (CNPH/EMBRAPA), **Brazil.** – Potato germplasm evaluation for resistance to bacterial wilt. *Carlos A. Lopez*
21. Instituto Colombiano Agropecuario, (ICA), Rio Negro, **Colombia** – Evaluacion de la resistencia de material genetico de papa a *Pseudomonas solanacearum* y *Phytophthora infestans*. *P. L. Gomez*
22. Instituto Nacional de Investigaciones Agropecuarias (INIAP), **Ecuador** – Estudio y control de las enfermedades lanosa y roya de la papa en Ecuador. *H. Orellana*
23. L.E.H.R.I. Experimental Station of AARD, **Indonesia** – Breeding for resistance to bacterial wilt of potato in Indonesia. *Sudjako Sahat*
24. Gilat Regional Experimental Station, **Israel** – Verticillium wilt and early-blight tolerance of potato in hot climates. *A. Nachmias*
25. National Agricultural Laboratories, Nairobi, **Kenya** – The reaction of selected potato clones to two races of *Pseudomonas solanacearum* in Kenya. *A. O. Michieka*
26. Universidad Nacional Agraria-La Molina, **Peru** – Consultancy on early blight of potatoes: specialization of *Alternaria* spp. *T. Ames de Icochea*
27. Universidad Nacional de Huanuco, **Peru** – Desarrollo de variedades de papa con resistencia a enfermedades y adaptacion a zonas ecologicas del Departamento de Huanuco. *E. Torres Vera*
28. Cornell University, Ithaca, New York, **U.S.A.** – Population genetics of *Phytophthora infestans* in its natural ecosystem at Toluca. *W. E. Fry*
29. University of Wisconsin, **U.S.A.** – Fundamental research to develop control measures for bacterial pathogens of the potato. *A. Kelman and L. Sequeira*
30. Centro de Investigaciones Agricolas "A. Boerger" (CIAAB), **Uruguay** – Seleccion de clones con resistencia a *A. solani* y precocidad en materiales con antecedentes de resistencia a virus. *F. Vilaro and C. Crisci*

Thrust IV

Control of Virus and Virus-Like Diseases

31. Istituto Agronomico per l'Oltremare (I.A.O.), **Italy.** – Production of antisera against major potato viruses. *M. Broggio and M. Galanti*
32. Universidad Nacional Agraria-La Molina, **Peru** – Consultative contract on maintenance of monoclonal antibodies for potato viruses. *J. Castillo*

33. Universidad Nacional Agraria-La Molina), **Peru** – Maintenance of monoclonal antibodies for potato viruses. *J. Castillo.*
34. Instytut Ziemniaka, (Institute for Potato Research), **Poland** – Breeding potatoes resistant to the potato leafroll virus, PLRV. *K. M. Swiezynski*
35. Scottish Crop Research Institute, **Scotland.** – Resistance to potato leafroll virus. *B. D. Harrison*
36. Louisiana State University, **U.S.A.** – Attempts to elucidate the etiology of sweet potato chlorotic leaf distortion. *C. A. Clark.*
37. North Carolina State University, **U.S.A.** – Development of virus testing procedures for sweet potatoes. *J. Moyer*
38. North Carolina State University, **U.S.A.** – The accumulation of sweet potato feathery mottle virus, dsRNA, and selected viral proteins in sweet potatoes. *J. Moyer*
39. Centro de Investigaciones Agricolas "A. Boerger" (CIAAB) **Uruguay** – Evaluation of genetic material for resistance to PVX and PLRV under field conditions. *C. Crisci and F. Vilaro*

Thrust V

Integrated Pest Management

40. Instituto Nacional de Investigaciones Agropecuarias (INIAP), **Ecuador** – Evaluacion de clones resistentes al nematodo del quiste (*Globodera* spp.) en el Ecuador. *R. Eguiguren and J. Revelo*
41. Universidad Nacional Agraria-La Molina, **Peru** – Consultancy on biological and selective chemical control of potato and sweet potato insect pests. *J. Sarmiento and Colleagues*
42. Universidad Nacional Agraria-La Molina, **Peru** – Consultancy on *Pratylenchus* spp. as important nematode pests of potatoes. *M. Canto*
43. The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), **The Philippines** – Management of thrips and mites attacking potato in the lowland. *E. N. Bernardo*
44. University of the Philippines, Los Baños (UPLB), **The Philippines** – Integrated control of nematodes and weeds by the use of biological control agents and solarization. *R. Davide*
45. Institute of Virology, **U. K.** – Studies on the potato tuber moth. *P. Entwistle.*
46. North Carolina State University, **U.S.A.** – Evaluation of potato lines for resistance to the major species and races of root-knot nematodes (*Meloidogyne* spp.). *J. N. Sasser*

Thrust VI

Warm Climate Potato and Sweet Potato Production

47. Maritius Sugar Industry Research Institute (MSIRI), Rednit, **Mauritius** – Development of potato varieties for lowland tropical conditions. *K. Wong Yen Cheong*
48. Universidad Nacional Agraria-La Molina, **Peru** – Manejo de suelos, fertilizantes y nutricion mineral de la papa bajo condiciones adversas de suelo y clima. *S. Villagarcia*
49. Scottish Crop Research Institute, **Scotland** – Drought tolerance in potatoes. *P. Waister*

Thrust VIII

Postharvest Technology

50. The Philippine Root Crop Research and Training Center (PRCRTC), **The Philippines** – Development of simple processing technologies for sweet potato/potato-based products for low-income groups as target consumers. *T. van Den*
51. Society for Development of Appropriate Technology (SOTEC). **India** – Development of village-level potato processing and utilization of potato in local foods. *R. W. Nave*

Thrust IX

Seed Technology

52. Victoria Department of Agriculture, **Australia** – Production of pathogen-tested potato germplasm for Southeast Asian and Pacific Countries. *P. T. Jenkins*
53. Instituto de Investigaciones Agropecuarias (INIA), Osorno, **Chile** – Produccion de semilla botanica de papa en Chile. *J. Santos Rojas and A. Cubillos*
54. Istituto Agronomico per l'Oltremare (IAO), **Italy** – The use of novel antibacterial genes to confer bacterial disease resistance to potato plants. *D. E. Foard*
55. Istituto di Agronomia, Universita di Napoli, **Italy** – Selection of TPS parental lines in high seed production. *L. Monti and L. Politano*
56. Universidad Nacional Agraria-La Molina, **Peru** – Training and consultancy research in effects of soil management and fertilization on flowering, fruit setting and seed quality of the potato. *S. Villagarcia*
57. Louisiana State University (LSU), **U.S.A.** – The use of agrobacterium plasmid vectors to insert anti-bacterial, anti-insect and frost resistance genes into potato plants. *J. M. Jaynes*

Thrust X

Potato and Sweet Potato in Food Systems

58. Instituto Nacional de Tecnologia Agropecuaria (INTA), **Argentina** – Consultancy on sweet potato production and utilization. A. Boy
59. **England** – Sweet potato: an untapped food resource. *J. A. Woolfe*
60. H. P. University, **India** – Demand study for processed potatoes. *B. K. Sikka*
61. **Peru** – Demand for sweet potato. *M. Collins*
62. **Peru** – Study of farmer selection of potato varieties in Kenya. *L. Crissman*
63. International Food Policy Research Institute (IFPRI), **U.S.A.** – White potato/sweet potato development in China. *B. Stone*
64. University of Arizona, **U.S.A.** – Houseshold gardens. *V. Ninez*
65. Centro de Investigaciones Agricolas, "A. Boerger" (CIAAB), **Uruguay** – Consultancy on breeding and propagation of sweet potato. *F. Vilaro*

Support Department

66. Consultancy Contract. La Molina, **Peru** – Management of light and temperature in CIP greenhouses. *U. Moreno*
67. Consultancy Contract. Lima, **Peru** – Management of sweet potato germplasm. *R. del Carpio*

Regional Research and Training

68. International Agricultural Centre, Wageningen, **The Netherlands** – Consultancy for regional research and training. *H. P. Beukema*

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RESEARCH THRUSTS
(Leaders and Co-Leaders)

I. Collection, Maintenance, and Utilization of Unexploited Genetic Resources
(P. Schmiediche—Z. Huaman)

II. Production and Distribution of Advanced Breeding Material
(H. Mendoza—M. Iwanaga)

III. Control of Bacterial and Fungal Diseases
(E. French)

IV. Control of Virus and Virus-Like Diseases
(L. Salazar—U. Jayasinghe)

V. Integrated Pest Management
(F. Cisneros—P. Jatala)

VI. Warm Climate Potato and Sweet Potato Production
(D. Midmore—H. Mendoza)

VII. Cool Climate Potato and Sweet Potato Production
(J. Landeo—D. Midmore)

VIII. Postharvest Technology
(S. Wiersema—R. Rhoades)

IX. Seed Technology
(P. Malagamba—A. Golmirzaie)

X. Potato and Sweet Potato in Food Systems
(D. Horton—R. Rhoades)

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Juan Landeo, Ph.D., Breeder
Il Gin Mok, Ph.D., Sweet Potato Breeder (Nigeria)
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Genetic Resources

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* Left during the year.

† These positions are separately funded as Special Projects by the following donor agencies:
Australian Development Assistance Agency
Belgium, General Administration for Cooperation and Development (AGCD)
Canada, International Development Research Centre (IDRC)
Food and Agriculture Organization of the United Nations (FAO)
Italy, Ministry of Foreign Affairs
Japan, International Board for Plant Genetic Resource
Netherlands, Ministry of Foreign Affairs
Rockefeller Foundation
Swiss Development Cooperation and Humanitarian Agency
United Kingdom, Overseas Development Administration (ODA)
United States, Agency for International Development (USAID)
United States, Pepsico Food International
United States, McDonald's Corporation
World Bank/INIPA

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Moreno Patiño

REPORT OF INDEPENDENT ACCOUNTANTS

March 3, 1989

To the Members of the Board of Trustees
International Potato Center - CIP

We have examined the balance sheets of International Potato Center - CIP (a non-profit organization) as of December 31, 1988 and 1987, and the related statements of revenue, expenditures and changes in unexpended fund balances and changes in financial position for the years then ended. Our examinations were made in accordance with generally accepted auditing standards and, accordingly, included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

As described in Note 2-c), and in accordance with guidelines established by the Consultative Group for International Agricultural Research for the preparation of financial statements by International Agricultural Research Centers, firm orders for purchases of fixed assets and services are recorded in the year of their commitment rather than at the time when the actual liability arises.

In our opinion, except for effect of the matter described in the preceding paragraph, the financial statements examined by us present fairly the financial position of International Potato Center - CIP as of December 31, 1988 and 1987 and its revenues, expenditures and changes in its unexpended fund balances and changes in its financial position for the years then ended, in conformity with generally accepted accounting principles consistently applied.

Moreno Patiño

Countersigned by

----------(partner)
Francisco J. Moreno
Peruvian Public Accountant
Registration No. 155

INTERNATIONAL POTATO CENTER — CIP

BALANCE SHEET (Notes* 1 and 2)
as of December 31, 1988 and 1987
(Expressed in U.S. dollars)

	1988	1987
ASSETS		
CURRENT ASSETS		
Cash and short-term deposits	3,352,991	2,716,847
Accounts receivable		
Donors	1,558,152	3,099,626
Advances to personnel	59,544	18,075
Loans to executives and employees – current portion (Note 3)	118,304	115,366
Other (Note 4)	496,096	352,219
Inventories of laboratory and other supplies	720,349	624,473
Prepaid expenses and other current assets	97,222	113,502
Total current assets	6,402,658	7,040,108
RESTRICTED FUNDS (Note 3)	203,578	275,000
LOANS TO EXECUTIVES AND EMPLOYEES – NON-CURRENT PORTION (Note 3)	74,212	176,545
FIXED ASSETS (Note 5)	15,235,347	11,355,942
	21,915,795	18,847,595

* *The accompanying notes are an integral part of the financial statements.*

	1988	1987
LIABILITIES AND FUND BALANCES		
CURRENT LIABILITIES		
Bank overdrafts and current portion of long-term debt (Notes 3 and 6)	140,200	283,353
Accounts payable and other liabilities	1,424,455	1,040,334
Grants received in advance	–	2,182,245
Other payables and accrued expenses	383,494	229,026
Total current liabilities	1,948,149	3,734,958
LONG-TERM DEBT (Note 3)	55,237	167,509
PROVISION FOR SEVERANCE INDEMNITIES, net of advances of 23,012 (61,273 in 1987)	212,919	425,029
FUND BALANCES		
Funds invested in fixed assets (Note 5)	15,235,347	11,355,942
Unexpended funds –		
Operating funds – Unrestricted	3,591	6,195
– Restricted	564,680	88,888
Capital fund	–	188,000
Working funds	1,575,000	1,317,000
Special projects	2,219,116	1,510,969
Cooperative activities	101,756	53,105
	4,464,143	3,164,157
GRANTS PLEDGED (Note 7)		
	21,915,795	18,847,595

The accompanying notes are an integral part of the financial statements.

INTERNATIONAL POTATO CENTER — CIP

STATEMENT OF REVENUE, EXPENDITURES AND CHANGES IN UNEXPENDED FUND BALANCES (Notes 1 and 2)

for the years ended December 31, 1988 and 1987

(Expressed in U.S. dollars)

	1988	1987
REVENUE		
Operating grants:		
Unrestricted	12,418,294	9,211,096
Restricted	3,081,939	2,194,525
Other restricted core grants	851,549	723,860
	16,351,782	12,129,481
Special project grants	2,215,755	1,840,181
Grants for fixed asset additions	1,188,000	806,547
Grants for cooperative activities	140,562	444,755
Working fund grants	258,000	17,000
Other income, net	560,927	665,991
	20,715,026	15,903,955
EXPENDITURES		
Operating costs:		
Potato and sweet potato research program	3,983,190	3,795,862
Research services	1,614,033	1,602,004
Regional research program and training	3,477,441	2,958,629
Conferences and seminars	152,401	103,593
Library and information services	646,616	642,913
Administration costs	1,281,626	1,434,283
Other operating costs, including replacement of an aircraft for 3,019,180 in 1988	4,641,182	1,563,061
	15,796,489	12,100,345
Other restricted core expenditures	604,589	807,615
Special projects	1,503,137	1,963,173
Cooperative activities	91,911	403,378
Grants returned	4,471	3,432
	18,000,597	15,277,943
Additions to fixed assets	1,414,443	618,547
	19,415,040	15,896,490
Excess of revenue over expenditures	1,299,986	7,465
Unexpended fund balance, beginning of year	3,164,157	3,156,692
UNEXPENDED FUND BALANCE, END OF YEAR	4,464,143	3,164,157

The accompanying notes are an integral part of the financial statements

INTERNATIONAL POTATO CENTER — CIP

STATEMENT OF CHANGES IN FINANCIAL POSITION

for the years ended December 31, 1988 and 1987

(Expressed in U.S. dollars)

	1988	1987
SOURCE OF FUNDS		
Excess of revenue over expenditures	1,299,986	7,465
Decrease in accounts receivable	1,353,190	–
Decrease in prepaid expenses and other assets	16,280	–
Decrease in restricted funds	71,422	25,000
Decrease in loans to executives and employees – non-current portion	102,333	180,489
Increase in funds invested in fixed assets	3,879,405	868,682
Increase in accounts payable and other liabilities	395,436	–
Increase in grants received in advance	–	2,182,245
Provision for severance indemnities	216,236	42,651
	7,334,288	3,306,532
APPLICATION OF FUNDS		
Purchase and replacement of fixed assets		
– Core acquisitions	1,414,443	618,547
– Special projects	70,501	207,098
– Net cost of replacement	2,394,461	43,037
Increase in accounts receivable	–	1,607,313
Increase in inventories	95,876	106,978
Increase in prepaid expenses and other current assets	–	32,427
Decrease in accounts payable and other liabilities	–	998,984
Decrease in grants received in advance	2,182,245	–
Decrease in long-term debt	112,272	116,251
Payment and advances of severance indemnities	428,346	75,033
	6,698,144	3,805,668
Increase (decrease) in cash and short-term deposits	636,144	(499,136)
Cash and short-term deposits, beginning of year	2,716,847	3,215,983
CASH AND SHORT-TERM DEPOSITS, END OF YEAR	3,352,991	2,716,847

The accompanying notes are an integral part of the financial statements

INTERNATIONAL POTATO CENTER — CIP

NOTES TO FINANCIAL STATEMENTS
as of December 31, 1988 and 1987
(Expressed in U.S. dollars)

1. Operations

The International Potato Center (CIP) is a non-profit organization located in Lima, Peru, with programs throughout Latin America, Central America and the Caribbean, the Near and Middle East, Asia and Africa. CIP's principal objective is to contribute to the development of the potato, sweet potato and other tuberous roots through scientific research programs, preparation and training of scientists, dissemination of research results in publications, conferences, forums and seminars, and other activities, in accordance with its objectives.

CIP was established in 1972, in accordance with an Agreement for Scientific Cooperation with the Government of Peru signed in 1971 and expiring in 2000. The Center is a member of the group of International Agricultural Research Centers which is supported by the Consultative Group for International Agricultural Research (CGIAR).

In accordance with existing legislation and provisions of the Agreement described above, CIP is exempt from income tax and other taxes. If for any reason the Center's operations are terminated, all of its assets are to be transferred to the Peruvian Ministry of Agriculture.

2. Summary of significant accounting policies

The principal accounting policies are as follows:

a. Foreign currency —
The books and accounts are maintained in U.S. dollars. Transactions are mainly in U.S. dollars. Assets and liabilities denominated in currencies other than the U.S. dollar are expressed at year-end exchange rates. Exchange gains and losses are included in the statement of revenue, expenditures and changes in unexpended fund balances.

b. Revenue —
Grant transactions are recorded as revenue on the basis of donor commitments.

Core unrestricted grants, capital and working fund grants are pledged on an annual basis and as such are recognized a revenue in the year in which the grant is pledged as long as they are deemed to be probable of collection.

Restricted operating and special project grants are accounted for in the period stipulated by the donor. Other income net is recorded when earned and is comprised primarily of interest on investments, proceeds from sales of fixed assets and supplies, translation gains and losses, and of administrative costs of special projects.

c. Expenditures —
Firm orders for purchases of fixed assets and services are recorded in the year of their commitment. At December 31, 1988 the amount recorded under this practice totalled 892,740 (364,100 in 1987).

Expenditures made by international programs are recorded on the basis of advices received. Expenses related to special projects are applied when incurred against the respective income.

d. Investments —
Short-term investments are principally comprised of certificates of deposit bearing interest at current bank rates and are valued at cost.

e. Inventories of laboratory and other supplies —
Inventories of laboratory, supplies and other materials are valued at estimated market value, which approximates cost.

f. Fixed assets —
Fixed assets are stated at cost. Additions to fixed assets are recorded as grant expenditures and cost of replacements are reported as operating expenses in the statement of revenue, expenditures and changes in fund balances and added to the related equity account. Upon the sale or retirement of fixed assets, their cost is removed from the fixed asset and related equity accounts. Fixed assets are not depreciated.

Maintenance and repairs are recorded as operating costs in the year incurred.

g. Vacations —
Employee vacation expenses are charged to operating expenses when they are taken.

h. Provision for severance indemnities —
Peruvian employees' severance indemnities are accounted for on an accrual basis and are calculated in accordance with current legal dispositions. The amount accrued represents the amount that would have to be paid to the employees if they were to terminate as of the date of the financial statements.

3. Loans to executives and employees and long-term debt

CIP provides loans to certain of its executives for the acquisition of homes and/or vehicles. These loans are funded by a term loan from Citibank N.A. - New York and in certain instances with CIP's own funds. At December 31, 1988, outstanding loans obtained from Citibank N.A. amount to 157,409 (265,753 in 1987), and bear interest at the New York prime rate plus 1.5% and are repayable in monthly installments until June 1990.

Loan balances with executives and employees at December 31, are as follows:

	1988	1987
Loans funded by line of credit of Citibank N.A., secured by related homes and/or vehicles, repayable under the same conditions as advances under the term loan at no direct cost to CIP	157,409	265,753
Loans funded by CIP, repayable over a one-to three-year period, bearing interest (as from 1988) of 11.5% per annum and secured by employees' homes	35,107	26,158
	192,516	291,911
Less current portion	(118,304)	(115,366)
	74,212	176,545

In addition, at December 31, amounts outstanding under the term loan from Citibank N.A. are as follows:

	1988	1987
Current portion (Note 6)	102,172	98,244
Non-current portion (maturing 1989-1990)	55,237	167,509
	157,409	265,753

These amounts are guaranteed by a position of a deposit of 203,578 (275,000 in 1987) in the aforementioned financial institution, which earns interest at 8% per annum (6.3% in 1987).

4. **Accounts receivable — Other**

This balance is comprised of the following at December 31:

	1988	1987
Advances to organizations for research work	264,150	248,679
Travel advances	72,399	46,809
Advances to contractors and other	113,267	8,014
Other	46,280	48,717
	496,096	352,219

5. **Fixed assets**

Fixed assets at December 31, comprise the following:

	1988	1987
Buildings and constructions	3,709,009	3,001,705
Research equipment	1,779,833	1,567,297
Vehicles and aircraft	4,828,323	2,313,207
Furniture, fixtures and office equipment	1,330,152	1,220,813
Operating farm equipment	546,887	456,782
Installations	1,654,791	1,373,237
Site development	783,671	776,706
Communications equipment and other	581,217	561,250
Construction in progress	21,461	84,945
	15,235,347	11,355,942

Vehicles and other fixed assets replaced or retired are transferred from the fixed asset and related equity accounts to a memorandum account. Fixed assets sold or donated are eliminated from the memorandum account. The balance of the memorandum account at December 31, 1988 is 817,010 (699,891 in 1987).

6. **Bank overdrafts and current portion of long-term debt**

At December 31, this balance is comprised of the following:

	1988	1987
Bank overdrafts	38,028	185,109
Current portion of long-term debt (Note 3)	102,172	98,244
	140,200	283,353

CIP has various credit lines and loan arrangements with Citibank N.A. totalling 525,000 (680,000 in 1987), which bear interest at the New York prime rate plus 1.5%. As of December 31, 1988, unused amounts under these credit facilities totalled 300,000 (400,000 in 1987).

7. Grants pledged

During 1988 the following donations were pledged to CIP for special projects in 1989 through 1992:

	1989	1990	1991	1992
International Development Research Centre – Canada	146,600	–	–	–
Swiss Development Cooperation and Humanitarian Aid	731,258	660,692	653,746	528,730
United States Agency for International Development	345,975	404,875	22,500	–
Netherlands Government	71,955	108,556	–	–
Pepsico Food International/ McDonald's Corporation	50,000	–	–	–
Belgian Government	435,120	–	–	–
German Agency for Technical Cooperation – BBA	17,900	28,200	–	–
Food Industry Crusade Against Hunger	90,000	–	–	–
	1,888,808	1,202,323	676,246	528,730

The above amounts are not reflected in the accompanying financial statements.

The CGIAR: A Global Agricultural Research System

The Consultative Group on International Agricultural Research (CGIAR) was established in 1971 to bring together countries, public and private institutions, international and regional organizations, and representatives from developing countries in support of a network of international agricultural research centers. The basic objective of this effort is to increase the quantity and improve the quality of food production in developing countries. The research supported by the CGIAR concentrates on the critical aspects of food production in developing countries, of global importance, that are not covered adequately by other institutions. Currently, the CGIAR network is involved in research on all of the major food crops and farming systems in the major ecological zones of the developing world.

The CGIAR consists of over 40 donor organizations. They meet twice a year to consider program and budget proposals as well as policy issues of the 13 international agricultural research institutes supported by the group. The World Bank provides the CGIAR with its chairman and secretariat, while the Food and Agriculture Organization (FAO) of the United Nations provides a separate secretariat for the group's Technical Advisory Committee (TAC). The TAC regularly reviews the scientific and technical aspects of all center programs and advises the CGIAR on needs, priorities, and opportunities for research.

Of the thirteen centers, ten have commodity-oriented programs covering a range of crops and livestock, and farming systems that provide three-fourths of the developing world's total food supply. The remaining three centers are concerned with problems of food policy, national agricultural research, and plant genetic resources.

CIAT
International Center for Tropical Agriculture
Cali, Colombia

CIMMYT
International Maize and Wheat Improvement Center
Mexico City, Mexico

CIP
International Potato Center
Lima, Peru

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

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

IITA
International Institute of Tropical Agriculture
Ibadan, Nigeria

ILCA
International Livestock Center for Africa
Addis Ababa, Ethiopia

ILRAD
International Laboratory for Research on Animal Diseases
Nairobi, Kenya

IRRI
International Rice Research Institute
Manila, Philippines

WARDA
West Africa Rice Development Association
Bouake, Ivory Coast

IBPGR
International Board for Plant Genetic Resources
Rome, Italy

IFPRI
International Food Policy Research Institute
Washington, D.C., U.S.A.

ISNAR
International Service for National Agricultural Research
The Hague, Netherlands