CIP 1990

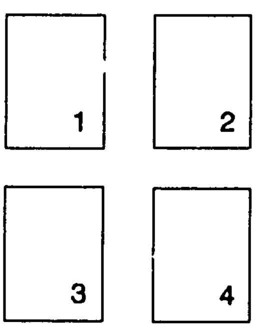
ANNUAL REPORT

Cover Illustrations

The original watercolor paintings on the cover were commissioned for Carlos Ochoa's book: *The Potatoes of South America: Bolivia*, and were painted by artist Franz Frey. This authoritative and scholarly publication represents the culmination of a lifetime of study by Ochoa and is Volume 1 of a series to be published by Cambridge University Press and CIP. Both Ochoa and Frey have extensive professional experience with CIP, where they collaborated on the paintings.

Dr. Donald Ugent, ethnobotanist, Southern Illinois University, and Linda Peterson, former CIP editor, translated and edited the book, and were also contracted by CIP to produce a portfolio of 25 of Frey's paintings: *The Potatoes of South America: Bolivia. A Portfolio of Fine Botanical Prints.* The larger-format portfolio prints are reproduced from the plates in the Ochoa book.

The Potatoes of South America: Bolivia is available from Cambridge University Press, The Edinburgh Building, Shaftesbury Road, CB2 2RU, England. The portfolio is available from CIP.



FRONT

1. *Solanum acaule* Bitter.
2. *Solanum bombycinum* Ochoa.

BACK

3. *Solanum infundibuliforme* Philippi.
4. *Solanum vidaurrei* Cárdenas.

International Potato Center

Annual Report 1990

Worldwide Potato and Sweet Potato Improvement

International Potato Center
Apartado 5969, Lima, Peru

1990

The **International Potato Center (CIP)** is a nonprofit, autonomous scientific institution established in 1971 by agreement with the Government of Peru. The Center develops and disseminates knowledge to facilitate use of the potato 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 1989, through the CGIAR, CIP received funding from the following donors: the governments of Australia, Austria, Belgium, Finland, France, Germany, India, Italy, Japan, 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 Farmer Community Development Foundation; the German Agency for Technical Cooperation (GTZ); the Inter-American Development Bank (IDB); the International Board for Plant Genetic Resources (IBPGR); the International Fund for Agricultural Development (IFAD); McDonald's Corporation; Pepsico Foods International; the Rockefeller Foundation; 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 1990 *Annual Report* is published in English and Spanish by the International Potato Center (CIP). This report covers the period from 1 November 1988 to 31 October 1989. Mention of specific products by trade name does not imply endorsement of or discrimination against such products by CIP.

Citation:
International Potato Center. 1990. Annual Report CIP 1990. Lima, Peru. 258 p.

Printed by the International Potato Center, Apartado 5969, Lima, Peru. July 1990.
Copies printed: 3500.

Contents

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Foreword

We are now shaping CIP's strategic planning for the 1990s, building upon two years of intensive self study and analysis, as well as our recent external management and program reviews. And each step of our programming for change draws upon CIP's unique, widely decentralized institutional approach, which has been clearly approved by the donors and by our national program partners. With almost 20 years of experience, we are looking at the lessons learned alongside our collaborators in over 80 countries, and we are asking for their continuing input. However, CIP's phasing of the self-study into the external review process was the first attempt at a comprehensive review of a decentralized Center within the CGIAR. Thus, we are busy implementing some of the immediate plans, while sorting out priorities for the next decade.

In the accompanying lead article, I've summarized some major events, issues, and values that are combined in our institutional philosophy and global approach to potato and sweet potato research and development. There you will find a broader historical background. as well as a more detailed analysis of recent events at CIP. Here in the Foreword, I've chosen to address three key issues highlighted by the review process, which can help guide our thinking and actions as we develop our strategy in collaboration with our colleagues throughout the global networks.

Strategic Plan

Our strategy to meet 21st-century needs stems directly from CIP's initial Profile of 1979, which was a first in strategic planning within the CGIAR; however, our recent reviews highlighted the need to re-assess and adapt our Centerwide operations to keep pace with fast-changing technology and shifting political and economic events. Although we have regularly used our strategic plan as a working blueprint, an updated plan can help focus on specific current needs identified in our recent studies, particularly for the sweet potato research that more recently became a part of our mandate.

The external review teams, as well as the TAC and our donors, have discussed CIP's role in association with other Centers with responsibilities for sweet potato research. When our work with sweet potatoes began with special project funds in 1986, sweet potato research also was included in the mandates of two other Centers. CIP received its first core funding for this commodity in 1988. However, in 1987, IITA discontinued research with sweet potatoes, and the board of AVRDC decided to phase out of sweet potato research in 1990. Thus, as we update the strategic plan, CIP is the only Center working with sweet potatoes, which suggests both a clearer and stronger global role for CIP.

We recognize that priorities set within the overall strategy must take into account continuing rapid shifts in a maturing research community, as well as in farmer/consumer needs and food requirements. Both potatoes and sweet potatoes will have to play a greater role in the future; thus our plan must provide a good indication of future needs and how they will be met. Probably CIP's greatest challenge during the next five years will be that of fitting potatoes and sweet potatoes into farming systems based on cereals and agroforestry, using good land already under cultivation.

Center Impact

Donors indicated that they would like to have impact identified as early as possible in the life of a Center. Recent reviews of CIP, and other Centers, also have stressed the need to identify impact. A special challenge for CIP will be to develop short-term criteria to measure impact, which will be comparable with criteria that have characterized the successes of the "green revolution." Even in the sophisticated research and seed production environments of North America and Europe, adoption of new potato improvements is a lengthy process. An average of 25 years may be required for adoption – from the first cross leading to a new variety until a superior potential variety has been identified, named, and grown on 4,000 hectares in farmers' fields. And 4,000 hectares is a small parcel compared to the millions of hectares of cereals that gave us the "green revolution." Clearly, assessment of the "bottom line" impact is crucial, but we must also find indicators that can clearly predict potential impact, giving some measure of progress and achievement before final results are in hand. And, in the process of assessing individual Center impact, full credit must be given to our developing-country partners, with whom we share all our achievements. They continue to be the key players in CIP's overall strategy.

Evaluating CIP's Decentralized Approach

Although the donors and reviewers had special praise for CIP's heavily decentralized approach, it seems likely that Centers using such a broad-based approach will require an external review different from that of Centers where most activities are based at headquarters. Clearly the donors need the reviews to justify current financing and to support newly identified needs; however, some combinations of a self-study and modified external reviews probably will be needed to effectively evaluate a center that has most of its staff posted away from headquarters.

In the body of this report, we have documented the work of our staff and their collaborative efforts with colleagues in national programs and allied institutions, which will continue as the central force driving all CIP efforts.

Whatever methods used to assess the Centers in the future, or to measure their impact, the potential for a "green revolution" in the 1990s will likely be found in an increased role for these scientists as they work with intensively produced crops such as tubers, root crops, and vegetables in the farming systems of Asia and Africa.

Richard L. Sawyer

Richard L. Sawyer
Director General

CIP: Programmed for Change

Within the CGIAR system, CIP has earned special recognition for its decentralized institutional approach to research and development on a global basis. In the following account, Dr. Sawyer, director of the Center since its beginning in 1971, outlines both the philosophy and the historical events that have shaped this approach over the last two decades.

CIP's current global operations are briefly described on pages XV to XVIII, with the map of collaborative networks showing the interactive flow of CIP research and development throughout the world. The Center is one of 13 sister institutions in the CGIAR, which is described on the final page of this report. CIP's donor organizations and mandate are listed following the title page.

CIP's Early Years: A Different Path

As conceptualized in the early 1960s, the first Centers developed from plans that called for extensive campuses and facilities for headquarters that were basically self-contained. They were established to become Centers of excellence through their own facilities, staffing, and the support provided. At CIP, we took a very different route. We also established key basic facilities, but our Center of excellence has been built upon bridges of collaboration that span national programs around the world (see maps, page XV). We interchange expertise with these programs while working on priority problems of potato and sweet potato improvement.

Our headquarters in Peru is located near the original home of the potato, where the greatest diversity of wild species still exists. Thus, our initial efforts were to establish a world collection of native cultivars and wild species, and to develop methods for identifying and eliminating diseases, so that clean material could be provided to potato breeders around the world. To help earmark materials and support breeders' work priorities, research stations were established within specific agroecological zones in Peru (page XVI). Three of these were in warm- to hot-climate tropical ecologies. Peru is only a short distance south of the equator, with wide variations in ecology, from the hot tropics of the Amazon basin to the cool highlands of the Andes.

At these sites, we started to look at the classical problems that potato scientists had been working on for years, such as late blight, viruses, and seed production. However, we realized that world statistics on food production indicated that potato production was increasing most rapidly in Asia and Africa on a percentage basis. In many countries, potatoes had only recently begun to be used as a staple-food commodity, as well as a vegetable. We needed to determine first-hand what the problems were and where help would be needed from an international center.

Thus we concentrated only a portion of our resources at headquarters and established a network of regional research stations around the world. Their major responsibility would be to link us with the countries of the region so we could best provide our three major services: research, training, and communications.

Our regional programs quickly started to feed information back to us, greatly influencing our research priorities. We found that:

1. Potato could no longer be considered a cool season, northern-latitude or highland crop since it also was being grown in the warm and hot climates of the tropics.

2. The dependency on imported seed was the factor most limiting the use of the tremendous nutritional value of the potato. As a single food for survival, there is no other major plant food which approaches the nutritional quality of the potato.

3. Only scant human capital had been invested in potato research and development in many countries, and these limited resources were scattered among institutions. A high priority was assigned to helping national potato programs, which we could backstop in responding to the needs of their farmers.

4. The "green revolution" with the cereals had become a major recognized breakthrough in agriculture in the 1970s. Countries that had thought that major portions of their populations would always be hungry were achieving self-sufficiency in rice. And, in their search for alternative crops, the potato was found to have exceptional promise for diversification: the crop grows quickly and has high nutritional value, good cash crop return, and high levels of production per unit area per unit of time. The potato also fits well within cereal-based farming systems.

5. The Food and Agriculture Organization's (FAO) statistics on potato production are misleading, because much of the production never entered the channels from which FAO usually obtained their data. Nevertheless, their statistics showed that potatoes were increasing faster than any other major food commodity in Africa and Asia.

These are the principal influences that helped determine CIP's research priorities, including our decision to place major research emphasis on potatoes for the warm and hot tropics. Although it is sometimes argued that we have pushed the potato into climates for which it is not suited, the facts are that we are serving the needs of developing countries where potatoes are already being grown. Such countries have steadily mounting needs for this food to feed their rising populations.

Setting Priorities

As our regional network was set in place, our regional staff and the national program scientists soon let us know that bacterial wilt - brown rot was as important as late blight in many potato-producing areas. As the potato moved into the warmer tropics, whole new lists of pests and diseases were being encountered that had never been found in the northern-latitude countries that were exporting the seed. For example, the tuber moth was never mentioned as a major problem in the initial planning conference held in 1972, although participants came from developing and developed countries around the world where potatoes were important.

The regional research structure and our collaborators' feedback to headquarters have been a key influence in helping set our research priorities. This input is a principal reason that our research today is aimed at improving potatoes grown in developing countries of the warm and hot tropical climates.

Achievements and Lessons Learned

Many readers of this Report have participated actively in the research that stems from our decentralized work. Our combined efforts have given the potato a very favorable position in today's agriculture, pointing to an even greater role that the crop must play in meeting tomorrow's food needs.

Early on, when we began building a world germplasm collection for use by breeders of today and of future generations, we started to look at ways of producing seed in warm tropical climates. With production from imported seed, the cost of seed alone could be over 50 percent of the production costs in many countries. After learning how to multiply imported seed with low levels of virus build-up in tropical climates, we moved on to rapid multiplication and true seed research. Adaptations of these techniques are now in place in many countries around the world.

Local seed production was essential in shifting the role of the potato from that of a relatively expensive vegetable to that of a staple food. As local seed production programs have come on line, attitudes of policy makers have changed rapidly. Even in lowland tropical countries such as Vietnam, potatoes have become the second-highest priority food commodity.

The ability to store planting materials from harvest to planting became a second major concern. Many countries were depending on expensive refrigerated storages. CIP's diffused-light technique was our first major research result to spread rapidly around the world.

Our collaborative bridges around the world gave us the ability to distribute potential varietal material from developed and developing countries to other areas of the world where it would be useful. We did not have to wait for our own material to become available. Although CIP is less than 20 years old, developing countries are now receiving a steady flow of excellent potential varieties with built-in resistances to the pests and diseases of warm tropical climates. In addition, we have been distributing the excellent material from other breeding programs that may fit national program requirements.

In my opinion, the major impact of CIP reaches beyond the research that has been accomplished; our most enduring achievement has been in helping build the national potato programs across the developing world, through training, consultancies, and the establishment of networks. In many countries where there was not a single man-year invested in potato research in 1972, there are today well-trained scientists working as national teams for potato research and seed production.

Our support for potato production in the warm tropics of Africa and Asia has only begun. We are still using less than 10% of the wild species available to help solve varietal adaptation and resistance problems. Much of our research for seed production programs, such as the place of true seed in seed programs, is only now coming on line. The new tools of biotechnology, which are so easy to use with the potato, are just beginning to be available. CIP, with its decentralized program and collaborative bridges, has a solid base of operations to respond to the potato improvement needs of national programs, and to adjust quickly to their changing conditions.

Our Future

As we look at the role the potato must play in meeting the food needs of the global village, we have to examine past and present trends. The proven production and nutritional values of the potato will be needed to a much greater extent in future years. Over the next two decades, agriculture will be faced with its greatest obstacles since early civilizations began their systematic development of food systems for survival.

Tomorrow's major obstacles include:

1. Population increases

The world's population will double in approximately two decades. The World Bank Atlas shows many developing countries with annual population increases of 3% to 4%, clearly indicating that many population-control programs have been unsuccessful. Many of the burdens of these failures are passed on for agriculture to remedy.

2. Scarcity of good land

Many of the countries with the highest annual rates of increase in population are running out of good land for cultivation. Often they turn to marginal lands with fragile ecologies to try to stay abreast of food needs. Recent statistics on current population concentration and the related pressures on land are well described in an IRED Forum publication: "If our world were a village of 1,000 people, in the village would be 564 Asians, 210 Europeans, 86 Africans, 80 South Americans, and 60

North Americans. Of these people, 60 persons would have half the income, 500 would be hungry, 600 would live in shantytowns, 700 would be illiterate."

Thus it is clear that most of the increases in food production must be grown on the good land now under production. And this is going to require a major change to include the more intensively produced vegetables and tuber-root crops within the annual food production systems where cereals are now usually followed by other cereals.

3. · Concern for the environment

The world is finally catching up with the fact that the environment has been too long forgotten as a major concern in agricultural programs, population control, and industrial development. The Bruntland report for the United Nations has rightfully triggered international concern, and has resulted in the implementation of programs that will affect how we work, how we play, and the food we eat in the immediate future. The Plan on Environmental Policy of the Dutch government, "To Choose or to Lose," may well become a model for the European Economic Community. It recommends a very ambitious, and necessary, full-scale application of known technology, if the goals for our environment are to be achieved while agricultural production increases.

4. The International Agricultural Research Community

A major positive force for further development has evolved over the past 20 years through the system of international agricultural research centers (IARCs) that specifically address major food-production problems of developing countries. These Centers have programs of research, training, and information exchange that are gradually joining the agricultural research world into a united community. Their efforts draw upon the combined strengths of developed and developing countries, the public and private sector, and the IARCs. *There must be no doubt about the pivotal role that this international center system must play in dealing with problems of population, agriculture, and environment over the next two decades.*

Both of CIP's present commodities are basic staple foods in some parts of the world, but are classified and utilized as vegetables in many areas, particularly where they have most recently been introduced. Both commodities produce more calories per unit area per unit of time than almost any of the other major food crops, including the cereals. Sweet potato production has been decreasing in many parts of the world, where economic conditions allow the consumer to choose foods other than those that have traditionally been considered subsistence foods, with a perceived lower status.

In Summary

CIP's two major commodities are ideally suited to meet the challenges facing agriculture. Both potato and sweet potato fit well within cereal-based farming systems, and can boost food production per unit area per year. They are fast-growing, and produce good ground cover to prevent erosion. Also, they are mainly grown in ridge-type planting to protect the tubers, a practice that also prevents erosion when used in contour plantings.

Over the next 20 years, CIP's challenge in fulfilling global agricultural needs is to fit potatoes and sweet potatoes into cereal and agroforestry farming systems that will:

- Increase productivity of quality food per unit area per unit of time;
- Increase the efficiency of inputs such as fertilizer and water; and
- Sustain the increases in productivity with practices that are friendly to the environment.

This challenge is based on the assumption that (1) cereals will continue to be the world's mainstay for food security, while other, more productive, foods will play a role of mounting importance; (2) most of the increased production needs in the coming years will be grown on good land now under cultivation; and (3) fragile soils of the highland and lowland tropics, where agroforestry has a comparative advantage, will become increasingly important for food production.

Each of these components is being programmed into CIP's global effort to improve potato and sweet potato for the 1990s.

Richard L. Sawyer
Director General

Solanum acaule Bitter.

Solanum bombycinum Ochoa.

Solanum infundibuliforme Philippi.

Solanum vidaurrei Cárdenas.

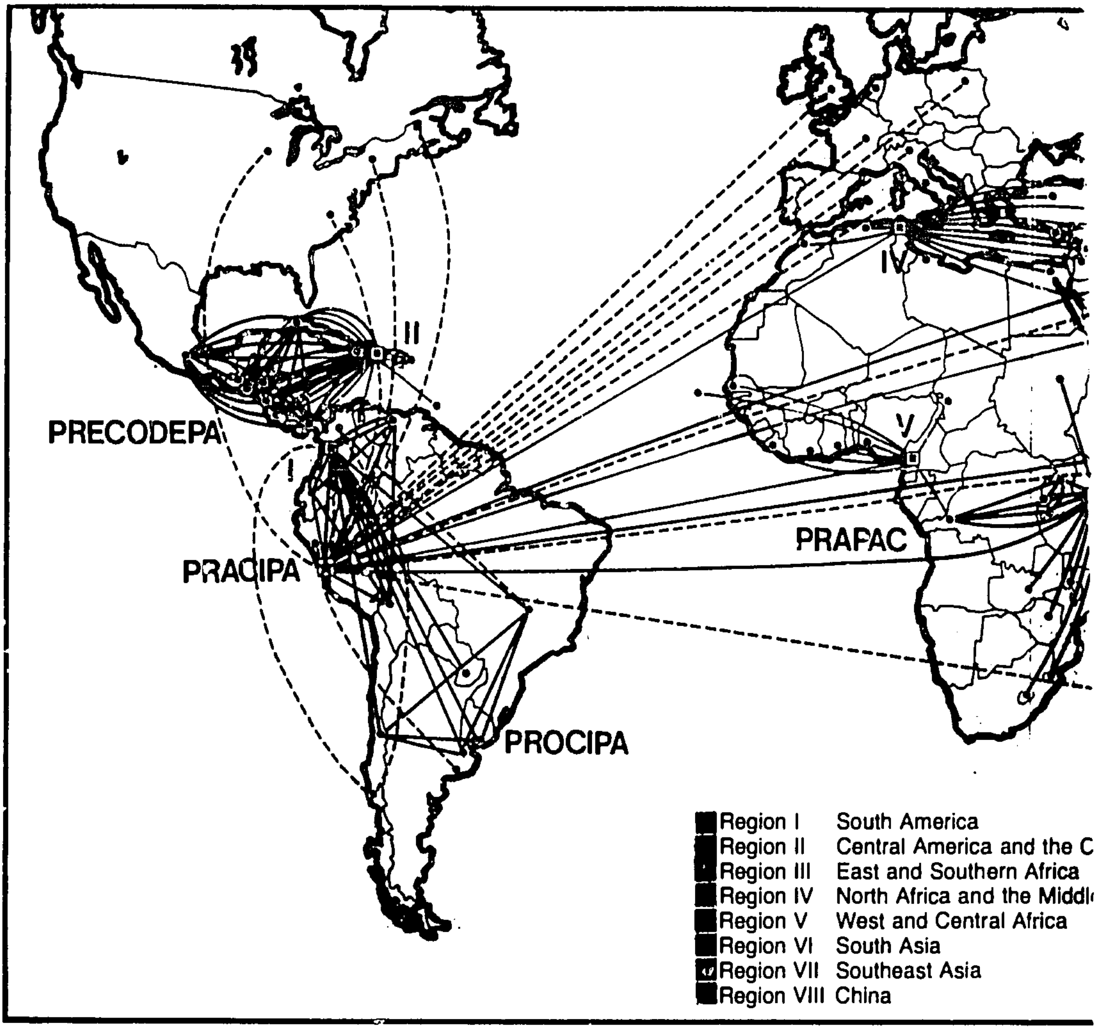
Painted by Franz Frey. Reproduced from The Potatoes of South America: Bolivia, by Carlos M. Ochoa. Published by Cambridge University Press in collaboration with the International Potato Center, 1990.

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)

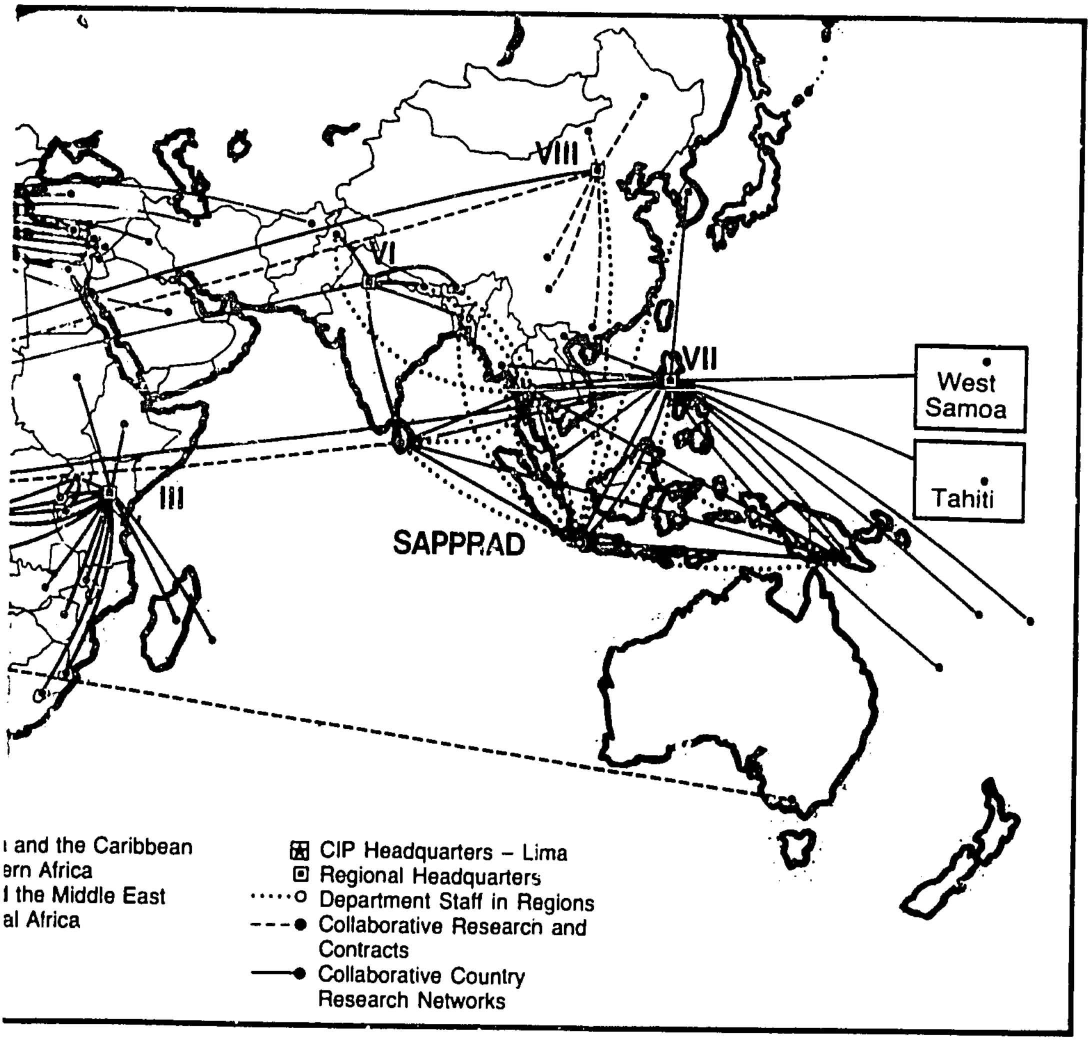
CIP's capabilities are enhanced by numerous research and consultancy contracts that take advantage of the expertise and facilities available at other institutions, often in collaborative research in developed countries. Through contracts with developing-country institutions, we share specialized human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



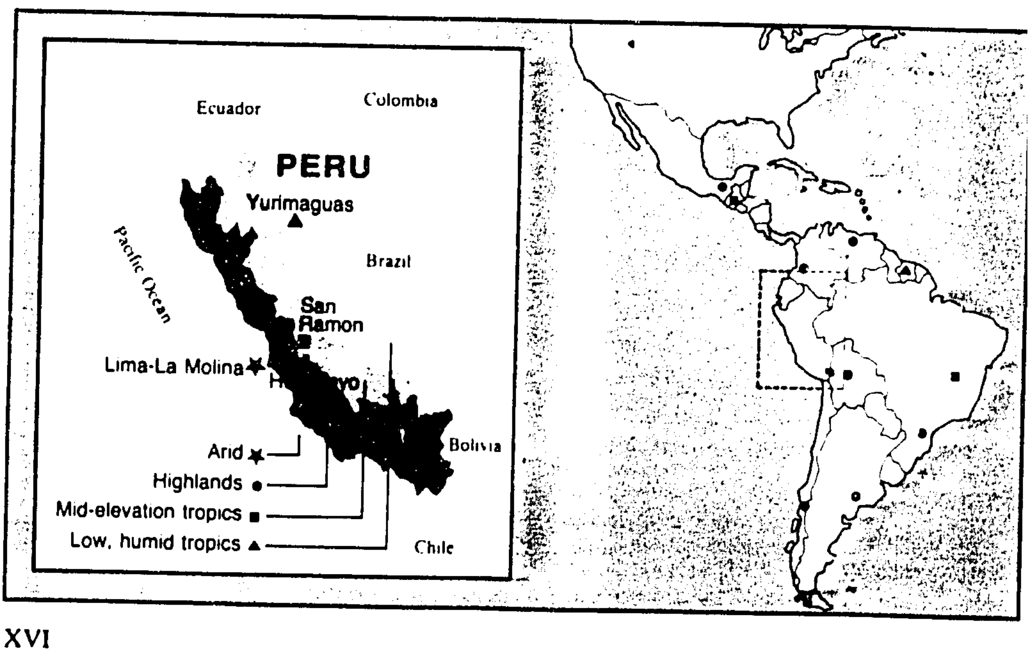
Agroecological Zones and Related Thrust Research in 8 CIP Regions

CIP has four experiment stations in Peru, one in each of the major agroecological 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 1989 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 89	May-Nov 89	Nov-May 88 89	Nov-Mar 88 89	May-Aug 89 89	May-Aug 89 89
Air max (° C)	27.49	19.92	18.50	31.10	30.87	30.88
Air min (° C)	19.06	14.15	4.70	19.25	16.19	19.29
Evaporation (total mm)	569.78	540.95	809.73	1042.99	533.05	*236.60
Rainfall (total mm)	1.50	9.10	706.30	1300.43	289.70	540.04
Solar radiation (daily MJ/m²)	no data	11.70	no data	19.78	18.85	no data

* Data from weather booth.



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 than 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

PRACIPA	PRAPAC	PRECODEPA	PROCIPA	SAPPRAD
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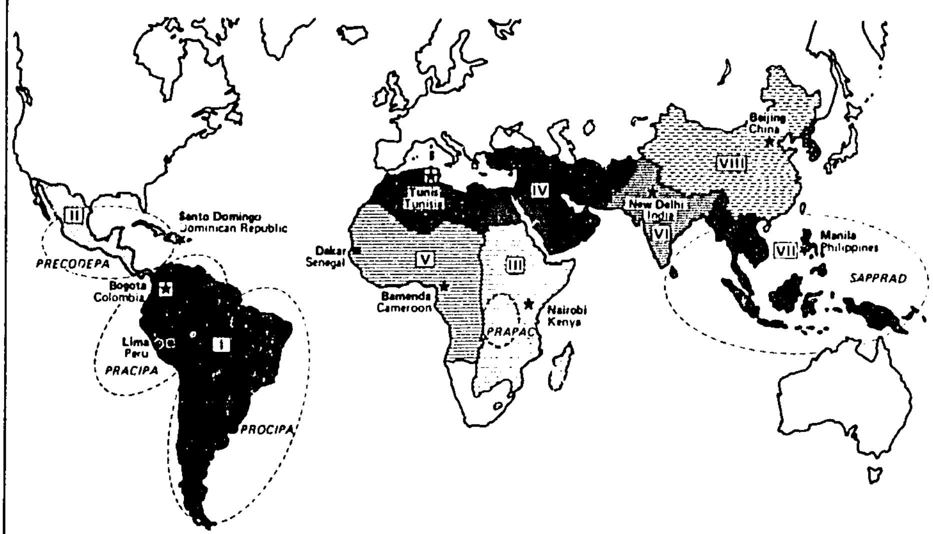
REGIONAL RESEARCH PROGRAM



INTERNATIONAL POTATO CENTER (CIP)

REGIONS AND COUNTRY NETWORKS

Regional (★) and Subregional (●) Headquarters

Argentine Husband/Wife Team Combines Business and Virology Tests

Traditionally, we have used the words of CIP scientists and administrators in our Annual Report. In this article, however, we focus on some practical applications of the scientific research and training being done at CIP headquarters and in the regions. This account is drawn from Tito Alberto Brovelli's interview with Ana Maria Escarrá and Juan Barrenechea, owners of Diagnósticos Vegetales, a private firm devoted to potato virus detection. In future Annual Reports, we will publish similar accounts of collaborative efforts of potato and sweet potato enterprizes in the private-sector and national program institutions in the regions. Their words express, better than ours, the usefulness and developmental impact of CIP's global program. (See CIP Circular Vol. 17(1), 1989 for additional background information on CIP's virology research and training related to ELISA and Latex tests.)

Agricultural engineers Ana María Escarrá and Juan Lorenzo Barrenechea, a husband-and-wife team, are the owners of Diagnósticos Vegetales, a company that offers virus-detection services and produces pathogen-free potato seed. During the 1980s, they equipped the foremost Argentine laboratory for the identification of potato viruses using enyzme-linked immunosorbent assay (ELISA) tests.

After the laboratory was well established, they began to develop a production process for completely healthy seed that would supply the internal market. Today, they export seed, as well as virus-detection technology.

Their rapidly growing business represents a trend in Latin America. The accomplishments of this couple have proven that it is possible, with a minimum of capital and financial credit, to launch a commercial potato-virus analysis system to complement government activities, such as Argentina's National Seed Program.

To get their business started, Ana María went for training to the potato seed laboratory at the experiment station of INTA-Balcarce (Instituto Nacional de Tecnología Agropecuaria), where she received instruction from virologist, Dr. Iván Butzonitch.

Ana María examining plantlets in the final stage of micropropagation.

With this new knowledge, and a great deal of determination, she and Juan managed to build two greenhouses in Otamendi, a small potato-producing community south of Mar del Plata. She explained that, "there we were able to reproduce what I had been doing at the INTA laboratory."

She was fortunate in being able to learn from an INTA investigator, the late agricultural engineer Atilio Calderoni, about the new diagnostic method, ELISA. This method involves an immuno-enzyme system that had recently been developed for vegetables, and which CIP had begun to put into practice.

To learn more about ELISA, Ana María immediately set about making contacts with international centers. Through them she learned about a virology course offered at CIP, where this diagnostic technique would be taught. She signed up for the course to be held in October 1981 that was directed by Dr. Luis Salazar, who was assisted by his team from the CIP Virology Program.

"That training experience," she said, "brought me much closer to a practical and academic understanding of potato virology, and at the same time I made many good friends."

After receiving authorization to use the new technique in Argentina and acquiring the necessary space and equipment, the couple met with producers to work out costs and make agreements.

Traditionally, the importation of seed potatoes had been an annual event in Argentina, because new seed tended to become highly infested. But with knowledge gained from ELISA and research on aphid populations, there were real

Dispensing antibody solutions into plates for the ELISA test.

The couple discusses business at the Diagnósticos Vegetales headquarters.

possibilities of keeping seeds healthy for a longer time.

In December, Ana María took part in the "First International Course on the Production and Storage of Seed Potato," organized by CIP in Osorno, Chile. Dr. Fernando Ezeta, a scientist at CIP and coordinator of the Program for the Production of Basic Potato Seed in Peru, described his experiences in the area. A method was discussed for supplying nothing less than completely healthy seed.

Ana María recalls that "this concept was a revelation for me. I saw that if it were possible to transfer this methodology to my own country, we would be able to move towards seed self-sufficiency and eliminate imports."

Juan added that "the idea of beginning healthy-seed production in our country also represented the challenge of more work for us." The couple made arrangements to study the new technique. In March 1984, they set off for Peru, for a short but intensive training period at CIP.

Assessing the quality of mini-tubers grown from in vitro plantets.

After they returned to Argentina, they installed a greenhouse in the Sierra de los Padres area, and started a small tissue culture laboratory at their main office. CIP supplied healthy seed of the varieties used in Argentina.

In 1986, producers in all of Argentina's potato-growing areas planted trials with this disease-free seed; then national authorities took note and urged other producers to do the same.

As a result of these experiments, Diagnósticos Vegetales was recognized as a leader in this area and their contracts increased. For the first time, profits began to justify the years of study and work.

In 1987, other teams of private-sector professionals decided to produce healthy seed, and new business partnerships were formed.

In the particular case of Diagnósticos Vegetales, the opportunity was ideal for establishing contacts with businesses and producers in other Latin American countries interested in finding similar solutions. With training from the Diagnósticos Vegetales team, Mexican technicians have set up a virus-detection laboratory in La Junta, Mexico. Technicians from Chile and Uruguay have also received training to set up similar laboratories in their countries.

Ana María and Juan Lorenzo continue to look for new ways to combine their scientific and business interests with Argentine institutions and professionals, and with CIP and other research organizations. And the combination promises to pay off with better crops and additional oportunities for economic development in Argentina.

Participants in a CIP Virology course practicing the ELISA test for the detection of potato and sweet potato viruses.

Summary of Research Programs

Our Thrust activities continue to build within a stronger regional framework of NARS and CIP scientists in Latin America, Africa, and Asia. The individual Thrust reports reflect substantial achievements of this combined team approach, particularly in the development of improved CIP potato materials that provide combinations of resistances and tolerances to biotic and abiotic stresses, either alone or in crosses with locally adapted material. We have also helped in the successful integration of selected sources other than the Center's breeding program. Other Thrust research payoffs include integrated pest and disease control methods, potato seed production schemes that yield clean planting materials, and new postharvest methodologies.

Our research on sweet potato has progressed rapidly and CIP's sweet potato genebank is now the largest and best documented in the world, with duplicates obtained from national collections in Latin America, the Caribbean, China, Japan, and the United States. Simultaneously, we have mounted an intensive CIP/IBPGR collection effort to systematically explore Latin American and Caribbean countries where good genetic diversity is found in sweet potatoes.

The IITA collection has been placed in vitro and duplicated for transfer to the CIP collection and AVRDC has recently agreed to the transfer of a complete duplicate of its collection to CIP. In a systematic evaluation of CIP's sweet potato collection, we have found resistances to some important pests, tolerance to several abiotic stresses, and other quality factors that will help better serve needs identified by developing countries. As in our collaborative work with potatoes, we are seeking ways to eliminate pathogens and to confirm their elimination. This difficult and labor-intensive work is designed specifically to yield technology for use by developing countries. Rapid progress in improvement of sweet potato flowering and seed set has facilitated new wide crosses.

The continuing needs of developing countries are being assessed by surveys of sweet potato workers in those countries, and by CIP social scientists working alongside local scientists and farmers.

Similarly, they are recording the successful technologies and their adaptations for further improvement and diffusion.

Potato

Our genetic resources potato research concentrated on biosystematic studies, germplasm maintenance and utilization, and germplasm enhancement.

In the biosystematic studies, we described three new potato species, *S. amayanum* and *S. bill-hookerii* of the taxonomic series Tuberosa, and *S. salasianum* of the series Conicibaccata. All three are from the central Andes of Peru and have a chromosome number of 2n = 2x = 24. In addition, we identified a new form of the important tetraploid wild species *S. acaule*, which appears to have good potential in the development of improved resistance to PLRV and to mechanical inoculation of PSTVd. Studies of various herbaria in the USA, in Europe, and in Peru at CIP have shown that *S. bukasovii* has enormous genetic variability, to the extent that four species, *S. canasense*, *S. multidissectum*, *S. punoense*, and *S. pumilum* Hawkes, are all synonyms of *S. bukasovii*. This is an important taxonomic clarification, because it means that *S. bukasovii* can be used in breeding, without major problems.

We are making good progress in determining the endosperm balance number (EBN) of wild potato species. This work helps us understand and predict the crossability of wild potato species with each other and with cultivated potatoes; it also helps us obtain a better understanding of the evolutionary processes in species formation.

We continue to identify new cultivars, and the CIP field-planted collection now consists of 3,439 Andean cultivars, with

99% of these cultivars also maintained in vitro. After electrophoretic verification, 603 duplicates were eliminated from material obtained from Argentina, Bolivia, and Peru. To conserve potato diversity in the fields of Andean farmers, we are testing a novel approach that involves training farmers to select segregating TPS materials according to their local needs and preferences. Farmers in three localities are now using TPS of about 20 native cultivars that are popular in traditional agricultural areas such as Cajamarca, Cuzco, and Puno, Peru.

Of 200 Andean cultivars screening for resistance to the potato tuber moth *Phthorimaea operculella*, 15 were found to be resistant and 35 moderately resistant. Pathogen-tested Andean cultivars were distributed to 14 countries as tuber samples, in vitro plantlets, or seeds.

For increased security, CIP has duplicated a set of tubers of Peruvian cultivars in a high-altitude field genebank in central Peru, which is maintained by the

National Agrarian University. This material has been fully duplicated outside of Peru through a collaborative agreement with INIAP in Ecuador.

We have completed the transfer of the world potato collection to in vitro culture. Computerization of maintenance procedures of the collection is complete and all labelling is now done by computer.

In utilization studies, our work focused on use of *Solanum acaule*, and 124 clones of *Solanum acaule* that had been found (by mechanical inoculation) to be resistant to PSTVd were further tested by *Agrobacterium*-mediated PSTVd cDNA inoculation. In these tests, 21 clones were shown to be resistant to this mode of inoculation. An additional 4 clones were identified as apparently resistant to PLRV, based on their resistance to aphid infestation and multiplication of the virus. The 25 clones have been transferred to in vitro and are ready for utilization in germplasm enhancement and breeding. From this *S. acaule* material (which may also carry resistance to PVY and PVX) F2 and backcross populations have been generated that will be used in RFLP mapping projects. This project will help to map genes that determine resistance to PSTVd and to some viruses. We have further developed several schemes for the effective utilization of the *S. acaule* material, including a cross combination between *S. acaule* and tetraploid cultivated potato clones. Previously, this combination had failed, due to the operation of the triploid block or the EBN barrier.

Our germplasm enhancement work included the identification of high levels of resistance to root knot nematodes in 5 new diploid clones, using a newly developed in vitro method that has eliminated temperature problems encountered in the traditional testing environment. This source of resistance represents a broadening of the base for root-knot-nematode resistance at CIP, since the only previous effective and usable wild sources of resistance were clones of *S. sparsipilum*. The new diploid material has *S. multidissectum*, *S. bukasovii*, *S. canasense*, and *S. gourlayi* in its background. These wild species had been crossed with dihaploid *S. tuberosum* and ssp. *tuberosum* clones that were produced under a research contract with the University of Wisconsin. Some of these clones have good 2n pollen production and are now in use in a 4x x 2x crossing program. They have excellent tuber appearance.

Resistance to bacterial wilt was found in selected 2x clones that have the clone MI49.10 in their pedigree; this clone had previously been selected for bacterial wilt resistance and 2n pollen production. Among other clones showing resistance to bacterial wilt, one clone showed a root knot-nematode resistance that can be transmitted to progenies from 4x x 2x crosses. Thus, this clone combines both bacterial-wilt and root knot-nematode resistance.

Excellent progress was made in transferring potato tuber moth resistance from the wild species *Solanum sparsipilum* to 2x cultivated germplasm. The findings indicated that the presence of *S. sparsipilum* is desirable, but not essential, for the expression of resistance. We have also shown that resistance to root-knot nematodes, bacterial wilt, and potato tuber wilt, as well as 2n pollen production, can be combined in individual diploid genotypes that will transmit these characteristics to their 4x offspring.

We are making rapid advances in use of *Agrobacterium* plasmid gene constructs to transform potato clones. A range of new promoter (control) sequences was obtained and tested, thus helping us to regulate the amount and site of a particular gene product. Collaborative work with institutions in Florence, Naples, Rome, and Vitervo, Italy, have lead to transformation for resistance to several pests and diseases, and to the use of in vitro methods to select for resistance to biotic and abiotic stresses.

A new research contract with Cornell University has been designed to help produce a more detailed RFLP linkage map of potato. The map is based on tomato probes, and has already been used effectively by plant breeders as they begin to elucidate the phyllogeny of tuber-bearing *Solanums*. The next step is population development and identification of useful traits.

In potato breeding, our research focuses on population development and true potato seed (TPS) studies. We have made extensive selections for parental lines to be used for variety selection and for TPS utilization. At La Molina, 30 clones from CIP's program and 12 clones from the University of Maine were evaluated for their parental value, using a tester that showed combined immunity to both PVY and PVX. Clones C83.383, Maine-37, C1-137, C84.081, and C84.707 showed good parental value for yield and tuber uniformity, and had medium maturity rates. Based on these findings, we are selecting the progenitors for the next crossing block. At San Ramon, we evaluated a sample of 25 clones for general combining ability (GCA), using a line-by-tester design. This sample included clones with immunity to PVY (simplexes and duplexes) and PVX, with combined immunity to PVX and PVY. Yields were acceptable, with many of the progenies showing high yields, good tuber uniformity, and earliness. All progenies segregated for either PVY or PVX immunity, and clones XY.15 and C84.705 were found to have a high GCA for yield, tuber uniformity, and earliness. At La Molina, we also evaluated a sample of 286 clones introduced from Uruguay to assess their agronomic attributes. The sample was generated from TPS progenies segregating for processing attributes and virus resistances (PVX, PVY, and PLRV), and 23 clones were selected. They are now being tested for immunity to several viruses.

To evaluate drought tolerance, 800 potato clones (selected at San Ramon and La Molina) were tested at Tacna. We found high yields and good levels of earliness in several clones and this population contains many combinations of resistances to virus and other diseases that can be useful in developing parental clones. We also evaluated populations bred for adaptation to warm tropical environments and for TPS parental line development. Ten clones evaluated at La Molina and 2 clones at San Ramon, were selected for making chips and french fries because they had good processing characteristics: good tuber shape, color, and uniformity. The national programs of Burundi, Ethiopia, Rwanda, Tanzania, Uganda, and Zaire participated in a regional trial in which we evaluated a set of the best clones from the national programs and CIP under a broad range of environments in eastern and southern

African countries. Clones considered for release as new varieties include: CIP clones 381295.1, 381293.3, and PLAP 8201.12 in Rwanda; and CIP clones 374080.5, 380606.6, and 380602.22 in Zaire. These clones have gone through several cycles of selection including multilocational national yield trials. We have selected promising new clones in experiments to assess cultivars of diverse genetic types for yield and other qualities in New Caledonia, Thailand, Fiji, Tonga, and French Polynesia, as well as the Solomon Islands and the Cook Islands. Clone 377850.1 was selected in Fiji and has shown good bacterial wilt and virus resistance, along with heat tolerance and good storability.

In China, more than 200 CIP cultivars have been evaluated. In Enshi Hubei Province in southern China, CIP clones 386221.7, 386081, and 386198 outyielded the local cultivar and are being further evaluated.

At San Ramon, several clones showed excellent agronomic and reproductive characteristics under rainy- and dry-season conditions. These clones come from 1987 and 1988 TPS populations and have now been put in crossing blocks to assess their parental value.

In China, the area grown from TPS transplants increased from 80.5 ha in 1987, to 110 ha in 1988, to 150 ha in 1989. This increase extended over 20 provinces in southwest China and in northern China, and can be attributed to improved logistics, availability of high quality TPS, the establishment of TPS collection distribution procedures, and CIP input in personnel training.

Sweet potato

Sweet potato studies primarily emphasized collection, taxonomic identification, germplasm maintenance, duplicate identification, evaluation, distribution, and enhancement. Six collecting expeditions were made (one each in Guatemala and Panama, and four in Peru) with a total of 299 accessions collected at 130 sites. Of the accessions, 155 were *I. batatas*; nine represented two *Ipomoea* species from section Batatas, 12 represented seven species from other sections, and 123 have not been classified.

We began duplication of the IITA sweet potato germplasm collection at CIP with a transfer of 210 accessions maintained in vitro. This genetic material includes 34 advanced selections and 176 breeding lines. The 1,202 IITA accessions have been more thoroughly documented, and a computerized database now contains all of the available data. A total of 3,520 sweet potato accessions were planted at La Molina, with 1,868 Peruvian cultivars and 338 breeding lines grown in the field. Another 966 sweet potato cultivars from other countries were grown in pots in the quarantine screenhouse and 348 accessions have been maintained as in vitro culture. We are transferring materials to in vitro culture as rapidly as possible, and a total of 2,430 sweet potato accessions are now being maintained in vitro under slow-growth conditions. Some of these accessions are being duplicated outside of Peru under an agreement with IDEAS in Venezuela. Duplicate verifications by electrophoretic analyses were made at the Institute of Biochemistry in Braunschweig, West Germany, where studies were made of 252 Peruvian cultivated accessions from 60 groups with identical morphological characters. The results and the groupings based on morphological data were found to be in agreement for about 85% of the accessions.

AVRDC analyzed nutritional components of storage roots from 897 Peruvian cultivars. Of these cultivars, 35 had dry-matter content levels greater than 40%; 13 had starch-content levels greater than 70%; 4 had combined levels of more than 35% dry-matter content with more than 10% of total protein; 4 had less than 2% total sugar content, and 26 had less than 2% fiber content. Significant negative correlations were found between dry-matter content and total protein content, and between dry-matter and fiber content. Positive correlations were found between dry-matter and starch contents. Eighteen cultivars of *I. batatas* were rated as resistant, and another 12 as moderately resistant to *Euscepes postfasciatus* weevil. In the People's Republic of China (Xuzhou and Guangdong), scientists are characterizing the Chinese national sweet potato collection, computerizing the data, and introducing the clones to in vitro culture.

In sweet potato germplasm enhancement research, we are combining both innovative and traditional cytogenetic methods. Studies of wild 2x and 4x *I. trifida* species have shown exceptional promise for future sweet potato work. Within the section Batatas, only *I. trifida* has been used in our sweet potato germplasm research; however, we have begun a crossability study to determine the feasibility of using the rest of this taxonomic section. In this work, 2n pollen was formed in 6 of the 11 species studied, and of 70 interspecific combinations examined, 28 were successful, while parents of the same ploidy level were shown to be highly crossable. All 11 species studied have become genetically accessible, either directly or indirectly. Thus this section shows promise for future sweet potato enhancement work.

In our sweet potato population breeding work, in the coastal desert and the Amazon Basin in Peru, we have made good progress in selecting material with high and early yields, broad adaptation, and a range of characteristics important to consumers. We have emphasized studies of the newly collected Peruvian germplasm.

CIP distributed genetic materials to cooperators in 88 NARS. Materials now available from the pathogen-tested list include 245 advanced cultivars of varieties, 35 cultivars in the clean-up process, 172 accessions from native and wild germplasm, plus 56 in the clean-up process. Six sweet potato cultivars are now on the pathogen-tested list and 62 are in the clean-up process.

Integrated Control of Diseases and Pests

In bacterial-wilt research, our collaboration with NARS in several developing countries continues to concentrate on the selection of tetraploid populations with resistance to *Pseudomonas solanacearum* inherited from cultivated diploid *Solanum* species. We have substantially increased our tests and development of potentially useful breeding materials in locations within Peru and worldwide,

thus intensifying the selection for resistance to localized strains of the bacterium. Our combined efforts have produced a new population from a series of crosses between the best bacterial wilt-resistant clones, and a late blight-resistant population (including some clones that were free from R-genes). A wide range of materials was selected for acceptable yield potential, and further progress has been made in the selection of clones that show no latent infection by *P. solanacearum* at harvest. Some of this work has been done in association with the Peruvian National Potato Program INIAA. We have selected intensively for bacterial-wilt resistance, combined with adaptation and agronomic quality, in several parts of the world, including the Philippine , Indonesia, China, and Brazil.

Additionally, we have developed a more precise and severe screening method to enhance levels of resistance to bacterial wilt. This method uses rooted cuttings immersed in the inoculum suspension, and is uniform and reproducible for segregating individual plants resistance to bacterial wilt.

Taxonomic studies were made on *Pseudomonas* using biochemical tests in multiple-well microtiter plates. These resulted in the subdivision of Biovar 2 *P. solanacearum* into two distinct phenotypes related to their geographic distribution. This finding will help focus the breeding strategy.

Collaborative work between CIP and NARS on the integrated control of bacterial wilt is designed to provide low-cost control of bacterial wilt by small farmers in developing countries. The philosophy is to complement the performance of tolerant cultivars. In collaboration with the Department of Plant Protection of ISABU, Burundi, a survey to evaluate the occurrence of bacterial wilt in farmers' fields provided valuable findings to help develop integrated control strategies. Wilt incidence was shown to be affected by the previous rotation, with the lowest level of carry-over shown after rotation with cassava during the September-to-January season, and after banana, during the following season. The bacterial wilt-tolerant variety Ndinamagara (CIP accession number 720118) was grown on 77% of the total land planted with potato. On average, our varieties showed less wilt than did other varieties; however, bacterial-wilt incidence was found to be low in susceptible varieties, when the seed was obtained from the ISABU seed farm and the crop was grown in a two-year crop rotation. Increased extension efforts to prevent planting of potato as a monoculture have helped considerably, but volunteer potato plants are still recognized as a major source of bacterial wilt. In Bukidnon, Philippines, the inoculum potential of *P. solanacearum* (race 1) in the soil was highest following a potato crop, and lowest following maize, although the potential remained sufficiently high to cause disease. Rotation with maize or beans reduced bacterial-wilt incidence and increased yield in a subsequent potato crop, whereas potato monoculture increased wilt and reduced yield. At San Ramon, bacterial-wilt incidence increased when the crop followed rotation with cowpea or beans, whereas the incidence decreased when following maize or a herbicide-treated fallow. These incidences were correlated with the level of rootknot-nematode damage.

In our screenhouse tests, the pre- and post-emergence application of the herbicide Metribuyin effectively controlled weed hosts of *P. solanacearum* and *Meloidogyne* spp. Soil amendments also retarded the development of bacterial wilt. The incidence of bacterial wilt in screenhouse tests could be lowered substantially by application of calcium oxide or urea, or combinations of the two. Field-soil amendment with calcium oxide, urea, and composted sugarcane bagasse also retarded the development of bacterial wilt in the field. We are making follow-up studies of these findings in cooperation with INIA in Cajamarca, Peru, with LEHRI in Indonesia, and with CIP staff in Kenya.

Alternative screening methods were evaluated to support breeding for resistance to *Erwinia* soft rot and black leg, and we have developed a new method that involves placing cuttings in infested perlite, thus permitting the selection of several resistant genotypes. Our research showed a synergistic interaction between *Erwinia caratovora* ssp. *caratovora* and two *fusarium* spp. inoculated to tubers, which suggests the need to consider a breeding strategy that takes both diseases into account simultaneously.

In our late-blight work, breeding for resistance to *Phytophthora infestans* continues to involve two populations: 1) advanced materials containing dominant genes for vertical resistance (R genes), as well as horizontal-resistance genes; and 2) materials free of R genes that are agronomically less advanced. Our aim is to increasingly emphasize the R gene-free population. In both populations, however, our objectives are to increase levels of horizontal resistance to add suitable agronomic characters, as well as to select high levels of late-blight resistance.

We selected 166 new clonesin screening at Rionegro, Colombia and Toluca, Mexico and 39 clones were selected after a second testing and have been added to the international late-blight resistance trial collection. This collection now contains 170 clones that are available for testing by NARS.

New sources of resistance were tapped for population B. A sample of 123 accessions from three wild diploid species is being tested in Peru, and we are planning to cross haploids and *andigena*-resistant clones. The aim is to introduce resistance into cultivated forms extracted to make crosses with wild diploid species.

Progenies with characteristics for early-blight resistance combined with earliness, were selected in the field at San Ramon, and similar progenies were found to show early-blight resistance in tests in Israel. Our findings provide additional evidence of the potential for con-

trolling this disease through selection for resistance.

Our survey of sweet potato diseases continued at La Molina, and we began screening for tuber-rot resistance with emphasis on Java black rot and *Fusarium* root rot. In experiments at San Ramon, foot rot and soft rot caused severe losses in storage. Chlorotic leaf distortion was shown to be caused by the fungus *Fusarium lateritium*.

In our virus research, we are emphasizing the breeding for resistance to potato leaf roll virus (PLRV) alone, or in combination with potato virus X (PVX) and potato virus Y (PVY) immunities. Because the resistance to PLRV is known to have multiple components, the search for parental genotypes within individual resistance components should facilitate efforts to combine them in later stages. One of these components, aphid antixenosis, was identified in four clones maintained at CIP.

Resistance to infection is another important component of the resistance to PLRV. This resistance can be broken down by growing resistant clones under high-temperature conditions. For example, of 62 advanced clones that resisted PLRV infection after 5 field exposures during the winter at Ica, Peru, only 16 showed moderate to high resistance to PLRV in the summer season. These findings indicate that final selections for resistance to PLRV should be done in locations having conditions similar to summer conditions at Ica.

Our studies show that resistance to virus multiplication is another important resistance mechanism. Although is very uncommon in cultivated potato, this mechanism has two important advantages: 1) It reduces the severity of the leafroll disease, and 2) It reduces the inoculate potential in plants having this type of resistance. In a collaborative research project with the Scottish Crops Research Institute, we have developed two clones with resistance to virus multiplication. These clones are G7461.1 and G7445.1. We found wide variability of PLRV among eight PLRV isolates, in studies that used monoclonal antibodies to examine the antigenic determinants (epitopes) on the protein coat of the PLRV particle. Knowledge of such variability is crucial in our strategy for resistance breeding

We continue our search for additional inexpensive and simple methods of virus detection for NARS; production of basic stocks free of viruses is crucial to seed programs. For example, we are studying ways to lower the costs of antisera that are the most expensive reagents used in ELISA, a sensitive, simple, and inexpensive method for virus detection. In one method being studied, virus antibodies (anti-idiotypes) are produced from a small supply of previously produced antibodies, rather than from purified virus. Complementary nucleic-acid sequences were developed for eight viroids and six viruses to increase the pool of virus and viroid detection methods at CIP.

In sweet potato virus research, we continued studies to detect and identify viruses, while also searching for resistance genes to sweet potato feathery mottle virus (SPFMV), which is the most important virus of the crop. Antisera and kits for detection of major viruses are now available for distribution to NARS. A previously unknown, mechanically transmitted virus (code-named C2) was found in the germplasm collection, and has been identified and partially characterized. Thirteen accessions in the CIP germplasm collection have been found to provide the best available resistance to SPFMV through graft inoculations.

Integrated pest management research continues to focus on the identification and use of resistant germplasm, biological control agents, and other non-pesticidal methods. In potato cyst-nematode research, 20 advanced clones were identified as resistant. Two clones, J16.10 and G.16, have been selected for release in Ecuador where 52 clones also were selected for further evaluation. Resistance to potato cyst nematode identified in *Solanum andigena* nas been transferred to other adapted material. We also have selected clones with combined resistances to potato-cyst nematode, and late blight viruses. Root knot-nematode resistance was identified in several potato progenies at the diploid and tetraploid level, and additional sources were identified in *S. multidissectum*, *S. bukasovii*, *S. canasense*, and *S. gourlayi*. An effective cropping sequence to control root-knot nematode was identified in Burundi. Several new sources of resistance to root-knot nematode in sweet potatoes were identified.

Resistance to potato tuber moth was reconfirmed in 7 potato clones with high densities of glandular trichomes type A and B. This work holds special promise because glandular trichomes provide resistance to many kinds of insects and to other pests, and even reduce incidence of late blight.

Our studies have confirmed the effectiveness of granulosis virus, talc, and the biological insecticide *Bacillus thuringiensis* in controlling potato tuber moth. In Egypt and Tunisia, the use of granulosis virus and *Bacillus thuringiensis* was found to be highly effective in storage. These components are now being used in integrated pest management.

Seasonal occurrence of potato tuber moth was studied using pheromone traps in Colombia, Peru, Burundi, and Ethiopia. The findings provide a basis for more efficient application of control measures and 11 clones have been selected for resistance to leafminer fly. We also have identified clones with resistance to Andean weevil, *Premnotrypes suturicallus*, *Thrips palmi*, and to the mites *Tetranichus urticae* and *Polyphagotarsonemus latus*. The fungus *Beauveria* was effective in controlling Andean weevil. Natural enemies in the host range of thrips and mites attacking potatoes were identified in the lowland Philippines. Good progress was made in selecting for resistance to the West Indian sweet potato weevil *Euscepes postfasciatus*. *Beauveria* also seems to be effective in controlling the larval, pupal, and adult stages of this pest.

Production and Postharvest Technology

Our studies continue to show gains in improving the sustainability of yields of potato following continuous production and diffused-light storage cycles. In the Philippines, clones 384515.9, 385131.52, 385130.8, and 385152.44 were found to be especially promising. In screening for yield capability of sweet potato clones, we obtained acceptable tuber-root yields at each of CIP's stations in Peru, as well as at the salty-environment site at Tacna. Unacceptable tuber-root yields were obtained only during the hot rainy season at Yurimaguas. A new line of research has begun to examine the physiology of tolerance to water logging. In sweet potato drought research, our studies have demonstrated the importance of maintaining a good foliage cover over the soil and of an early storage-root formation.

Our studies of potato under drought conditions have identified clones that can avoid drought (large root systems, e.g. clones P-3 and P-7) or escape drought (early tuberizing clones, e.g. cv. Berolina). Drought resistance was confirmed for cultivars *Huinkul*, LT-7, and MS-3527 R. In Egypt, sunflower was identified as a good alternative crop to maize to shade the early autumn potato crop. Shade-tolerant cultivars also were identified for strip cropping in China.

The advantages of pest control through intercropping practices have now been quantified in Southeast Asia. Our recent research has demonstrated the potential for use of the sweet potato germplasm collection in selection for shade tolerance. Thus we anticipate future selection of clones specifically for intercropping.

In our work on improvement of potato and sweet potato production in cool environments of developing countries, we have emphasized multidisciplinary approaches. In field testing and selection for potato tolerance to frost at Puno (3,850), we selected clones for tolerance to frost, earliness, desirable agronomic characters, and high yields despite severe drought and incidence of frost. The outstanding clones were chosen for multiplication and potential variety releases in collaboration with INIA, Chile. The clones selected for long-day adaptation from CIP's improved germplasm produced tuber yields up to 30% greater than did locally grown cultivars. In contract research with INIA, Chile, the early sprouting CIP clone DT0-33 showed the most promising performance under suboptimal temperatures. The most important characteristics of such performance appeared to involve shorter dormancy and early tuber initiations, along with a rapid bulking rate. Studies in Cameroon indicated that poultry manure at an application rate of 5 t/ha produced the best results, as compared with yields obtained with locally available fertilizers. Reports from Ethiopia and Cameroon on the use of TPS for potato production indicated that the threshold for resistance to late blight in the segregating progenies is necessary for the success of this technology. Good progress was made in screening sweet potato clones for adaptation to cool environments at two coastal locations in Peru.

In potato storage research, our studies have emphasized consumer potato storage. Evaporative cooling techniques were studied in Peru, Kenya, and India, and forced-air techniques were studied in Pakistan. Simple rustic stores were tested in India. Household storage in bamboo baskets and sacks was analyzed in Burundi. In Peru, clones were evaluated for storage characteristics. Seed storage under rustic versus refrigerator conditions was studied in Egypt. Rustic storage of seed was evaluated in Cameroon. Storage in sand of tubers produced from TPS was examined in India. A storage workshop was held in Malaysia.

In potato processing research, our focus was on clonal evaluation (Peru, Thailand), continued testing and evaluation (including costs and returns) for rustic processing techniques (India), and marketing and demand for processed products in selected countries (India and Thailand). We also surveyed postharvest practices (China) and backstopping of ongoing CIP-related research and processing (Colombia, Guatemala, Peru, and Zaire) and in thesis work (Kenya). Sweet potato studies have also examined village-level rustic processing techniques in India. At Lima, thesis research continued to evaluate the nutritional and chemical characteristics of CIP's sweet potato germplasm collection, and a similar evaluation is now underway in Thailand. Sweet potato storage research using rustic stores has begun in India and Kenya.

Worldwide collaborative research continues to improve the agronomic characteristics of selected TPS progenies intended for seed production and use in warm-climate areas. Several parental clones were identified with acceptable berry-setting capacity to produce TPS with tolerance to bacterial wilt infection, and for transplanting stock with tuber uniformity and quality, and high-yield stability. Techniques for increasing the production of hybrid TPS were tested in Chile, India, Italy, and Peru.

We have intensified our research in postharvest handling of TPS. Seed-vigor losses following harvesting of TPS were shown to occur at a slower rate during storage, when the seed had been produced with high N rates. A dry environment during storage was found to be important. Seedling-vigor testing of selected TPS progenies at various periods of storage demonstrated that the seed must be after-ripened at about 5% to 7% moisture content (dry-weight basis) and under moderate-temperature (20C) conditions for at least 12 months, before the seed can be effectively stored in high-temperature environments. Pre-sowing TPS in a solution of KNO_3 plus K_3PO_4, followed by seed priming, was an effective treatment for enhancing seed vigor at sub-optimal temperatures.

In India and Peru, further improvements were made in the efficiency of seedling-tuber production techniques. The collaborative approach continues to investigate the technical problems and modifications needed at each site for optimal use of TPS in a seedling tuber production system. Paraguay, Venezuela, Cameroon, and Indonesia are more recent partners in this research.

Collaboration also has continued in strengthening or developing seed-tuber propagation systems in Bolivia, Burundi, Colombia, Venezuela, Kenya, Myanmar, the Philippines, and Peru. These projects seek to analyze the factors limiting potato production in traditional seed-tuber distribution systems. Their objectives also include the transfer of technology such as simple positive selection of healthy plants, advanced rapid multiplication and diffused-light storage techniques, and the development of simple flush-out methods for basic seed systems. This work strongly emphasizes the participation of farmers. In Kenya, an exceptional case study was completed as part of a series aiming to explore the strengths and weaknesses of local seed systems. Sweet potato propagation techniques were studied under a wide range of environments, and agronomic and climatic factors affecting flowering and seed production were identified. The use of in vitro-propagated plantlets, larger unrooted cuttings and rooted cuttings, were shown to result in faster establishment and growth, and increased flowering.

Food Systems Research

In our needs and impact assessment research, we focused on food systems characterizations, marketing, demand and utilization studies, and impact assessment. Food-systems characterization studies were greatly expanded as we analyzed the surveys completed by national scientists on constraints to potato and sweet potato production. Potato seed problems appear to be important in all countries, but are particularly serious in tropical rainy and dry areas. For sweet potato, the importance of the weevil as a production constraint is limited to tropical rainy zones. In other climatic zones, lack of planting material, moisture, and soil fertility were found to be production problems. And postharvest – especially marketing – problems were severe in all zones studied. We made case studies of potato and sweet potato food systems in Asia, Africa, and Latin America. In China, we deepened our knowledge of

utilization patterns in different provinces. Our studies underlined the variability of the production and utilization systems between the two crops and between provinces. Intra-provincial variability trends also were studied. The principal marketing research involved a project to synthesize the six potato marketing case studies completed over the past six years. Preliminary findings highlight the geographical concentration of potato production in Asia and the importance of rural marketing and rural consumption in South Asia and sub-Saharan Africa, as compared with urban marketing in Latin America.

The 1984 impact study "Potatoes for the Developing World" was updated, using a new questionnaire prepared for national program leaders and CIP senior headquarters staff and regional leaders. The results indicated growth in national program research in areas related to CIP's research, thus reflecting a strong correlation in priorities. CIP training activities were felt to have the greatest impact on NARS, followed by a number of production technologies especially related to seed. A much lower level of benefit was perceived for non-technical and non-production activities, perhaps due in part to the strong production orientation of most program leaders.

Our work in strengthening NARS is closely involved with two food systems-oriented networks. The PRACIPA marketing network completed two years of activities in 1989, and backstopping continues via workshops and annual meetings. The Users' Perspective with Agricultural Research and Development Project (UPWARD) began activities in Southeast Asia, with 12 projects focused on production, postharvest or consumption issues within a food-systems context. In addition to participation in informal courses or workshops, strengthening of NARS capacity has also been achieved through diagnostic studies of sweet potato food systems completed or being planned in Latin America or Africa.

Future Challenges

Our Thrusts reports reflect strong progress in potato and sweet potato research, with the basic strategies used for potato now paying off rapidly for sweet potatoes. Now we must find new ways to quantify and index the progress we have made.

What has been our impact? CIP and the NARS are inextricably linked in our efforts to improve global potato and sweet potato agriculture and we have no intention of changing our team approach. Nor do we intend to claim credit for all progress reported here. However, we do need to know which of our efforts are providing the best results for the NARS and their client farm families. To make best use of our combined resources we must understand the results that can be

attributed to CIP efforts versus those of NARS. We have begun to identify and describe such indicators of CIP's progress in all Thrust components: research, training, and communications. And consistent with one of CIP's basic principles we will continue to use our own expertise, and we will explore new ways to interact with other institutions that can help us through contracts and international planning conferences to be held in 1991.

In CIP's germplasm enhancement project, an alternative path has been developed to screen wild 2x and 4x accessions for desirable characteristics.

Thrust I

Collection, Maintenance, and Utilization of Unexploited Genetic Resources

Thrust Profile: 1990

Excellent progress has been made in the utilization and enhancement of diploid and tetraploid wild and cultivated potato germplasm, using traditional and newly-developed methods and their combinations.

Three diploid potato species new to science and a new form of the tetraploid species *S. acaule* were described and reported, and the biosystematic position was clarified for several species with excellent potential for germplasm enhancement.

The field-maintained cultivated potato collection planted in 1989 contained a total of 3,439 Andean cultivars, and about 99% of this material is now also maintained in vitro. More than 1,500 newly obtained accessions are being studied to eliminate duplication and to be added to the world collection. Security procedures have provided for further duplication of important potato germplasm outside CIP. A new approach is being tested to help in the conservation of genetic diversity in the potato fields of Andean farmers.

The genetic transformation of potato clones using *Agrobacterium* sp. plasmid vectors has also progressed rapidly.

A computerized database for the collection has been developed using all the available data. A total of 299 *Ipomoea* accessions were collected in 130 localities in Guatemala, Panama, and Peru and added to CIP's collection, and additional accessions were received as donations from Brazil and Australia. The IITA sweet potato germplasm collection is being transferred to CIP. A total of 3,520 sweet potato accessions of various provenances were planted, either in the field or in the quarantine screenhouse of CIP headquarters in La Molina, on the outskirts of Lima. In vitro introduction and duplication of this collection continued outside Peru. Additional emphasis was given to the use of electrophoresis to identify duplicates. CIP distributed 20,572 stem cuttings from 1,810 accessions, 3,810 storage roots from 561 accessions, and 2,345 seeds from 281 wild *Ipomoea* accessions for evaluation and utilization.

Sweet potato germplasm enhancement continued successfully, combining both innovative and traditional cytogenetic methods. Studies of wild 2x and 4x *I. trifida* species have shown exceptional promise for use in future sweet potato breeding work.

Biosystematic Studies on Potato

CIP researchers described three potato species new to science in 1989: *S. amayanum* and *S. bill hookerii* of the taxonomic series Tuberosa, and *S. salasanium* of the series Conicibaccata. All 3 have a chromosome number of $2n=2x=24$ and are from the central Andes of Peru (2,700 m to 3,700 m). A new form of the important tetraploid wild species *S. acaule* was also identified and named *F. incuyanum*. Preliminary tests of *F. incuyanum* have shown apparent resistance to multiplication of the PLRV virus and to mechanical inoculation of PSTVd. Taxonomic research on one of the putative ancestors of *S. acaule*, the diploid, highly frost-resistant species *S. bukasovii*, has greatly clarified the taxonomic position of this species. Comparative studies at various herbaria in the U.S.A., Europe, and at CIP have shown that the species *S. canasense, S. multidissectum, S. punoense,* and *S. pumilum* Hawkes (but not *S. pumilum* Dun. or *S. pumilum* Rojas) are all synonyms of *S. bukasovii*. This taxonomic clarification has underlined the enormous genetic variability present in *S. bukasovii*, a species that can be used in breeding without major problems. Accessions from the species *S. bukasovii, S. acaule, S. lepthophyes, S. marinasense,* and *S. chiquidenum* have been tested for resistance to *Globodera pallida*. In all of these species, the tests showed resistance to pathotype P4A and P5A, and *S. marinasense* and *S. chiquidenum* showed combined high resistance to both pathotypes.

Current systematic screening for 2n pollen production in CIP's wild germplasm collection has two objectives: 1) to better understand evolutionary processes in species formation and 2) to find new ways to utilize wild germplasm in breeding. Unreduced pollen was identified in the hexaploid Mexican species *S. fendleri*. In Peruvian coastal material, *S. medians* was found to have a high frequency of 2n pollen production (30%), which helps to explain the high frequency of the triploid cytotypes of this species.

Hundreds of intra- and interspecific crosses were made to determine the Endosperm Balance Number (EBN) of species for which the EBN was not known or needed to be confirmed. The results of crosses between 1EBN and 2EBN species are being analyzed to assess the effects of this specific crossability barrier. Several hybrids with progenitors having different types of resistance genes have been obtained within the wild species genepool, and hybrid materials with potential for combined resistances will be evaluated for these resistances.

Potato Germplasm Collection

Potato Germplasm Maintenance

The total cultivated potato collection planted in the field in 1989 consisted of 3,439 Andean cultivars. About 99 percent of these cultivars are also maintained in vitro. Another 1,600 accessions from recent introductions are being studied to identify new cultivars that are not represented in the world collection.

As a security measure for the potato collection, CIP has duplicated a set of tubers of Peruvian cultivars at the National Agrarian University in Peru. This university maintains a national potato collection in a high-altitude field genebank in central Peru. In collaboration with the SEINPA project in Peru, a new approach is being tested to conserve potato genetic diversity in the fields of Andean farmers. This project helps train farmers in the true-potato-seed (TPS) technology as applied to native Andean cultivars. Selection of segregating virus-free plants is made by the farmers according to their local needs and preferences. Farmers in three localities are now using TPS of about 20 native cultivars that are most popular in those geographical areas with traditional agriculture, such as Cajamarca, Cuzco, and Puno.

A new cold room (-15C) for long-term storage of seeds has been added to the Genetic Resources Laboratory and sufficient space is now available to house duplicate sets of seeds from other potato genebanks.

Elimination of Duplicates

Duplicate identification is continuing within 1,600 potato accessions from recent introductions. After electrophoretic verification, 603 duplicates were eliminated in material obtained from Argentina, Bolivia, and Peru.

Evaluation and Distribution of Potato Germplasm

Of 200 Andean cultivars screened for resistance to the potato tuber moth, *Phthorimaea operculella* (PTM), 15 were found to be resistant and 35 moderately resistant. Pathogen-tested Andean cultivars were distributed to 14 countries as 215 tuber samples, 357 in vitro plantlets, and 7,090 seeds.

In Vitro Collection of Potato Germplasm

The transfer of the world potato collection to in vitro culture is now complete. The material is fully duplicated outside of Peru through a collaborative agreement with INIAP, the national agricultural research organization of Ecuador. In vitro introduction of clonal material of odd ploidy and wild species was begun during the year. Computerization of maintenance procedures of the collection is now complete, and all labelling is prepared by computer.

Utilization Studies on Potato

The Utilization of *S. acaule*

In selection, maintenance, and utilization of clones resistant to PLRV and PSTVd, 124 clones of *S. acaule* that had been found to be resistant to PSTVd by mechanical inoculation were further tested by *Agrobacterium*-mediated PSTVd cDNA inoculation (strain p160a) for resistance to the same pathogen. Twenty-one clones from this material were found to be resistant to *Agrobacterium*-mediated PSTVd inoculation, and an additional 4 were identified with apparent resistance to PLRV. The PLRV resistance is based on resistance to aphid infestation and multiplication of the virus. The 25 clones thus identified have been transferred to in vitro and are ready for utilization in germplasm enhancement and breeding. Preliminary screening results indicate that some of this material also might carry resistance to PVY and PVX. From this *S. acaule* material, F_2 and backcross populations have been generated that will be used in RFLP mapping projects for the identification of genes that determine resistance to PSTVd and to some viruses.

Several systematic schemes for the effective utilization of this *S. acaule* material have been developed, including a cross combination between *S. acaule* and tetraploid-cultivated potato clones, a combination that always failed in the past, due to the operation of the triploid block or the EBN barrier. An innovative approach using counterfeit pollination with the haploid inducer IvP 35 and embryo rescue resulted in six 4x *S. acaule* x *tuberosum/andigena* hybrids. This material was further crossed with 2x breeding material, and the resulting tetraploid hybrid clone AA-3 is resistant to PSTVd, is immune to PVY, and is hypersensitive to PVX. All of these resistances were obtained from the *S. acaule* source. Some of the sibs of AA-3 are aneuploid and will thus provide excellent material for RFLP gene-marker studies.

Potato Germplasm Enhancement

Diploid and 4x x 2x Potato Germplasm

Screening for resistance to root-knot nematode (RKN). Findings confirmed that CIP's 2x progenitors with resistance to RKN transmit that resistance to their 4x progenies which result from 4x x 2x crosses. About 18% of the 4x progenies thus obtained were resistant to RKN. These results also indicated that male x female interaction determines the levels of resistance expressed in the 4x hybrid material. An average increase of 5C in the testing environment caused by a change of roofing material, further demonstrated that higher temperatures might eliminate resistance reactions observed in the same material in previous seasons.

Because of the temperature problem encountered in the customary testing environment, an in vitro method was used to test newly developed diploid clones for RKN resistance. High levels of resistance were identified in 5 new diploid clones. This material broadens the specific genetic base of RKN resistance at CIP, since the only previous effective and usable wild sources of RKN resistance were clones of *S. sparsipilum*. The new diploid material has *S. multidissectum*, *S. bukasovii*, *S. canasense*, and *S. gorlayi* in its background. These wild species were crossed with dihaploid *S. tuberosum* ssp. *tuberosum* clones that were produced under a research contract with the University of Wisconsin. Some of these clones have good 2n pollen production and are now in use in a 4x x 2x crossing program. Their excellent tuber appearance had been confirmed in a previous growing season.

Resistance to bacterial wilt in selected 2x clones. A total of 40 diploid clones were evaluated by inoculation with isolate 204 of *Pseudomonas solanacearum*. Each clone was represented by 10 plants that were evaluated for wilt symptoms after 12, 25, and 32 days. The scale used in this evaluation ranked from 1 (no wilting) to 5 (completely wilted plant). Three clones from this group (84.193.30, 85.37.38, and 85.123.8) had a score of 2 at 25 days after inoculation, whereas the completely susceptible check, the Peruvian variety "Yungay," had a score of 3.4. All of the resistant genotypes have clone MI.49.10 in their pedigrees. This clone had previously been selected for bacterial wilt resistance and 2n pollen production. Similarly, 84.193.30 and 85.123.8 had previously demonstrated resistance to BW. Clone 85.37.38 is known to transmit RKN resistance to its 4x progenies resulting from 4x x 2x crosses; thus this clone combines BW and RKN resistance, and it has been used as a pollen parent in seventeen 4x x 2x combinations to obtain more than 12,000 seeds.

Resistance to the Potato Tuber Moth (PTM). Excellent progress has been made in transferring PTM resistance from the wild species *S. sparsipilum* to 2x cultivated germplasm, with findings indicating that the presence of *S. sparsipilum* is desirable, but not essential, for the expression of resistance. A total of 466 clones from nineteen 2x families were evaluated for their resistance to PTM, under storage conditions at San Ramon. Five replications per genotype were used, and the material was evaluated 150 days after it had entered storage, using a scale ranking from 1 (resistant) to 4 (completely susceptible). High levels of resistance were identified in family 2x-TS-2 x PTM1.33, which had *tuberosum* cytoplasm. The average resistance score of this family was 2.28, and 4 clones had a score of 1. Doubling of the chromosome number of these clones is now under way. Parental 2x clone MI.49.10 appears to transmit PTM resistance as two families with this progenitor, which had been crossed with susceptible females, showed good levels of resistance to PTM. Initially, MI.49.10 had been selected for resistance to bacterial wilt and for its ability to produce 2n pollen. Since its wild progenitor is a clone of *S. sparsipilum*, this result might be expected. In comparing progenies derived from 2x x 4x crosses with MI.49.10 and FH122 (PTM susceptible clones of *S. stenotomum*) as pollen parents, the progenies with MI.49.10 in their pedigrees showed considerably higher levels of resistance than did those derived from FH122. The 116 seedlings from 5 families with MI.49.10 as male parent had an average score of 2.86 after 150 days of storage, whereas 93 seedlings from 4 families with FH122 as their male parent scored as high as 3.31 after the same length of time in storage. These findings are the more remarkable because MI.49.10, which is clearly the source of this resistance, was not specifically selected for this characteristic. These results support the idea that RKN, BW, and PTM resistance, as well as 2n pollen production, can be combined in individual diploid genotypes that will transmit these characteristics to their 4x offspring.

From material identified as PTM resistant in previous experiments under conditions of natural infestation in San Ramon, 152 clones were further studied with a laboratory non-choice test, and three groups were identified in the 2x material according to their levels of resistance. The first group is from crosses between *S. tuberosum* haploids and PTM-resistant diploid clones (S x R). Of 89 clones studied, 7 were classified as resistant (R) and 29 as moderately resistant (MR). The identification of 7 clones with a clear-cut resistance reaction supports the conclusion that PTM-resistant clones can be developed without the *S. sparsipilum* cytoplasm. The second group was a reciprocal cross of the first (R x S). Only 5 clones were tested, and none were resistant. The third group represented a cross between resistant clones (R x R). Of the 17 clones tested from this group, only one was susceptible, whereas 9 were resistant and 7 moderately resistant. Previous results had indicated that clone MI.49.10 transmitted some PTM resistance to its 4x progenies in 4x x 2x crosses. However, when thirty-eight 4x clones that had MI.49.10 as a male progenitor were tested by the laboratory method, none was resistant. It appears that all clones identified as moderately resistant under San Ramon conditions turned out to be susceptible when tested by the laboratory method.

Yield trials of 4x x 2x progenies. Tetraploid progenies obtained from 4x x 2x crosses were field tested to ascertain whether the 2x progenitors, which were often derived from wild species, would transmit their resistance to their 4x progenies. The agronomic performance of the 4x material was evaluated at the same time. The 4x material derived from wild species often produced high-yielding clones with excellent agronomic characteristics and the desired resistances, but this material was usually late-maturing. Use of early-maturing 4x females in 4x x 2x crosses was suggested to correct this deficiency. To assess the relative importance of 4x female parents in the expression of maturity in their 4x offspring following a 4x x 2x cross, two groups of genetic material were produced. The first group consisted of families derived from crosses between five 4x female parents (P-3, LT-8, Atzimba, I-1035, and 781313F2) and 11 male parents, of which seven were 2x and four 4x. Of 55 cross combinations, 49 hybrid TPS families were produced. Use of the wide range of maturity types within the group of female parents is expected to provide a clear understanding of locally adapted, early-maturing females that could be considered for this type of 4x x 2x cross. The second group was produced by crossing early-maturing females (Atlantic, Katahdin, AVRDC 1287.19, LT-1, and HP278.22) with five male parents (of which four were 2x and one, 7XY-1, 4x). This group was generated to assess whether known early-maturing females can correct the late maturity derived from 2x males with specific resistances. Collaborative research is under way in a doctoral thesis study at the University of Wisconsin.

Distribution of seeds from 4x x 2x crosses to CIP breeders. Critical evaluation of progenies derived from 4x x 2x crosses in breeding programs is essential to assess the parental value of the resistant 2x progenitors. Therefore, a list of 158 TPS families derived from 2x x 4x crosses was distributed to CIP breeders to enable them to make use of this material in their advanced breeding programs, as well as to assess the parental value of the 2x progenitors that are 2n pollen producers with specific resistances to BW and RKN.

Application of molecular methods for potato germplasm enhancement. Significant advances were made in the use of *Agrobacterium* plasmid gene constructs to transform potato clones. A range of new promoter (control) sequences was obtained and tested, and it is now possible to regulate the amount and site of a particular gene product. Such control allowed direct production of synthetic proteins high in essential amino acids and specifically directed to potato tubers.

A relatively new marker gene, known as GUS, was added to all gene constructions. GUS, which codes for the production of an enzyme that reacts when the plant is given a particular substratum,

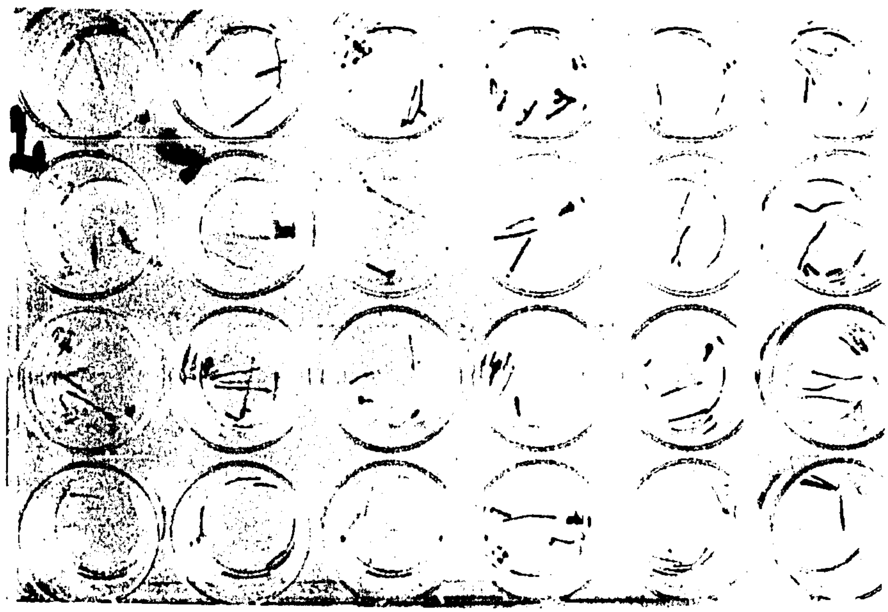


Figure 1-1. Isolated roots in test for GUS activity. This test indicates preliminary evidence for gene insertion. GUS-positive reaction is indicated by blue-stain reaction.

represents a simple colorimetric test to ascertain the presence or absence of this gene product. Figure 1-1 shows the results of a GUS assay.

A wide range of transformation experiments was performed in 1989 using both *A. rhizogenes* and *A. tumefaciens*. The transformation products from these experiments have been tested using both kanamycin resistance and GUS reaction. New, more potent genes that show activity against *Pseudomonas solanacearum*, the causal agent of bacterial wilt, have been synthesized under contract with Louisiana State University in the U.S.A. These genes code for antibacterial proteins such as attacin and cecropin.

However, synthetic modifications known as SB-1 and Shiva show a substantially higher level of antibacterial activity than does the natural component. Plantlets transformed with Shiva have already been tested with kanamycin and GUS and have been through early screening trials conducted by CIP's pathologists. Cuttings from the survivors of the early screening are being re-tested.

Collaborating with institutions in Florence, Naples, Rome, and Viterbo, CIP assisted in studies on transformation for pest and disease resistance and the use of in vitro methods to select for resistance to biotic and abiotic stresses.

Restriction Fragment Length Polymorphism (RFLP) Analysis. During 1989, CIP established a new research contract with Cornell University in the U.S.A. to further develop the already existing RFLP linkage map of potato (shown in Fig. 1-2). The map has advanced significantly and is based on tomato probes. On the basis of this map, a collaborative Cornell University-CIP project was car-

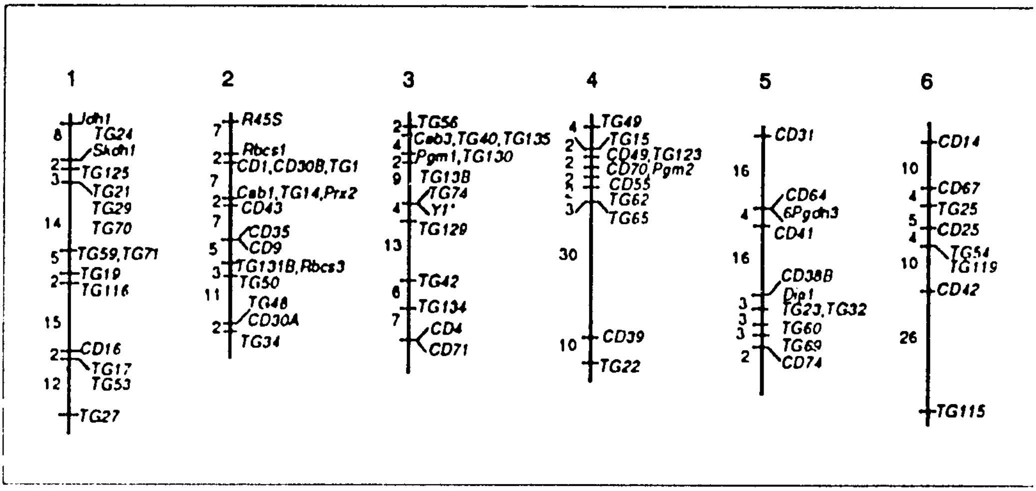


Figure 1-2. Genetic linkage map of potato.

ried out by a CIP scientist on sabbatical leave at Cornell. The map was principally used to elucidate, in preliminary fashion, the phylogeny for tuber-bearing *Solanums*. The results are shown in Figure 1-3. This figure demonstrates how RFLP data can be used to assist plant breeders. The next step is population development and identification of useful traits. A number of populations are currently being

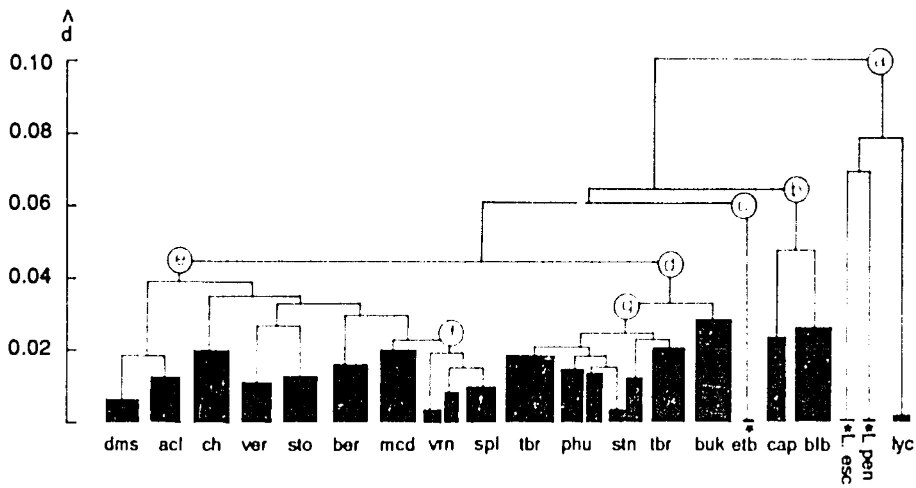
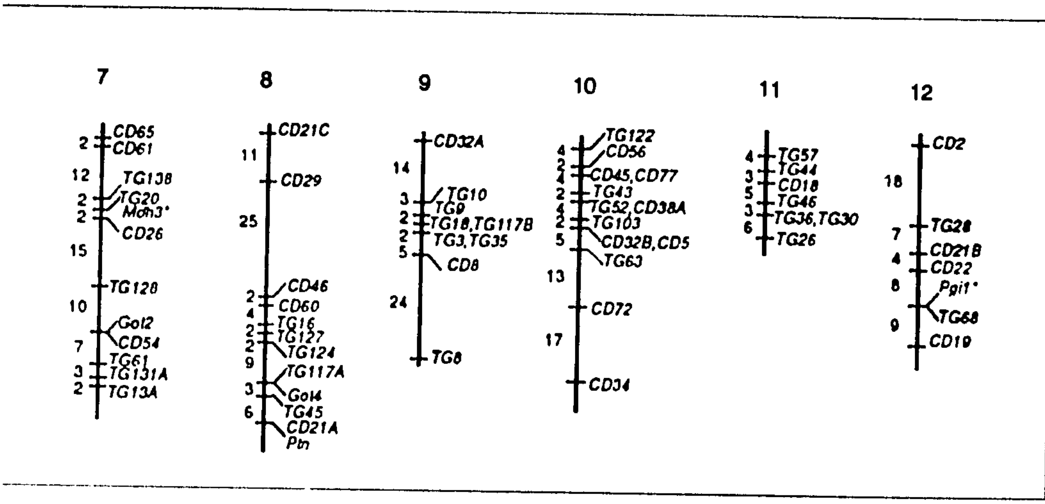


Figure 1-3. Dendrogram representing estimates of genetic distance (d) based on all RFLPs observed among 18 *Solanum* and two *Lycopersicon* species. Abbreviations for species are as follows: dms = *demissum*; acl = *acaule*; chc = *chacoense*; ver = *verrucosum*; sto = *stoloniferum*; ber = *berthaultii*; mcd = *microdontum*; vrn = *vernei*; sp' = *sparsipilum*; tbr = *tuberosum*; phu = *phureja*; stn = *stenotomum*; tbr = *tuberosum*; buk = *bukasovii*; etb = *etuberosum*; cap = *capsicibaccatum*; blb = *bulbocastanum*; L. esc = *Lycopersicon esculentum*; L. pen = *Lycopersicon peruvianum*; lyc = *lycopersicoides*.



produced at CIP which will allow further development of the potato RFLP linkage map. During 1989, CIP also began to establish a cooperative network for RFLP research. This network should expand quickly to include a database and mapping clone bank.

Sweet Potato Genetic Resources

Collecting Activities and Taxonomic Identification

During 1989, six collecting expeditions were made: one each in Guatemala and Panama, and four in Peru, with a total of 299 accessions collected in 130 localities. Of these accessions, 155 were *I. batatas*; 9 represented two *Ipomoea* species from section *Batatas*; 12 represented seven species from other sections, and 123 are not yet classified (Table 1-1).

Germplasm Donations

EMBRAPA donated in vitro cultures of 79 sweet potato accessions from Brazil, and PRI donated an in vitro shipment of 11 accessions from Australia.

Duplication of the IITA sweet potato germplasm collection at CIP has been initiated with the transfer of 210 accessions maintained in vitro. This genetic material includes 34 advanced selections and 176 breeding lines. The 1,202 IITA accessions have been thoroughly documented, and a computerized database now contains all available data.

Table 1-1. Taxonomic identification of *Ipomoea* species collected in 1989.

Species	Guatemala	Panama	Peru	Total
Section Batatas				
I. batatas	14	71	70	155
I. trifida	8	0	0	8
I. peruviana	0	0	1	1
Other sections				
Seven species	7	0	5	12
Undetermined	108	6	9	123
				299

Germplasm Maintenance

In 1989, a total of 3,520 sweet potato accessions were planted at La Molina. From these 3,520 accessions, 1,868 Peruvian cultivars and 338 breeding lines were grown in the field. Another 966 sweet potato cultivars from countries other than Peru were grown in pots in the quarantine screenhouse, and 348 accessions are being maintained as in vitro culture.

The genetic resources staff of two INIAA experiment stations in Peru received training related to the maintenance of seed potato germplasm.

A total of 54,379 open-pollinated seeds were obtained from 78 accessions of 10 wild *Ipomoea* species of section *Batatas* grown in pots at La Molina. Additionally, 2,933 seeds from self-pollinations of 17 accessions (representing five species) were received from North Carolina State University (NCSU).

The In Vitro Germplasm Collection

During 1989, in vitro introduction of new sweet potato accessions was limited to material of highest priority because of lack of adequate growth space. A total of 2,400 sweet potato accessions have now been introduced into in vitro and maintained under slow growth conditions. Various experiments are under way to improve the existing slow-growth conditions that allow approximately 9-12 months between sub-cultures. Of the 2,400 accessions maintained in vitro, 900 were duplicated outside of Peru under an agreement with Centro IDEAS in Venezuela. Such agreements help to safeguard these valuable genetic resources.

Duplicate Identification

Duplicate verifications by electrophoretic analyses were made in 252 Peruvian cultivated accessions that were from 60 groups with identical morphological characters. These analyses were made at the Institute of Biochemistry in Braunschweig, West Germany, and the electrophoretic results and the groupings based on morphological data were found to be in agreement for approximately 85% of the accessions. Experiments were also designed to test the stability of the sweet potato electropherograms. No electrophoretic differences were found in comparing storage roots from the same cultivar at weights of approximately 30, 60, 120, and 250 grams. In addition, no differences were found in protein and esterase patterns, when comparing storage roots of different physiological states. Analyses of samples of the same cultivar harvested at weekly intervals (begun 45 days before the main harvest) showed only minor electrophoretic differences in the youngest storage roots.

Training courses in the use of morphological descriptors for duplicate identification in sweet potato germplasm collections were conducted in Kenya and Togo, where several institutions maintain similar collections.

Germplasm Evaluation

Nutritional components of storage roots were analyzed at AVRDC on samples from 897 Peruvian cultivars with the following findings. Of the cultivars, 35 had a dry-matter content of more than 40%; 13 had a starch content of more than 70%; 4 cultivars combined more than 35% of dry matter with more than 10% of total protein; 4 cultivars had less than 2% total sugar content; and 26 cultivars had less than 2% fiber content. Significant negative correlations were found between dry matter and total protein content (r = -0.106) and between dry matter and fiber content (r = -0.411). The correlation was positive between dry matter and starch content (r = 0.432).

Peruvian sweet potatoes collected at more than 2,000 m were evaluated in cool environments in Caraz, Peru (2,300 m) and at three other locations in Peru. Temperatures reached 10C to 12C at 40 to 60 days after planting, resulting primarily in a shortening of the internode length and reduction in leaf size. The most noticeable effect was on storage root development; of 57 accessions grown at Caraz, 18 yielded more than 800 grams per plant in a growing period of five months. A general observation was that those accessions having leaves with medium to deep lobing showed higher tolerance to cool temperatures.

Twenty-five Peruvian sweet potato cultivars with vernacular names that are associated with potato or cassava or stem plants because of their low sugar content, skin color, or flesh color, also were evaluated for yield potential at Caraz. Three of the 25 cultivars tested yielded more than 800 grams per plant in 5 months.

Storage roots of 106 accessions of *I. batatas* were screened for resistance to the *Euscepes postfasciatus* weevil. A total of 18 cultivars were rated as resistant and another 12 as moderately resistant.

CIP has worked with the national programs through two research contracts in the People's Republic of China (Xuzhou and Guandong) to characterize the Chinese National Sweet Potato Collection, to computerize the data, and to introduce the clones to in vitro culture.

Germplasm Distribution

Distribution of genetic materials for evaluation or utilization at CIP included 20,572 stem cuttings from 1,810 accessions; 3,810 storage roots from 561 accessions; and 2,345 seeds from 281 accessions of wild *Ipomoea* species.

Sweet Potato Germplasm Enhancement

Production of Cultivated Hybrid Material with Specific Traits

True sweet potato seeds have been produced in polycrosses for some traits of interest to breeders. These traits are low sugar content in storage roots, orange flesh color, white flesh color, tolerance to cool environment, and adaptation to high altitude.

Development of Cytological and In Vitro Techniques

The development and use of a synthetic 6x I. trifida population. After colchicine treatment of 3x *I. trifida* hybrids, 55 genotypes with good pollen stainability were identified and selected. They are either synthetic 6x clones or 3x clones with a high frequency of 2n pollen. To develop a 6x population with reduced breeding effects, these 55 selected genotypes were inter-mated by hand pollination, and a total of 236 plump seeds were obtained from 58 families. A polycross also was set up in San Ramon to produce quantities of seed, while eliminating labor-intensive and time-consuming hand pollinations. Five plants per genotype were planted in pots and the polycross block was isolated from other *Ipomoea* plants by at least 800 m to ensure complete isolation. Each of the genotypes planted in San Ramon had previously been checked for self-incompatibility. The 38 genotypes produced more than 3,000 plump seeds, and eight of the genotypes produced more than 100 seeds each, all of them hexaploid. Hexaploid clone A.19.2.1 produced 622 plump seeds, the highest number obtained from a single clone in this experiment. Of the 55 clones that had entered the polycross block, 17 did not produce any seeds. They are mostly 3x clones with 2n pollen production. However, 18 of the 3x clones did produce some seed, indicating the production of 2n eggs in this material. The value of the polycross method for the production of large quantities of seeds was well demonstrated with this experiment, and the seeds obtained represent a new cycle of a 6x I. trifida with improvements for male and female fertility. These seeds have been sent to China and the Philippines for use in interspecific breeding programs there, and another set of this 6x material will be made available under CIP's research contract with NCSU.

The 55 genotypes selected for the polycross experiment in San Ramon were also tested for their resistance to RKN at La Molina. Six genotypes demonstrated a high level of resistance to this nematode, and another 17 were classified as resistant. The resistant clones were field-tested in San Ramon, and 19 out of 23 clones were again found to be highly resistant. They are now being used as a new source of resistance to complement available sources of RKN resistance in cultivated sweet potato material.

The production of interspecific hybrids of I. batatas and I. trifida. In La Molina, 9,054 hand-pollinations in crosses between 6 sweet potato cultivars and the 55 selected *I. trifida* clones mentioned earlier, produced 1,130 seeds from 135 families. When these seeds were sown in San Ramon, however, only 60 (5.3%) germinated. This result confirms the hypothesis that there is an incompatibility between the cultivated sweet potato *I. batatas* and *I. trifida*, which is expressed as low germinability of the hybrid seeds. This may represent a constraint for the efficient use of *I. trifida* in sweet potato breeding. Further interspecific crosses between *I. batatas* and *I. trifida* resulted in 322 seeds from more than 8,000 hand pollinations. This seed is being made available to regional breeding programs upon request.

Production and use of 4x interspecific hybrids. The successful production of 4x interspecific hybrids was reported in the 1989 Annual Report and these hybrids were evaluated in the field at San Ramon last year. The yielding ability varied widely and the majority of the 4x hybrids yielded little (less than 200 g per plant), or nothing. However, 4 hybrid clones yielded more than 1 kg per plant, whereas the cultivated 6x parents of these clones, which had been planted as checks, yielded only 0.49 kg per plant or less. Twenty of the 4x hybrids were selected for their high yields and were crossed with accessions of 2x and 4x *I. trifida*. It was expected that the 3x or 4x hybrids resulting from these crosses would produce storage roots as a result of the input of genes that determine this character from the root-producing, 4x hybrid progenitors. Evaluation of the performance of the hybrids thus obtained allows an indirect estimation of the value of 2x and 4x accessions. Table 1-2 shows the

Table 1-2. The production of hybrid seeds by inter-mating 2x and 4x *I. trifida* and 4x interspecific hybrids in various combinations.

Cross combination	No. of pollinations	No. of seeds[a] A	B	C	No. of A seeds/ 100 pollinations
2x *trifida* x 4x hybrids	5287	193	304	525	3.65
4x hybrids x 2x *trifida*	5307	1380	96	110	26.00
4x *trifida* x 4x hybrids	1529	1529	312	100	20.41
4x hybrids x 4x *trifida*	4977	1528	80	199	30.70
4x hybrids x 4x hybrids	8450	799	97	119	9.45

[a] A = plump seeds, B = intermediate, C = empty seeds.

results of the crosses involving selected 4x hybrid progenitors. More than 25,000 pollinations were made, and 4,212 plump seeds were obtained. Seed-set results (number of seeds per 100 pollinations) indicated a clear reciprocal difference in crosses between 2x *I. trifida* and 4x interspecific hybrids. This finding is in accordance with empirical data indicating that the plant with the lower ploidy level should be used as a male in inter-ploidy crosses. These 4x hybrids may have low male and female fertility rates, which might be expected in interspecific hybrids. Field experiments are under way to test the hypothesis that 4x interspecific hybrids, which are able to form storage roots, might be used as testers to indirectly determine the genetic value of wild 2x and 4x *Ipomoea* materials that are unable to form storage roots.

The low fertility of the 4x interspecific hybrid material reduces the efficiency of seed production in crosses with 2x or 4x wild *Ipomoea* clones; thus some of the 4x interspecific hybrids were intermated and their progenies were checked for pollen stainability. Dramatic improvement in pollen stainability was observed in these progenies, as compared with that of the original parental material. About 77% of the new population had pollen stainability higher than 50%, whereas only 6.2% of the original 4x interspecific hybrid population had such values.

Crossability Studies Within Section Batatas

The taxonomic section Batatas of the *Convolvulaceae*, to which the cultivated sweet potato belongs, contains many wild species; only *I. trifida* has been used in the work of sweet potato germplasm enhancement. This crossability study was begun within this section to study the feasibility of using the rest of the taxonomic section for germplasm enhancement work. In six of the 11 species studied, 2n pollen was formed. Of 70 interspecific combinations examined, 28 were successful, and high crossability was observed between parents of the same ploidy level. Through their use as bridging species within section *Batatas*, all 11 species studied have become genetically accessible either directly or indirectly; thus, this section has been opened up for future sweet potato germplasm enhancement work.

Attributes for resistances or tolerances to pests, diseases and stresses are being combined with those for yield, tuber characteristics, and processing quality.

Production and Distribution of Advanced Genetic Material

Thrust Profile: 1990

In selection of potato progenitors for variety development and for true potato seed (TPS) utilization, progenies of advanced clones from CIP and from research contracts were evaluated at several locations within Peru. The selected clones showed good parental value for yield, earliness, and tuber characteristics, and some of them had good attributes for processing quality. To evaluate tolerance to drought and salinity, 800 potato clones (selected at San Ramon and La Molina) were tested at Tacna during the 1989 winter season, using single plots of 20 tubers/clone. Some clones from this population showed high yield and earliness. The combination of these traits with resistance to viruses and other diseases that are present in this population give an added value to the progenitors to be selected in forthcoming evaluations.

Populations bred for adaptation to warm tropical environments and a selection of TPS progenitors were evaluated at San Ramon and La Molina. Of 200 clones, 10 were selected at La Molina and 2 at San Ramon. Specific gravity (SG) of these clones ranged from 1.066 to 1.093; reducing sugar content (RS) ranged from 0.05% to 0.18%, and yield ranged from 0.6 to 1.3 kg/plant. The clones showed good tuber shape, color, and quality attributes for making chips and french fries.

At San Ramon, Peru, approximately 220 clones from 1987 and 1988 TPS populations were evaluated for their agronomic and reproductive characters, under rainy- and dry-season conditions. Some clones showed excellent agronomic and reproductive characteristics, including LM88-B-40, LM88-B-38, LM88-B-10, LM87-B-217, and LM-87-B-27. These clones are being placed in crossing blocks to assess their parental value.

At present, identification of triplex and quadruplex (YYYy and YYYY) clones with immunity to PVY is under way. This is an important CIP achievement as it will permit definitively resolving the serious problem of PVY, one of the most damaging potato viruses. In fact, any susceptible clone crossed with the triplex or quadruplex clones will produce progenies with all individuals immune to PVY. Also, duplex clones immune to both PVY and PVX are being identified (YYyyXXxx). Any susceptible clone crossed with these duplex clones will produce progenies with 70% of individuals immune to both viruses.

Germplasm was distributed from CIP-Lima to countries in west and central Africa, including Ghana, Equatorial Guinea, Ivory Coast, Liberia, Cape Verde Island, and Mali. Clones were evaluated directly under farmers' conditions, independently, and in participation with the collaborative institutions. Only organic manure was used as fertilizer during the growing season.

Promising new clones have been selected in experiments to assess cultivars of diverse genetic types for yield and other qualities. These experiments were conducted in New Caledonia, Thailand, Fiji, Tonga, French Polynesia, the Solomon Islands, and the Cook Islands (Southeast Asia and the South Pacific). The clone 377850.1 was selected in Fiji and has shown good bacterial wilt and virus resistance, along with heat tolerance and good storability. Many other promising clones are now in the early stages of evaluation.

More than 200 CIP cultivars have been evaluated at the different locations in China. In yield trials conducted at Enshi, Hubei province in southern China, clones 386221.7, 386081.3, and 386198.3 outyielded the local cultivar and are being further evaluated.

In China, the area grown from TPS transplants increased from 80.5 ha in 1987 to 110 ha in 1988, and to 150 ha in 1989, and included farms in approximately 20 provinces in southwestern China, and Humeng and Datong in northern China. Improved logistics, availability of high quality TPS, the establishment of TPS collections, distribution procedures, and CIP input in personnel training contributed to this increase.

In sweet potato population-improvement work done in Peru in the coastal desert and in the Amazon basin, the initial goals are to select materials with high yield, early root bulking, broad adaptation, and a range of characteristics important to consumers. Emphasis is on evaluation and use of the newly collected Peruvian germplasm. Foreign sweet potato clones introduced into Peru will be used in breeding and to compare Peruvian materials with advanced foreign materials. However, quarantine restrictions have slowed the introduction of these foreign clones.

During 1989, CIP distributed potato genetic materials to cooperators in 88 NARS, and shipments of in vitro plantlets, tuber families, true seed families, and TPS showed increases over 1988. Materials now available from the pathogen-tested list include: 245 advanced cultivars and varieties, plus 35 in the clean-up process; and 172 accessions from native and wild germplasm, plus 56 in the clean-up process. Six sweet potato cultivars are now on the pathogen-tested list and 62 are in the clean-up process.

Potato Population Development

Extensive selections were made for parental lines to be used for variety selection and for true potato seed (TPS) utilization. During the summer, at La Molina, Peru, 42 advanced clones from CIP's program (30 clones) and from the University of Maine (12 clones) were evaluated for their parental value. The tester used was a pollen bulk of clones with combined immunity to both PVY and PVX. Clones C83.383, Maine-37, C1-137, C84.081, and C84.707 showed good parental value for yield, tuber uniformity, selected genotypes, and medium maturity rates.

At San Ramon, Peru during the summer, a sample of 35 clones was evaluated for general combining ability (GCA), using a line x tester design (5 x 7). This sample included clones with immunity to PVY (simplex and duplex) and PVX, and with combined immunity to both PVX and PVY.

The yields were acceptable (Table 2-1), with many of the progenies showing high yield, good tuber uniformity, and earliness. All of these progenies segregate for either PVY or PVX immunity. Clones XY.15 and C84.705 were found to have a high GCA for yield, tuber uniformity, and earliness.

During the winter at La Molina, a sample of 286 clones introduced from Uruguay, was evaluated for agronomic attributes using single plots of 10 hills. This sample had been generated from segregating TPS progenies for processing attributes and virus resistances (PVX, PVY, and PLRV). The resultant

Table 2-1. Top-performing progenies from a line x tester using 7 lines of 5 testers. San Ramon, summer 1989.

Progeny	Yield (g/plant)	Tuber uniformity	Earliness
C84.705 x YY-9	613	6.3	6
C84.705 x YY-15	556	6.3	7
C83.119 x YY-9	538	5.7	4
C84.705 x YY-1	510	6.3	8
I-1035 x XY-15	497	6.7	7
C83.119 x XY-15	466	6.8	4
I-1035 x LT-9	465	6.9	8
C83.119 x YY-1	457	6.6	5
B-71-240.2 x YY-9	456	6.6	6
C84.705 x Y87-013	451	6.2	8
C84.705 x Y87-018	434	6.3	6
C84.705 x YY-5	431	6.0	7
B-71-240.2 x XY-15	430	6.4	6
C84.412 x YY-9	416	6.9	6
C84.705 x LT-9	411	5.9	8
LSD (0.05)	152.8	0.7	1.9

Table 2-2. Top-performing advanced clones selected at San Ramon. Evaluated at Tacna at 90 days. Winter 1989.

	Clone	Plant survival (%)	Yield (t/ha)
1	(CFK-69.1 x 377964.5)21	70	22.42
2	(LT-9 x 378676.6)4	70	14.67
3	C86.027	80	12.17
4	C87.077	90	12.03
5	(LT-8 x 575049)1	80	11.11
6	(LT-8 x 377964.5)25	80	10.78
7	(CFK-69.1 x 377964.5)12	90	9.89
8	379418.1	70	7.94
9	C84.617	80	5.22
10	LT-8	80	3.83

clones were shown to have an adequate tuber shape for processing purposes, and 23 of them were selected and are being tested for immunity to several viruses.

To evaluate drought and salt tolerance, 800 potato clones (selected at San Ramon and La Molina) were tested in Tacna, Peru during the 1989 winter season, using single plots of 20 tubers/clone. The clones showed high yields and a good level of earliness (Table 2-2). This population contains many combinations of resistances to virus and other diseases that may be useful in developing parental clones in future evaluations.

Populations bred for adaptation to hot tropical environments and for TPS parental-line selection were evaluated at San Ramon and La Molina. Of 200 clones, 10 were selected at La Molina and 2 at San Ramon. Specific gravity (SG) of these clones ranged from 1.066 to 1.093; reducing sugar content (RS) ranged from 0.05% to 0.18% using the glucotest strip and yield ranged from 0.6 kg/plant to 1.3 kg/plant, with good tuber shape, color, and uniformity for making chips and french fries (Table 2-3).

In a genetic study, an 8 x 8 diallel design, including F1s and reciprocals,

Table 2-3. Clones selected for processing at La Molina (winter) and at San Ramon (dry season), 1989.

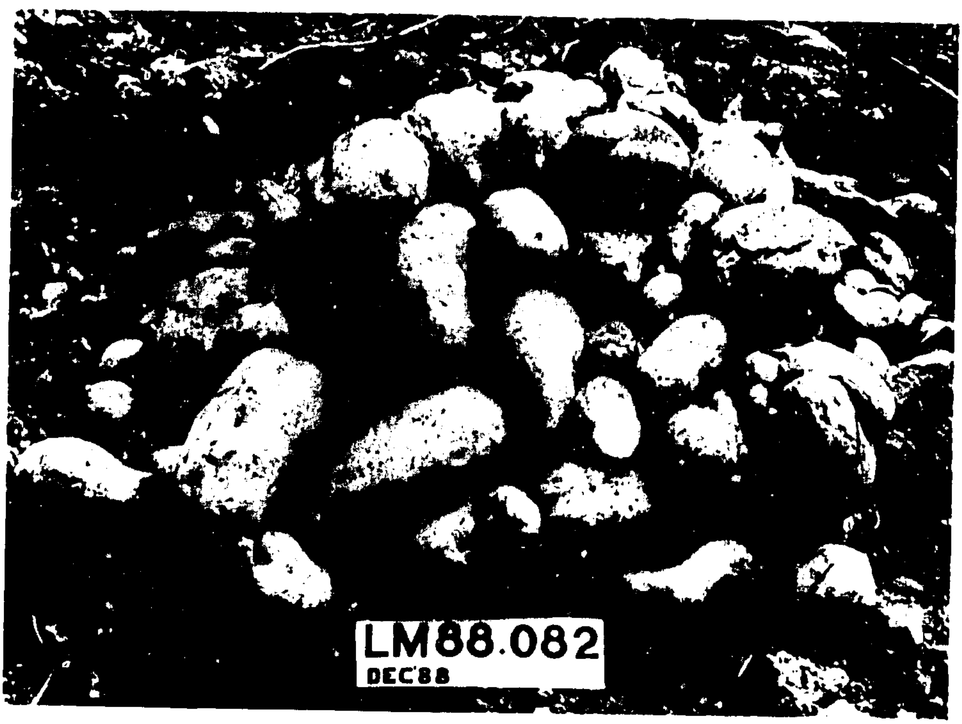
Clone	Pedigree	Use	Specific gravity	Dry matter	Reduced sugars
E86.562	Barta x LT-7	FF[a]		23.97	2.3
E86.731	Cleopatra x LT-7	FF		22.62	2.0
E86.692	CFS69.1 x Atlantic	CH[b]		21.30	1.5
E86.733	Cleopatra x LT-7	CH		22.26	1.8
LM86-2		CH			2.5
LM86-197	BL2.5 x 378015.3	CH	1.070		1.5
LM86-240	Aphrodite x LT-7	CH	1.066		1.5
LM86-242	Altema x LT-7	FF	1.071		2.4
LM86-663	Altema x LT-7	CH	1.064		2.1
LM86-320	CEX 69.1 x Atlantic	CH	1.066		1.8
377835.13	BR63.5 x Atlantic			19.42	2.0
(LT-7 x 378015.16)11				18.30	2.5

[a] French fries.
[b] Chips.

was planted to determine the hereditary pattern of specific gravity (SG) and reducing-sugar content (RS). At 10 days after harvest, RS1 and SG were assessed in all plants, and RS was again evaluated 60 days after harvest (RS2). Genetic analysis showed significant differences in GCA for yield and SG. No significant differences were found for reciprocal effects in the characters being evaluated. Three field experiments estimated genetic parameters and compared the effect of sexual vs. asexual generation.

Genetic variability of SG was due to additive genic effects with high narrow-sense heritability, 0.75 for the sexual generation, and 0.86 for the asexual generation. This means a selection for SG can be made in both sexual and asexual generations in spring or summer. Additive genetic variance was important in RS1 when seed tubers were used with heritability, 0.54. Dominance variance mainly influenced yield and RS2.

Taking into account the genetic results, a first phenotypic recurrent selection cycle was initiated at La Molina, and a population of 100 progenies was planted during the spring season to select progenies with processing potential for the warm tropical countries.



Promising advanced sweet potato clones are evaluated under a wide range of environments.

Table 2-4. Tuber yield and yield components of best 10 of 73 selected clones evaluated for length of storability under diffused-light storage (DLS) and adaptation to hot conditions in Canlubang, Laguna (150 m.a.s.l.), Philippines. December 15, 1989.

Clone	Parentage	Plants harvested (%)	Tubers/ plant (No.)	Average tuber wt. (g)	Tuber yield (g/plant)
385145.1	MS-1C.2 x Y84.012	37	11	65	750
384515.9	7XY.1 x Katahdin	64	7	109	750
385131.52	Y84.049 x 378015.16	90	6	121	739
385130.8	Y84.025 x 378015.16	74	11	55	588
385146.90	Pirola x Y84.012	47	9	61	579
385153.27	Y84.005 x LT-7	42	5	112	550
385152.44	Y84.004 x LT-7	73	11	51	536
385147.41	B71-240.2 x Y84.012	46	8	70	531
384515.8	7XY.1 x Katahdin	50	7	77	525
385378.9	C83.387 x AVRDC 1287.19	41	11	45	514
LT-7 (check)		50	6	44	253
Cosima (check)		40	6	35	217
Ackersegen (check)		45	6	21	123
Mean		60	7	50	348

NARS and Regions

Evaluation and Utilization of Advanced Genetic Materials

The Philippines. A third field evaluation was made of clones stored in diffused-light stores (DLS) for 8 months and selected for long storability and for high yield under hot conditions. The five highest yielders were 385145.1, 384515.9, 385131.52, 385130.8, and 385146.90 (Table 2-4). All tubers of each clone were planted without replication. At harvest, clones with high tuber yield and uniform tuber shape and size were selected and stored in DLS for another 8 months for further evaluation. Plant survival was low in some clones, because the tubers were old.

All clones that gave high yields had good canopy cover and virtually no virus symptoms; this was particularly true of those clones that produce more than 500 g/plant. The check cultivars (Berolina, Cosima, LT-7, and Ackersegen) had low yields.

Colombia. Materials of the Colombian breeding program, as well as introductions from CIP and other institutions, were evaluated at the San Jorge Experiment Station (3,100 m) to assess the value of clones in the National Program (Table 2-5). Using an augmented design with 14 replicated clones plus 40 non-replicated ones, 54 clones were evaluated for important traits. The experiments were made with and without fungicides. Although late blight was not severe, there was a severe incidence of rust (*P. pittieriana*), thus permitting a good evaluation of this disease. Excellent yields were obtained in some entries and national program

Table 2-5. Yield and performance of some CIP clones of the International Late Blight Project when compared with and without fungicides. Selected at San Jorge, Cundinamarca, Colombia, 1989.

Clone	Earliness[a]	Rust[b]	LB[c]	Yield (kg/plant)	Rust[b]	LB[c]	Yield (kg/plant)	Specific gravity
81-144.10	3	0	1-2	2.50	0	2-2	2.66	1.070
82-300.1	5	1	1-1	2.43	5	2-2	2.62	1.086
82-229.1	4	0	1-2	2.51	3	3-3	2.08	1.082
82-242.3	4	0	2-2	2.19	0	2-2	2.18	1.091
798148.4	3	1	1-2	2.03	2	2-2	1.89	1.093
798143.3	3	1	2-2	2.17	3	4-4	1.94	1.091
79-94.3	5	0	1-2	1.95	1	2-2	1.79	1.098
380277.12	3	3	1-2	2.21	6	2-3	1.96	1.101
379055.1	4	0	2-3	1.94	5	4-5	1.90	1.093
378192.4	2	1	3-5	1.34	1	9-9	0.86	1.078
Monserrate	5	0	2-2	2.27	0	4-4	2.29	1.106
P. Pastusa	5	2	2-3	1.79	4	4-4	1.69	1.107
82-222.1	4		1-2	1.78	3	2-4	1.58	1.089

[a] 1 = Early, 5 = Late.
[b] Rust (maximum reading): 0 = 0%, 5 = 50%, 6=75%.
[c] LB (1-9): 1 = 0%, 9 = 100%.

clones 79.43.3 and 82.242.3 performed very well, especially 79.43.3, which will be released soon as a new cultivar.

East Africa. A regional trial is under way to evaluate a set of promising advanced clones under a broad range of environments in east and southern Africa to identify the best-adapted clones. The national programs of Burundi, Ethiopia, Rwanda, Tanzania, Uganda, and Zaire are participating in this trial, which includes some of the best clones from this program and from CIP. Rwanda, Ethiopia, and Zaire have reported clones ready for release as new varieties: CIP 381295.1, CIP 381293.3, and PNAP 8201.12, (Rwanda); CIP 374080.5 (Ethiopia); and CIP 380606.6 and CIP 380602.22 (Zaire). These clones have gone through several selection cycles, including multi-locational national yield trials.

Tunisia. Twenty-five clones selected in 1988 and previous years were planted in 1989 and 11 were selected for further testing in 1990, including CIP clones 382196.2, 385072.1, 385276.1, 386303.1, 386303.2, and 386303.4. These clones have an acceptable plant type for north Africa: large leaves, short to medium-sized stems, and good ground cover.

West and central Africa. During 1988 and 1989, germplasm was sent from CIP-Lima to several countries, including Ghana, Equatorial Guinea, Côte d'Ivoire, Liberia, Cape Verde, and Mali. Forty clones were sent to Equatorial Guinea and were evaluated directly under farmers' conditions. Table 2-6 summarizes the results.

In Mali, 45 clones were planted at Bamako in a farmer's field under the control of AMATEVI, the collaborative institution. Clones were planted in early

Table 2-6. Average yield and number of tubers/plant of best clones evaluated at four locations under farmer's conditions in Bioko Sur, Equatorial Guinea, 1989.

Clone	No. of plants	No. of tubers/plant	Yield (g/plant)
CIP 800946	5	16.6	1,160
CIP 720084	5	23.6	1,080
CIP 676025	5	18.0	760
CIP 382119.20	5	15.0	725
CIP 678008	5	11.6	700
CIP 381163.9	5	22.0	670
CIP 800957	5	7.0	560
CIP 381378.3	5	8.4	540
CIP 800950	5	16.2	420
CIP 676171	5	13.0	360

January and harvested at 90 days with only organic manure used as fertilizer (30 t/ha). Temperatures fluctuated between 15C and 35.6C during the growing season. Table 2-7 shows the yields of the highest yielding clones.

Southeast Asia and the South Pacific. Studies in New Caledonia, Thailand, Fiji, Tonga, French Polynesia, the Solomon Islands, and the Cook Islands assessed cultivars from diverse genetic sources for yield and other qualities. The cultivars Serrana and B71-240.2 continued to give superior yields from imported seed and from the second-generation crop; they also showed excellent virus resistance and good storage characteristics.

The clone 377850.1 was selected in Fiji, where it has shown bacterial-wilt resistance, along with heat tolerance, and good virus resistance and storability. It is now being cleaned for distribution to other countries, including the Cook Islands and the Solomon Islands. Many other promising clones are now in the early stages of evaluation.

Vietnam. Farmers in the hot lowlands of south vietnam did not have suitable adapted cultivars for potato production; thus evaluations were made of introduced potato germplasm. Of 58 clones evaluated, B71-240.2, 378597.1, LT-7, and I-1035 showed outstanding performance on sandy and clay soils; they had vigorous plant growth, high tuber yield (more than 20 t/ha), and good quality tubers, early tuber initiation, and well-developed canopy cover. LT-7 also showed good tuber storage characteristics. These clones were multiplied in the highlands to be further tested in the lowlands.

China. From 1987 to 1989, 12 high-yielding cultivars were identified in evaluations of more than 200 CIP cultivars at 6 experimental sites. The clones B71-240.2, Serrana, Baronesa, and LT-4 consistently outyielded the check cultivars, and are considered well adapted to the growing conditions of northern China.

Table 2-7. Average yield and number of tubers/plant from best clones out of 45 evaluated at Bamako, Mali, 1989.

Clone	No. of plants	No. of tubers/plant	Yield (g/plant)
CIP 720087	8	10.0	600
CIP 380496.2	3	10.1	567
CIP 377257.1	5	7.8	480
CIP 379706.34	10	10.7	470
CIP 720142	5	10.6	460
CIP 720109	5	18.4	440
CIP 800827	5	6.6	429
CIP 800938	5	12.0	360
CIP 676026	10	12.0	355
CIP 575031	10	20.0	350

In a yield trial at Enshi, Hubei province in southern China, clones 386221.7, 386081.3, and 386198.3 outyielded the local cultiv~. Mira and are being further evaluated.

Italy. Experiments were conducted to evaluate clones for high levels of starch content. Because of severe weather conditions, many tubers showed secondary growths and cracking, including tubers of the Primura variety that usually perform quite well. Some CIP clones performed as well as or better than the local varieties.

In evaluations of specific gravity, most of the CIP clones performed as well as or better than the two local varieties, and significantly better than Primura, despite the relatively short growing season (110 days) of the local varieties.

True Potato Seed

At San Ramon, Peru, under rainy- and dry-season conditions, approximately 220 clones from 1987 and 1988 TPS populations were evaluated for their agronomic and reproductive characters. A randomized complete block design was used with 3 replications and 10 plants per experimental unit. Some clones with excellent agronomic and reproductive characters were identified, and will be put in the crossing block to assess their parental value.

During the summer, at La Molina, Peru a random sample of 20 progenitors (including advanced heat-tolerant and virus-resistant clones) was evaluated in two sets using a North Carolina Design II crossing plan. The 25 progenies evaluated in each set were generated by mating 5 female clones with 5 male clones. In general, the progeny yields were acceptable, with good tuber uniformity and number of selected clones. The progenies Y84.003 x LT-7, Y84.010 x Katahdin, Y84.010 x 377964.5, and PW-31 x 377964.5 were the best yielders and showed good tuber uniformity for potato production from TPS. The heritability estimates ranged from high to medium for plant type, earliness, and tuber uniformity, but were low to very low for berry set, yield/plant, and selected clones. These findings suggest that by using the present breeding strategy, further gain can be made in the first group of attributes. In the second group, however, the parents must be selected by progeny test and variability can be enhanced by introduction of new genetic materials.

During the winter, at San Ramon, a sample of 40 advanced progenies segregating for resistance to several viruses (PVY and PVX) and other diseases was evaluated for heat tolerance, yield, and tuber uniformity, using an RCB design split into two sets. The progeny yields were relatively high, with good levels of earliness and a high number of selected clones. The progenies Y84.027 x LT-7, C84.705 x YY-9, and LT-8 x YY-9 showed high yield, a good number of selected clones, and very good tuber uniformity. The progeny Y84.027 x 377964.5 showed excellent tuber uniformity and a high number of selected clones. The clones Y84.027 and YY-9 again showed their good parental value for yield and tuber uniformity.

Forty-one clones produced by protoplast fusion were crossed with clones 7XY.1, LT-7, and Atzimba. The 41 clones had previously been evaluated for flower color, pollen germination, pollen stainability, and pollen shape. In field experiments at La Molina and Huancayo, evaluations were made of the performance of these clones in different crosses to examine the segregation for "tetrad" type cytoplasmic male sterility (CMS) in their progenies.

Two clones have shown tetrad CMS type of pollen, but only one had acceptable performance for several agronomic and reproductive characters. These clones transmit the tetrad CMS character to their progenies and thus can be used as TPS parental lines (Table 2-8).

More than 300 clones from the TPS population being developed for parental lines and from pathogen-tested clones were planted in Huancayo, San Ramon, and La Molina. They were evaluated for pollen germination, stainability, and shape, and were then screened for tetrad CMS pollen. Six of these clones have been identified as having tetrad type CMS pollen: C386LM87-B, C116LM87-B, C137LM87-B, 382301.1, 382302.2, and 382291.1. Their parental value will be assessed in 1990.

Evaluation and Utilization of TPS

Egypt. A crop using seedling tubers of 13 progenies (stored from spring to spring) was compared with imported Alpha seed tubers. The progenies 385438, 98001, 384061, and 384078 outyielded Alpha.

India. New hybrids from ongoing breeding cycles for TPS parental-line selection were planted to generate new TPS families, using the test-cross method. These families will be evaluated in diverse agroclimatic zones in India to assess their production potential.

Indonesia. Farmer-field research has shown that TPS technology may need further improvement before it can be used as a viable alternative to the traditional production system. Lack of adapted progenies, poor seedling establishment,

Table 2-8. Fourteen families that segregated for "tetrad" type cytoplasmic male sterility. Evaluation in Huancayo and La Molina, Peru, 1989.

Progeny	Pollen stainability Observed number		Expected ratios		
	Fertile	Sterile	Fertile	:	Sterile
GAL 1 x 7XY.1	16	13	1	:	1
GAL 6 x 7XY.1	33	0	1	:	0
GAL45 x 7XY.1	29	0	1	:	0
GAL55 x 7XY.1	48	0	1	:	0
GAL84 x 7XY.1	37	0	1	:	0
GAL74 x 7XY.1	48	0	1	:	0
Y-245.7 x 7XY.1	0	99	0	:	1
GAL46 x LT-7	36	0	1	:	0
GAL55 x LT-7	52	0	1	:	0
GAL56 x LT-7	42	0	1	:	0
GAL76 x LT-7	38	0	1	:	0
GAL78 x LT-7	40	0	1	:	0
GAL55 x Atzimba	26	0	1	:	0
GAL79 x Atzimba	40	0	1	:	0

and scant local availability of TPS are major constraints to widespread adoption. Research is under way to address these problems.

China. Many TPS hybrids and OPs have been evaluated by Chinese cooperator sites during the last three years with more than 580 TPS hybrids and 400 OPs evaluated at six institutes. Of these, 28 hybrids and 11 OPs were found to be promising and are being evaluated in on-farm trials. In 1989, 9 superior TPS progenies were included in national TPS trials at 5 locations throughout the country. Since 1986, 149 TPS hybrids or OPs have been introduced from CIP and from the U.S.A.

The results of assessments in various environments indicated that the TPS progeny 379702.6 x Bulk PVY outyielded local cultivars. Other excellent TPS progenies were Pirola x AVRDC 1287; CFK69.1 x 7XY.1; and 379703.37 x 7XY.1. The progeny 377964.5 x 7XY.1 yielded as much as 38 t/ha - 40 t/ha in N. Yunnan and outyielded the popular cultivar Kunmaeoa by 32% to 43%.

During the past three years, the area grown to TPS transplants increased from 80.5 ha in 1987, to 110 ha in 1988, to 150 ha in 1989 (in about 20 provinces in southwest China, and in Humeng and Datong in northern China). Improved crop management, availability of high quality TPS, the establishment of TPS collection and distribution procedures, and CIP help in staff training have contributed to this increase.

Maintenance, Multiplication, and Distribution of Pathogen-tested Materials

During 1989, CIP distributed genetic materials to collaborators in 88 NARS, as shown in Table 2-9. Increases are shown in shipments of in vitro plantlets, tuber families, true seed families, and TPS. The pathogen-tested list now includes 245 advanced cultivars and varieties, plus 35 in the clean-up process, and 172 accessions from native and wild germplasm, plus 56 in the clean-up process. Six sweet potato cultivars are now on the pathogen-tested list and 62 are in the clean-up process.

The TPS production begun in 1988 at La Molina and Huancayo, Peru has produced 0.764 kg of approved hybrids. In addition, 2.6 kg of several hybrids were produced using new and old parents. These progenies will be evaluated at three locations in Peru, and the best performers will be evaluated in the regional network. The objective is to identify the very best for large-scale production in Chile. TPS production in Chile has had difficulties with flowering, and production of usable seed was only 3.05 kg.

Advanced potato materials were distributed to 13 Southeast Asian countries from CIP's Regional Germplasm and Training Center, CIP-Lima and PRI Australia. Germplasm was distributed in the form of tuber families, tuberlets, in vitro plantlets, and TPS. The clones B-71.240.2, I-1025, Serrana, and CFK 69.1 continue to be the best adapted to many countries in Region VII (Thailand, Vietnam, and South Pacific countries). The clones LT-7, 378711.7, 379693.110, and 378597.1 were also outstanding in Thailand, Vietnam, and the Philippines. The clones MS 82.60, F1, and F3 were

Table 2-9. Distribution of all CIP germplasm to NARS and Regions, 1989.

	Clones		In vitro		In vitro plantlets		Tuber tuberlets		TPS family		TPS progeny	
Region	Units	Accs	Units	Accs	Units	Accs	Units	Accs	Units	Accs	Units	Accs
I (10)	3669	411	662	242	720	10	11245	284	226161	622	333000	222
II (15)	3624	520	133	61	0	0	3717	229	20200	101	219000	43
III (14)	3788	447	626	288	300	3	5092	392	81100	426	259000	191
IV (5)	230	23	0	0	0	0	5617	92	16200	81	3664200	28
V (11)	4196	593	0	0	0	0	8792	109	5600	28	347600	33
VI (8)	1380	37	387	160	0	0	0	0	0	0	5678800	88
VII (8)	3765	227	74	37	0	0	6966	31	52500	297	1346500	80
VIII (1)	0	0	94	47	0	0	0	0	50940	138	16000	8
Other (16)	286	55	542	241	0	0	0	0	89457	372	47000	21
Total (70)	20938	2313	2518	1076	1020	13	41429	1437	542158	2065	11911100	714

The numbers in parenthesis indicate the number of countries within each region, and for "other" the number of developed countries to which shipments were made.

promising in Papua New Guinea, the latter two having frost resistance and good adaptation to the country's highlands. In Fiji, the clone 377850.1 (BR 63.74 x DTO-28) was selected because of its resistance to bacterial wilt and viruses and because of its heat tolerance, and good tuber stability. It is now being cleaned for distribution to other countries.

Sweet Potato Population Development

Selection Site Development

CIP's *Ipomoea batatas* germplasm collection represents a largely untapped genetic resource of great potential value for improving the world's sweet potato crop. CIP research continues to evaluate and select accessions from the germplasm collection for use by NARS, either as clones or progenitors in breeding work. CIP's sweet potato populations continue to be assembled and improved using local germplasm accessions, as well as imported elite germplasm.

Germplasm evaluation and breeding work emphasizes characteristics identified through various priority-setting activities for the NARS, including a planning conference, workshops, and in-depth studies. Priorities include earliness, tolerance to biotic and abiotic stresses permitting high and stable yields, and root-quality factors, particularly high dry-matter content. The field evaluation of reactions to biotic and abiotic stresses is done at sites in Peru where the stresses occur. At Tacna (on the coast) root-knot nematodes are the principal pests, and drought, saline soils, and cool winter temperatures are the principal abiotic stresses. At Yurimaguas (in the Amazon basin) heat, excess moisture, and acidic and infertile soils are the principal abiotic stresses. La Molina and San Ramon provide more favorable sites on the coast and in the high jungle, for evaluation of the yield potential of materials selected at the two high-stress locations.

The varying levels of stress among these sites are reflected in the differences in fresh-root yields and root dry-matter contents of clones evaluated at Yurimaguas, San Ramon, La Molina, and Tacna. The mean yields of the La Molina and San Ramon trials were significantly higher than those of Tacna and Yurimaguas. The mean dry-matter content at Tacna was significantly lower than at the other three sites, possibly due to the low winter temperatures, or to the high salinity of the soils there. The conditions found at Tacna may prove to be useful for the identification of clones with high, stable dry-matter content.

Table 2-10 shows the foreign sweet potato populations introduced as seed in 1989. The majority of these introductions are advanced breeding materials and are thus potentially valuable sources for CIP's sweet potato breeding work. These seed introductions will be compared with the Peruvian germplasm at the various selection sites in Peru for earliness, adaptation, and reactions to biotic and abiotic stresses of importance to NARS. Results of these comparisons will indicate the potential usefulness of the Peruvian germplasm, as well as of the Peruvian selection sites. Foreign and Peruvian germplasm will be used in the assembly of CIP's improved populations. Also, crosses of Peruvian materials possessing desirable characteristics with foreign introductions from specific countries may be used for the rapid export of partially adapted sources of new variation to the countries of origin.

Breeding work continues at the Regional Germplasm and Training Center (RGTC) in the Philippines, where selected progenies obtained from polycross and controlled hybridization were evaluated and the best clones were selected for further evaluation. A random set of progenies, which is a representative sample of the CIP breeding germplasm collection, is being evaluated for important root traits in genetic experiments. Results from these experiments will provide the basis for breeding work with local germplasm in the Philippines.

In other work at RGTC, research was initiated to identify parental clones. Over 40 potential parents having profuse flowering, high seed-set earliness, high

Table 2-10. Sweet potato seed received from outside of Peru for use in breeding work at CIP headquarters, 1989.

Source		No. of	No. of
Country	Institute	families	seed
China	Xuzhou Inst. of SP. Xuzhou	22	220
USA	USDA Veg. Res. Lab., S. Carolina	11[a]	35,000
Vietnam	Food Crops Res. Inst., Haihung	3	300
Japan	Kyushu Ag. Exp. Stn., Ibusuki	20	4,412
Puerto Rico	USDA, Mayaguez	2[a]	918
Nigeria	IITA	8	26,826
Taiwan	AVRDC	22	5,500

[a] Multi-family bulks from crossing blocks.

dry-matter content, and high yield were identified and will be evaluated for their parental value. Potential parents were selected from among 200 clones that showed dry matter levels exceeding 35%.

Evaluation and Utilization of Advanced Genetic Material

Paraguay. In collaboration with SEAG and IAN, local varieties were collected during 1987 and 1988. These are maintained at the IAN station at Caacupé. Accessions have been classified by morphological descriptors, and they are now being transferred to in vitro. Six of the highest-yielding varieties have been multiplied and are being evaluated in on-farm trials, with farmers participating in the evaluations. Collection is continuing and materials from CIP are being introduced. On-farm evaluations will also continue and promising materials will be multiplied for distribution to interested local institutions.

Peru. In collaboration with INIAA, an ongoing series of on-farm variety trials has been established with farmers in the Cañete Valley, Peru's major sweet potato-producing area. The objectives of this work are 1) to identify selection criteria used by farmers at Cañete, and 2) to develop methods for including farmers' evaluations of germplasm that might be useful to other NARS' varietal selection programs. During 1990, this work, as well as the on-station trials, is being done at other sites in Peru.

Cameroon. CIP has begun sweet potato work for Cameroon and several other African countries with the transfer of the elite clones from the former IRA/IITA project to an IRA/CIP project. Two of these clones, Tib 1 and Tis 1112, have already been released as varieties in Cameroon under an IRA/IITA project, and multiplication of the varieties is continuing under an IRA/IITA/GATSBY project.

Additionally, 1,000 sweet potato seeds (10 families) were introduced to Cameroon from North Carolina State University and these have been sown and are undergoing evaluation at mid-elevation sites at Mfonta (1,350 m) and Babungo (1,175 m).

East and southern Africa. CIP sweet potato breeding work in east Africa is being developed in collaboration with NARS scientists, both directly and in participation with the ESARRN network established by IITA. Emphasis is on a multidisciplinary approach, using the farmer-back-to-farmer model, baseline surveys, and the evaluation of the locally available germplasm. Collection work is under way in Kenya, Tanzania, Ethiopia, and Uganda to evaluate the local germplasm for yield, resistances to pests and diseases, and other desirable characteristics. Collaborative work with other countries in this region is expected to begin during 1990.

India. Collaborative sweet potato breeding work with the CTCRI was initiated during 1989. The breeding work will be guided by the findings of ongoing socioeconomic studies. The first stage of breeding work has focused on the hybridization of advanced clones from the CTCRI program. Work during 1990 will focus on the evaluation of materials from the hybridizations, for earliness, yields, and consumer acceptance. Selected materials will enter the All-India variety trials network, and will also be distributed for international testing.

The Philippines. CIP's breeding and germplasm distribution work in the Philippines is conducted in collaboration with the NARS (NPRCRTC and VISCA) as well as independently. During 1989, work was carried out to develop improved sweet potato germplasm for the warm and cool tropics of Southeast Asia. This involved extensive collection of germplasm from both the lowlands and the highlands, including 243 accessions collected from the lowlands in Luzon, that are maintained at Canlubang and Santa Lucia; and 552 highland accessions, collected in Benguet, Mt. Province, Ifugao, and Nueva Vizcaya that are maintained at NPRCRTC, Benguet, along with germplasm from VISCA and the BPI Economic Garden.

The recently collected germplasm has been characterized for key morphological descriptors, and is being evaluated for yield, earliness, and dry-matter content in the highlands, and in the lowlands under dry- and rainy-season conditions. Preliminary laboratory and field evaluations for resistance to weevil (*Cyclas formicarius*) have shown promising results.

Distribution

Table 2-11 shows clonal germplasm distributed to national programs from CIP headquarters, from North Carolina State University (under the auspices of a research contract), and from the CIP Regional Germplasm Redistribution Center in the Philippines.

Table 2-11. Distribution of sweet potato germplasm to NARS and CIP regional programs during 1989.

Recipient country	Number of in vitro clones distributed from:			
	CIP-Headquarters	CIP Region VII	NCSU	Seed from NCSU[a]
Cameroon				1,000/10
Egypt	6		10	1,000/10
Bangladesh			7	
China			15	
India	6			
Indonesia			12	
Korea		23		
Malaysia		23	14	
Philippines				
CIP Region VII	6		15	
VISCA		23	18	
IPB		16		
Vietnam		24		
Bahamas			5	
Barbados			13	
Dominican Republic			13	
Paraguay	6			
Italy			15	

[a] Total number of seed/number of half-sib families.

Scanning electron microscope view of bacteria (*Pseudomonas solanacearum*) that have infected xylem vessels of a potato plant.

Thrust III

Control of Bacterial and Fungal Diseases

Thrust Profile: 1990

Bacteria and fungi cause diseases that limit production of potatoes and sweet potatoes in developing countries. Thrust III research helps farmers control diseases in the field, as well as during the storage of seed, and the shipping, marketing, and storage of farmers' produce. CIP collaborates with NARS and private industry to develop durable resistance to diseases and to adapt and promote integrated control practices that take advantage of these resistances.

Recent achievements included a new population developed specifically to reduce frequency of latent infection and to incorporate resistance to late blight. This population also has good quality and yield and therefore has been selected for use in several countries. A more precise and severe screening method has been developed to enhance levels of resistance. This method uses true potato seeds, cuttings, and minitubers, where established roods are immersed in the inoculum suspension.

Innovative taxonomic studies were made using biochemical tests in multiple-welled microtiter plates, which resulted in the subdivision of Biovar 2 of *Pseudomonas solanacearum* into two distinct phenotypes related to their geographic distribution. This finding helps in developing a well-focused breeding strategy.

Progress in integrated control through choice of rotation crops was reported in Burundi, Peru, and the Philippines.

Studies of alternative screening methods were made to better support breeding of resistance to *Erwinia* soft rot and blackleg. The screening for blackleg, which consists of placing cuttings in infested perlite, is a new method that permits the selection of several resistant genotypes. A low but useful correlation was found between vacuum infiltration and injection of potato tubers. The research showed a synergistic interaction of *Erwinia carotovora* subsp. *carotovora* and two *Fusarium* spp. inoculated to tubers, indicating the need to consider a breeding strategy that will take both diseases into account simultaneously.

In the late blight selection program, 166 new selections were made through screening at Rionegro and Toluca. A total of 39 clones were selected after being tested a second time, and were added to the International Late Blight Resistance Trial collection (now 170 clones), which is available to NARS for testing. Selection methodology was improved at Rionegro by using sprinkler irrigation to control humidity.

Progenies with early-blight resistance combined with earliness were selected in the field at San Ramon; similar progenies showed resistance in Israel. These findings indicate the potential for controlling this disease through selection for resistance.

A survey of sweet potato diseases continued in Peru and, at La Molina, screening for tuberous root resistance was begun for Java black rot and *Fusarium* root rot. At San Ramon, foot rot and soft rot were found to cause severe losses in storage. Chlorotic leaf distortion was shown to be caused by the fungus *Fusarium lateritium*.

Potato Diseases

Control of Bacterial and Fungal Diseases – Bacterial Wilt

Breeding for resistance. Research at CIP and in collaboration with NARS in several developing countries, continued to concentrate on the selection of tetraploid populations with resistance to *Pseudomonas solanacearum* inherited from cultivated diploid *Solanum* spp. (see Annual Reports 1984-1989). Major efforts have been directed to the testing and development of potentially useful breeding materials in a variety of locations, both within Peru and worldwide, thus intensifying the selection for resistance to localized strains of *P. solanacearum*.

A new population was produced from a series of crosses between the best BW-resistant clones and a late-blight resistant population (including some clones that were free from R-genes). Initial selections were for adaptation and agronomic quality under BW-free conditions in Huancayo and La Molina. Figure 3-1 shows the wide range of materials selected for acceptable yield potential. A

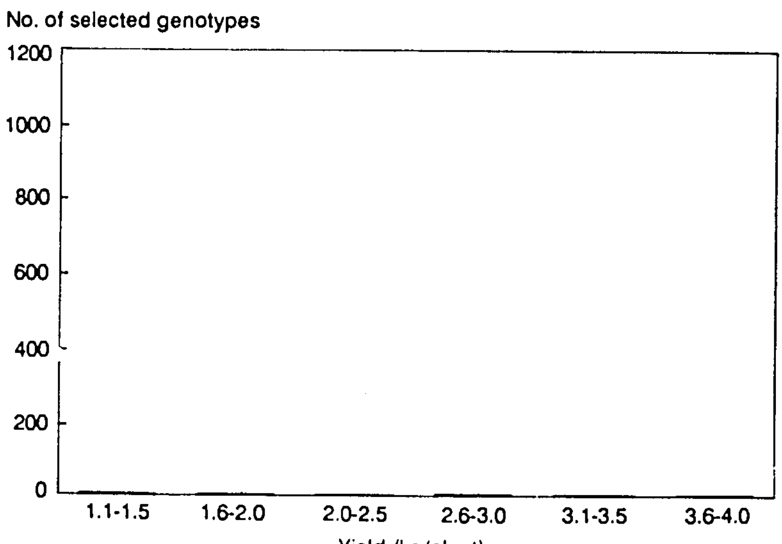


Figure 3-1. Yield range of genotypes selected in Huancayo and La Molina, Peru from new populations produced by crossing bacterial wilt and late, blight-resistant progenitors.

highly advanced population, representing the entire genetic basis of BW-resistant progenitors, was multiplied in Huancayo, and almost all showed acceptable agronomic characteristics and yields within the range of 1 kg to 2.5 kg per plant.

At San Ramon, in tests in farmers' fields that were naturally infested with race 1 of *P. solanacearum*, early-yielding clones with apparent field resistance to BW were selected after 90 days under warm humid conditions (Table 3-1). Four of these clones showed no latent infection at harvest. In associated studies with the Peruvian National Potato Program (INIAA), similar materials were tested at Carhuaz, Ancash Department (2,810 m), in a farmer's field that was naturally infested with race 3 of *P. solanacearum*. After harvest, 11 of the selected clones were found to be free from latent infection. In the same field, in segregating materials from 10 true-seed families with the same genetic background, the frequency of resistant genotypes detected was similar to that of the clonal materials (Table 3-1). Of the selected clones, 39 were found to be free from latent infection at harvest.

In collaboration with the Philippine Department of Agriculture, segregating materials were evaluated for adaptation and agronomic quality under low BW inoculum pressure at Intavas, Mindanao (1,200 m). Evaluated materials included second (26 clones) and third (27 clones) generations of materials developed locally from crosses between progenitors with superior BW resistance and local adaptation. For future evaluation, 89 clones were selected from 8 tuber families, and 10 progenies were selected from 52 seedling-tuber families produced from locally adapted and BW-resistant progenitors.

Table 3-1. Selection for resistance to bacterial wilt and agronomic quality under infested field conditions in Peru, the Philippines, China, and Brazil.

Test site	Material tested	Percentage genotypes selected	Yield range of selected genotypes
San Ramon, Peru	250 adv.[a] clones	19	0.4-1.2 kg/plant
San Ramon, Peru	401 adv. clones	12	0.4-1.0 kg/plant
Carhuaz, Peru	355 adv. clones	12	1.0-1.3 kg/p ant
Carhuaz, Peru	10 TPS families	9	1.0-2.3 kg/plant
Intavas, Mindanao, Philippines	26 adv. clones (BW resistant)	11	14.3-19.3 t/ha
Intavas, Mindanao, Philippines	27 adv. clones (RKN resistant)	15	9.2-20.0 t/ha
Penxian, China	21 adv. clones	33	na
Beijing, China	14 adv. clones	29	na
Beijing, China	20 adv. clones	30	na
Enshi, China	394 national cultivars	7	na
Brasilia, Brazil	43 adv. clones	0	

[a] Advanced.
na = Data not available.

At the Lembang Horticultural Research Institute (LEHRI) at Tangkubon Prahu in Indonesia, in pre-selection among 15,400 genotypes from 93 progenies, under BW-free conditions, 837 clones were identified as having acceptable agronomic characteristics and late-blight resistance. The BW resistance of the selected materials is to be studied in infested fields in West Java, where surveys show that all fields are infested and that 50% of the crop is infected after 4 multiplication cycles from originally disease-free seed.

At the Institute of Plant Protection - CAAS (IPP-CAAS), Beijing, China, 200 BW-resistant genotypes with good agronomic quality were selected from the progenies of crosses among the resistant clones 800928 (MS-42.3), 800935 (MS-1C.2), 377852.2, 381064.8, 800938 (AVRDC-1287.19), and locally adapted varieties. Three cooperating national institutions (The Southern China Potato Center, Bashang Agricultural Institute (BAI), and Haihua District Agricultural Institute) have now initiated breeding programs using BW-resistant germplasm distributed from CIP. An additional 17 combinations between the 5 resistant clones and locally adapted cultivars were made at IPP-CAAS in cooperation with BAI. Of 84 true-seed progenies introduced from CIP, 100 clones of 61 tuber families were selected for agronomic quality at BAI and the Upland Crop Institute, Shanxi Province. In tests of advanced clonal materials for resistance to BW at infested nurseries at Enshi, Penxian and Beijing, further selections were made of advanced CIP-distributed materials and national cultivars (Table 3-1).

Through contract research at CNPH-EMBRAPA, Brazil, segregating material distributed from CIP is also being pre-selected for agronomic suitability prior to field screening for BW resistance. Pre-selection involves two phases: phase I, in which individual genotypes are cloned in the screenhouse, and phase II, in which clones are selected according to their agronomic characteristics in the absence of BW. Selected clones are then planted in a field infested with race 1 of *P. solanacearum* to determine their resistance during phase III. During the past year, phase I included 54 true-seed families from 3 different CIP breeding programs; phase II included 39 seedling-tuber families, and phase III included 43 selected clones. In testing of the selected clones, the incidence of BW ranged from 53% to 89%, confirming observations from previous years that resistance in these materials is unsuitable for conditions in Brasilia.

Procedures for screening. Because successful breeding requires efficient methods to select the BW-resistant individuals from segregating populations, the uniformity and reproducibility of various screening techniques were evaluated in the greenhouse using susceptible potato cultivars Yungay and Ticahuasi. The most uniform results were obtained when rooted test cuttings (growing in rehydrated Jiffy-7 peat pellets) were immersed for 10 seconds in a suspension containing 5 x 10^7 c.f.u. per ml. When this method was compared with a standard inoculation method in which the soil mixture was drenched with 10 ml of inoculum per plant, the finding for the immersion method showed 0% of the plants escaping infection, whereas 43% escaped infection when drenched. The rate of disease development and the uniformity of the results increased when roots were wounded prior to inoculation by cutting with a scalpel. The immersion method also provides a mass screening technique, which allows evaluation of many genotypes in half the time required by earlier methods.

In Peru, further studies were made of the reliability of seedling screening techniques in the greenhouse and field, using 10 segregating TPS progenies from crosses between parents that have BW resistance and are adapted to the warm tropics. Using the soil-drench method, significant correlations were found between wilt incidences during repeated screenhouse tests in Lima with Biovar (Bv) 2, race 3 of *P. solanacearum* (r = 0:14, P<.01), and at San Ramon with Bv 1, race 1 (r =0.323, P <.05). However, due to the differences in pathogen race and environmental conditions, results were not correlated between the two locations. Similarly, no correlation was shown in wilt incidences, when the same families were transplanted to infested fields in San Ramon (Bv 1, race 1), Carhuaz (Bv 2, race 3), or Bukidnon, Philippines (Bv 3, race 1).

Taxonomy of Pseudomonas solanacearum. As indicated above, the variability of *P. solanacearum*, as well as that of the potato host, must be considered when breeding for resistance to BW. Hence, an international collaborative research program, involving CIP and NARS from developing and developed countries, has begun to improve the identification and classification procedures for strains of *P. solanacearum* and to map their distribution worldwide. At CIP headquarters, a visiting scientist from the University of Queensland, Australia, in association with CIP scientists, developed a method to characterize strains of the bacterium using a series of biochemical tests, many of which were conducted efficiently in microtiter plates. The test findings allowed the differentiation of 327 isolates of *P. solanacearum* (representing 5 Bvs from the CIP world collection) into three groups, on the basis of nitrate metabolism (Table 3-2). Apparently, the separation of 138 Bv 2 isolates of *P. solanacearum* into 2 distinct phenotypes according to their metabolic activity was also associated with their geographic distribution (Table 3-3).

Table 3-2. Reduction of nitrate to nitrite and production of gas from nitrate by different biovars of *Pseudomonas solanacearum*.

Biovar No. strains tested·	1 79	2 160	3 58	4 29	5 1
Reduction of nitrite from nitrate[a]	98 (99)[b]	153 (96)	58 (100)	28 (97)	1 (100)
Profuse gas production from nitrate	0 (0)	1 (1)	57 (98)	28 (97)	1 (100)
Trace gas production from nitrate	5 (6)	4 (2)	0 (0)	0 (0)	0 (0)

[a] Nitrite detected by the starch-iodide method.

[b] Data in parenthesis indicate percentage of isolates per biovar showing positive reaction.

Table 3-3. Differentiation of 138 isolates of *Pseudomonas solanacearum* Bv 2 into two phenotypes on the basis of differences in metabolic activity (data are shown as percentage of positives).

	Phenotype A[a] (19 isolates)	Phenotype B[b] (119 isolates)
Acid from ribose	100	0
Acid from trehalose	100	4
Utilization of L-tryptophane	100	0
Utilization of L (+) tartrate	95	0

[a] Isolates from warm climates (including 7 from Yurimaguas, Peru; 3 from La Chincana, San Ramon, Peru; and 9 from Brazil).

[b] Isolates from 28 countries: Argentina, Australia, Brazil, Burundi, Chile, China, Colombia, Costa Rica, Egypt, Greece, India, Indonesia, Iran, Israel, Kenya, Malaysia, Mexico, Nepal, Nigeria, Panama, Peru, the Philippines, Puerto Rico, Rwanda, Sri Lanka, Sweden, Uruguay, and Venezuela.

At IPP-CAAS, in Beijing, China, monoclonal antibodies against *P. solanacearum* have been produced by immunizing BALB/c mice with glycoprotein extracts from potato strains Po41 (race 3) and Po1 (race 1). Five subcloned hybridoma-cell lines stably secreted monoclonal antibodies that were specific to *P. solanacearum*, but not to the bacteria that cause ring rot or soft rot. Antibodies from one cell line (HPS3) were specific to all strains of *P. solanacearum* tested and were successfully used in an ELISA test to detect BW infection of potato plants and tubers. In response to wide demand, further research will emphasize the development of this technique to produce a reliable and inexpensive method to detect latent infection in potato seed tubers. Less specific monoclonal antibodies are being used to group distinct strains of *P. solanacearum*. Meanwhile, at CIP headquarters, 3 new polyclonal antisera were produced (one against race 1 and two against race 3) and their specificity is now being evaluated.

Integrated control of bacterial wilt. Collaborative research between CIP and NARS continues to focus on the selection of cropping systems that reduce the incidence of BW. Integrated control strategies are needed by farmers to reduce losses in the field. Such control measures are also required to complement the levels of bacterial wilt (BW) resistance in newly developed potato cultivars that are not completely resistant in adverse, high-temperature environments or under heavy inoculum pressure.

In collaboration with the Department of Plant Protection of ISABU, Burundi a survey to evaluate the occurrence of BW in farmers' fields provided valuable findings for helping to develop integrated control strategies. Wilt incidence was shown to be affected by the previous rotation, with the lowest levels occurring after cassava (during the September to January season) and after banana, during the following season. The BW-tolerant variety Ndinamagara (CIP germplasm accession No. 720118) occupied 77% of the total land planted with potato and, on average, wilted less than did other varieties. However, BW incidence also was notably low in susceptible varieties such as Muziranzara, when the seed had been obtained from the ISABU seed farm and a 2-year crop rotation had been practiced. Increased extension efforts have successfully prevented the planting of potato as a monoculture; however, volunteer potato plants were recognized as a major source of *P. solanacearum* in the field.

Results from a 3-year study of cropping systems in Bukidnon, Philippines, conducted in cooperation with the Philippine Department of Agriculture, also showed the effect of crop rotation on BW incidence in 3 locations over 6 seasons. The inoculum potential of *P. solanacearum* (race 1) in the soil was highest following a potato crop, and lowest following maize, although the potential remained sufficiently high to cause disease in all cases. Rotation with maize or beans reduced BW incidence and increased yield in a subsequent potato crop, whereas potato monoculture increased wilt and reduced yield. The incidence of BW was not influenced by the slope of the land or by terracing or contour-cropping.

In San Ramon, Peru, studies of potential components for integrated control of *P. solanacearum* (race 1) showed that BW incidence (in field-grown tomatoes) increased following rotation with cowpea or beans, whereas incidence decreased following maize or a herbicide-treated fallow. These incidences were correlated with the level of root-knot nematode damage ($r = 0.75$, $P < .05$). A direct effect of the herbicide metribuzin on soilborne populations of *P. solanacearum* was demonstrated in the screenhouse. When field soil in pots had been previously inoculated with a suspension of the bacterium (containing 10^8 viable cells per ml), an application rate equivalent to 4.8 l/ha was sufficient to reduce the bacterial population to < .01. Both pre- and post-emergence applications of this product in potato crops effectively controlled weed hosts of both *P. solanacearum* and *Meloidogyne* spp. Soil amendments also retarded the development of BW. In screenhouse tests, BW incidence in potato seedlings was reduced from 97% at 90 days after sowing, to only 10.7%, when the inoculated soil was previously amended with calcium oxide (0.5% by weight); to 2.7% when amended with urea (0.1% by weight); and to 0% when amended with a mixture of the two. Field soil amendment with calcium oxide (2 t/ha), urea (200 kg N/ha) and composted sugar cane bagasse (10 t/ha), also retarded the development of BW in the field (Fig. 3-2). Previous rotation with *Crotalaria spectabilis* or *Tagetes erecta* resulted in increased wilt in the subsequent potato crops, because even though the crops reduced root-knot nematode incidence, they tended to increase the inoculum potential of *P. solanacearum*. At San Ramon, in race 1-infested soils, tests evaluated the relative resistance of adapted potato cultivars. A substantial site-specific variability was observed (Fig. 3-3), and 2 cultivars (Yungay and Mariva) performed much the same as the resistant check clone BR-69.84.

Implementation of the above integrated control measures to complement the performance of tolerant cultivars can provide low-cost control of BW for immediate improvement of consumer potato production by small farmers in developing countries. In Peru, the effect of integrating the various control components has been studied in San Ramon, and, in association with INIAA, in Carhuaz. Results show a substantial decrease in BW incidence, with an associated increase in final yield most

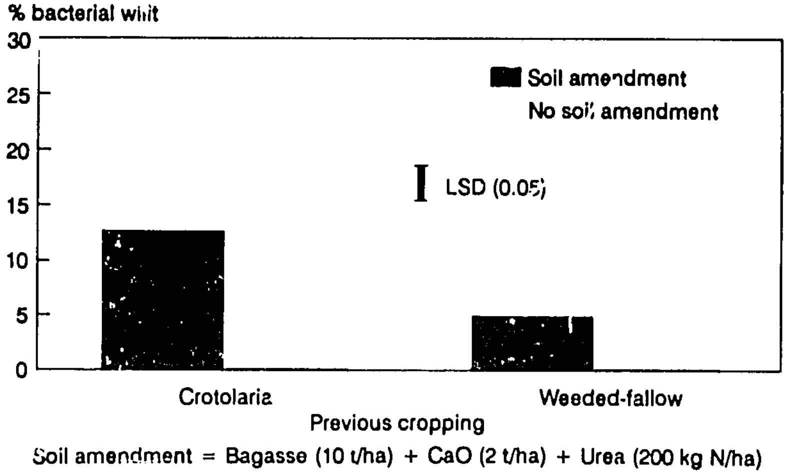


Figure 3-2. Effect of soil amendment and previous cropping practices on bacterial wilt incidence in a *Pseudomonas solanacearum* (race 1) infested field in San Ramon, Peru.

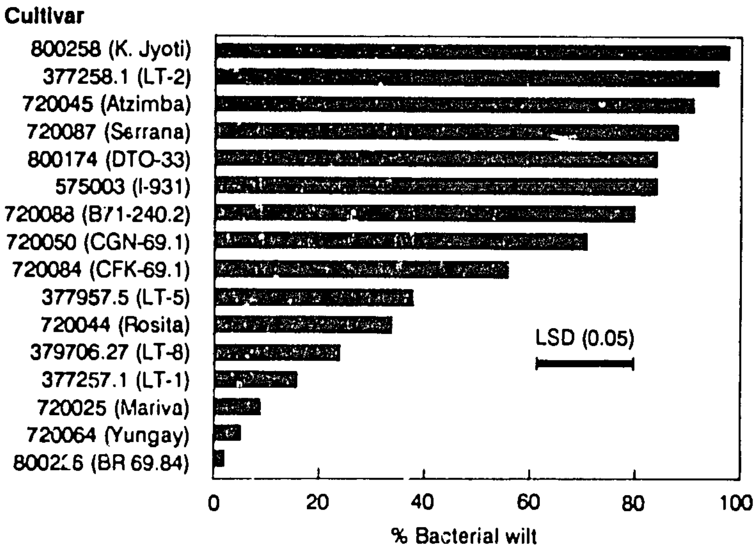


Figure 3-3. Relative resistance to *Pseudomonas solanacearum* (race 1) in adapted potato cultivars under field conditions in San Ramon, Peru.

noted in cultivars adapted to the warm growing conditions. In San Ramon the combined effects of crop rotation with maize, pre-emergence herbicide application (metribuziun), soil amendment with composted bagasse (10 t/ha), CaO (5 t/ha) and urea (200 kg/ha), and the use of adapted potato cultivars, were compared with the effects on a non-treated control, under highly-infested field conditions. Further studies are planned in cooperation with INIAA in Cajamarca, Peru, with LEHRI in Indonesia, and with a CIP pathologist recently stationed in Kenya.

Soft Rot and Blackleg

Selection for resistance. In breeding work for resistance to *Erwinias*, there have been few reliable screening methods to identify resistant and susceptible genotypes, particularly among populations at the early stages of development. Thus, 2 methods were compared during the evaluation of 2 populations (A and B). Tubers of 1,368 genotypes were inoculated with *Erwinia chrysanthemi* (Echr) by 1) vacuum infiltration with an aqueous suspension containing 10^6 c.f.u. per ml, and 2) injection of 0.05 ml of a suspension containing 10^5 c.f.u. per ml, 5 mm deep, avoiding lenticels. In both methods, the tubers were incubated under anaerobic conditions at 26C. Population A (approximately 30% of the genotypes tested) consisted of selections of progenies of cultivars of *Solanum tuberosum* ssp. *andigena* that showed resistance to soft rot. Population B contained selections of progenies from crosses among tropically adapted clones (mainly ssp. *tuberosum*). In population A, 4% were resistant (R) and 25% moderately resistant (MR) to inoculation by injection, whereas when inoculated by vacuum infiltration, the percentages were 10% R and 27% MR. In population B, after injection, selection percentages were 2% R and 18% MR; whereas they were 1% R and 4% MR after infiltration. Correlation between the results from the 2 methods was low (r = 0.14), however, 26% of the resistant (R + MR) genotypes were selected by both methods.

Population B had been previously selected from 96 hybrid families after seedling screening for blackleg resistance using a method in which TPS families were sown in sterilized compost and grown for 21 days. Apical cuttings were made, and then treated with rooting hormone. These cuttings were planted in trays containing sterilized perlite in which a suspension of Echr (10^5 c.f.u. per ml) had been evenly distributed. Typical blackleg symptoms did not develop in 47% of these cuttings, which were transplanted to the field, where additional selection reduced the population to 10% of the original. Eleven genotypes did not develop blackleg after 3 reinoculations, using 5 cuttings per genotype per test. Five of these genotypes produced tubers that were moderately resistant to soft rot after inoculation by injection.

Over 300 pathogen-tested cultivars have been tested in preliminary selections for resistance to blackleg and soft rot caused by Echr, using the vacuum infiltration method (CIP Annual Report 1988). Nine primitive cultivars demonstrated high levels of both stem and tuber resistance (Table 3-4), of which 5 were *S. stenotomum*, 2 were *S. chaucha*, and 2 were *S. phureja* and *S. goniocalyx*. The incidences of blackleg and soft rot during testing of these clones were highly correlated ($r = 0.72, p < .01$).

Interaction with Fusarium. To improve understanding of the interactions between potato seed storage pathogens, which account for serious production damage on a worldwide scale, the interaction between *Erwinia carotovora* ssp. *carotovora* (Ecc), *Fusarium oxysporum*, and *F. solani* was studied by a student at the Agrarian University, in Lima. Four

Table 3-4. Potential resistance to potato blackleg and soft rot in primitive cultivars from the CIP pathogen-tested collection.

CIP No.	Cultivar	*Solanum* sp.[a]	Tubers rotting per sample of 5	Blackleg plants per sample of 10
700318	SS-135	STN	0.0 c	0.7 cd
702547	Español Papa	STN	0.3 c	0.3 d
703244	Zapallo	GON	0.3 c	1.3 cd
703279	Unknown	PHU	0.3 c	1.3 cd
703299	Papa Piña	CHA	0.3 c	1.7 bcd
701088	Juana Blanca	CHA	0.7 c	0.0 d
703151	Señorita	STN	0.7 c	.0 cd
703321	Yana Ppuna	STN	0.7 c	1.0 cd
703197	Yana Sucre	STN	1.0 c	1.7 bcd
Checks				
800034	Pentland Crown	TBR	1.3 c	5.7 a
800085	Ultimus	TBR	2.7 b	3.0 b
800048	Désirée	TBR	3.7 b	2.3 bc
800959	Granola	TBR	5.0 a	6.0 a

Duncan ($P < 0.05$).

[a] STN = *Solanum stenotomum*; GON = *S. goniocalyx*; PHU = *S. phureja*; CHA = *S. chaucha*; TBR = *S. tuberosum* ssp. *tuberosum*.

cultivars were inoculated by stabbing with needles carrying suspensions containing 3.3 x 10^7 c.f.u./ml of Ecc and 2 x 10^5 conidia/ml of *Fusarium* sp., and the amount of rotted tissue was calculated by volume in cm3. Synergism between the bacterium and each of the fungi was particularly pronounced in the cultivar Revolución, but was not observed in the cultivar Désirée. The degree of synergism may be related to the cultivar's susceptibility to each pathogen alone.

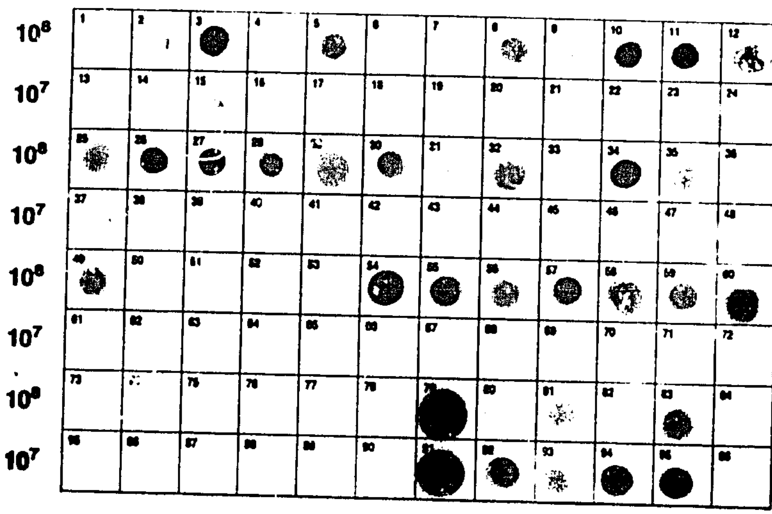
Tests were made of 70 clones of *S. tuberosum* ssp. *andigena*, that had been previously selected for combined resistance to Ecc, *F. oxysporum*, and *F. solani*. Two inoculation procedures confirmed resistance to *F. oxysporum* in 88% to 93% of the clones, and to *F. solani* in 72% to 74% of the clones. Resistance to the combination of fungal and bacterial pathogens is now being studied.

Detection of latent infection. A simple, accurate method to detect and quantify the presence of *Erwinia* spp. in latently infected seed potato tubers is needed for the development of both quarantine and seed certification regulations in both developing and developed countries. In Tunisia, collaborative studies at ESH at Chott-Meriem indicated that 50%-100% of seed tubers commonly imported from Europe were latently infected by *E. carotovora* ssp. *atroseptica* (Eca) as well as Ecc and Echr. However, the level of infection tended to decrease during local multiplication under dry field conditions.

At CIP, Lima, a student from the UNA used laboratory rabbits to produce polyclonal antisera to 6 Peruvian *Erwinia* isolates. Antisera against two Ecc strains and two Eca strains (either separately or in combination) reacted positively with a wide range of strains from the CIP collection, including 40 serotypes collected internationally (Fig. 3-4). Antisera against Echr were specific for Echr isolates from several countries. None of the antisera detected isolates of *Escherichia coli*, *P. solanacearum*, or *Agrobacterium tumefaciens*. Greater sensitivity and a wider range of detection were observed when the antisera were used in the NCM-ELISA method, than when they were used in the agar double-diffusion method. These antisera have been distributed to ESH in Tunisia and LEHRI in Indonesia, for preliminary testing.

Late Blight

Breeding for resistance. At CIP, the current approach to breeding for resistance to *Phytophthora infestans* involves 2



Notes:

1) Bacterial strains were positioned as follows:
   Ecc strains from Peru: 1-6, 13-18, 31-36, 43-48, 49-54, 61-66, 80-83, 92-95
   Ecc serotypes (supplied by S. De Boer, Agriculture Canada, Vancouver): 7-12, 19-24, 25-30, 37-42, 55-60, 67-72
   Pseudomonas solanacearum strains: 73-75, 85-87
   Escherichia coli strains: 76, 77, 88, 89
   Agrobacterium tumefaciens strain: 78, 90
   Eca homologous strain CIP 353: 79, 91
   Buffer Control: 84, 86
2) Numbers in left-hand column represent the concentration (c.f.u./ml) of the bacterial suspension used to blot the membrane (lowest dilution of any strain is situated directly below the highest).
3) A dark spot represents a strongly positive reaction (due to a high degree of homology or a high bacterial concentration).

Figure 3-4. Detection of different strains of *Erwinia carotovora* ssp. *carotovora* (Ecc) from diverse origins by NCM-ELISA using antisera prepared against strain CIP 353 of *E. carotovora* ssp. *atroseptica* (Eca).

potato populations: 1) advanced materials containing dominant genes for "vertical resistance" (R-genes), as well as horizontal resistance genes, and 2) materials free of R-genes, but agronomically less advanced. In both populations, the objectives are to increase levels of horizontal resistance, to add suitable agronomic characters, and to provide for cultivar selection.

Parental clones for the advanced population are chosen by progeny tests that determine the heritability of horizontal resistance and yield performance at several locations in different parts of the world. Plants are initially screened at the seedling stage by spraying with a suspension of sporangia and zoospores of *P. infestans*. In 1989, approximately 1,500 seedlings were selected from the 15,000 that had been screened. Another 1,500 seedlings also were selected at random to check the screening efficiency. These were multiplied and will be tested in the field in 1990 at both Rionegro, Colombia and at Ruhengeri, Rwanda.

Field screening involves the close cooperation of national programs in Colombia, Rwanda, and (for subsequent cycles) Mexico. National program cooperators participate in maintenance, screening, and selection of the advanced clonal generations, retaining promising clones for their respective programs.

Field screening has traditionally been based on natural infection. In 1989, inoculations were attempted in Mexico and Colombia; the latter were more successful due to the availability of overhead-sprinkler irrigation. Inoculations improve uniformity and help overcome problems of incompatibility between host plants and simple races of the fungus that occur naturally. It is anticipated that field inoculation will soon become a routine part of the screening in Colombia.

A new activity was adopted in 1989 to bridge populations A and B. In Colombia, clones selected as resistant were tested with a simple race to identify individuals having no R-genes. Clones that prove to be free of R-genes will be used as progenitors to improve the agronomic level of population B. To date, the R-gene-free population, based primarily on *Andigena* germplasm, has been evaluated in several sequences of greenhouse and field screening in Peru. Field-screening efforts have been slowed by loss of sites within Peru, but much of the field screening will soon be done near Quito, Ecuador.

New sources of resistance are being tapped for population B. A sample of 123 accessions from 3 wild diploid species is being tested in Peru, and crosses between haploids and *Andigena*-resistant clones are planned to introduce resistance into a cultivated form extracted to make crosses with diploid wild species.

International testing for selection of resistant cultivars. More than 2,300 clones from the advanced population of 169 families were tested at Rionegro, Colombia, and at Toluca, Mexico in 1989, and 166 clones were selected for resistance and agronomic characteristics. These were tested in a second cycle at Rionegro and will be tested at Toluca in 1990.

Beginning in 1990, the first generation of field testing will be done in Rwanda in collaboration with the national potato program, as well as in Colombia. The planting dates coincide at both sites, and both environments have high levels of inoculum early in the season due to the year-round potato cultivation.

After two cycles of field testing, selected clones become part of the International Late Blight Resistance Trial (ILBRT). The clones of the ILBRT are maintained under quarantine conditions and sent upon request to national programs. In 1989 there were 39 new clones added to the ILBRT collection (now totalling 170 clones).

Several changes are in progress to improve the ILBRT. Clones free of R-genes are being incorporated as checks to go to all sites. This will improve the comparability of results. Late-blight readings will be retrieved and compiled at CIP-Lima so that participating national programs can see how accessions perform in other parts of the world. As the ILBRT acquires a greater proportion of R-gene-free materials, this monitoring should give information about the stability of horizontal resistance in different parts of the world, and the adaptability of the clones.

A breeding and evaluation program continues with the Northern Philippine Root Crops Research and Training Center at La Trinidad. Unadapted genetic materials from Lima with a high level of resistance were used in two cycles of recurrent selection for resistance to LB and adaptation. Adaptation and yield were substantially improved while maintaining resistance to LB.

Procedures to screen for resistance. An experiment at Rionegro, Colombia tested the efficacy of field inoculation with *P. infestans*. Three concentrations of a suspension of fungal spores were sprayed on 4 cultivars with differing levels of horizontal resistance. Inoculation increased the percentage of foliage infested. This increase was most noticeable 8 days after inoculation, suggesting that the first evaluation after inoculation may be important in the overall assessment of horizontal resistance. Inoculation also reduced the coefficient of variability (CV) within genetically uniform plots of the AUDPC. The reduction of the CV from 17.8 to 14.1 is important because it represents an increase in uniformity of infection in the field, which is one of the objectives of inoculation.

An experiment also was begun to study the efficacy of seedling screening of individual plants. Families from 10 crosses were inoculated and individual seedlings were evaluated for percentage of infection. Prior to inoculation, the seedlings had been propagated from cuttings. These were multiplied and will be tested as adult plants in the field at Rionegro, Colombia in 1990.

Early Blight

Chemical control. Two fungicide combination treatments were compared in San Ramon in 1989 to develop a chemical control procedure to be used with host resistance in an integrated program. Dithane M45 + Dyrene were found to be effective, while Dithane M45 + Euparen controlled early blight only if applied before inoculation.

Resistance. At San Ramon, clones of the pathogen-tested list were evaluated for resistance to *Alternaria solani*. Clones were grouped into classes that had been shown to be susceptible, moderately resistant, and resistant. Results of the 1989 test were in agreement with those from 1988. The most resistant clones tested both years were: 700031, 720118

(Ndinamagara), 700431, 700528, Puca Duraznilla, Mollay Zarda, Tara Ccallo, Pinaza, Español papa, Amarilla, Conga, and Yana Ppima.

Breeding. A sample of 40 segregating progenies was evaluated for early-blight resistance after artificial field inoculation with *Alternaria* sp. The parental materials came from North Carolina State University, the University of Maine, and CIP. Progenies of Maine 48 x Y84.012 and of Maine 48 x Y84.011 were high-yielding, early-maturing, and had acceptable levels of resistance (Table 3-5). In general, early-blight resistance was correlated with moderate earliness, confirming the findings of other studies at CIP. Early-blight resistance also was identified in populations immune to PVY and PVX.

International screening. In cooperation with the Gilat Regional Experiment Station in Israel, numerous CIP clones have been screened for resistance to *Alternaria* sp. Tested clones segregated markedly for percentage of foliage affected by the disease, indicating that relative levels of resistance exist in materials currently available. Similar tests are being carried out in Uruguay at the CIAAB station of the national agricultural program.

Soilborne Diseases

Powdery scab. Field evaluations conducted in conjunction with the Peruvian national program (INIAA) for the last 3 years showed that two Ecuadorian varieties, Gabriela and Esperanza, were

Table 3-5. Performance of progenies with highest levels of resistance to early blight, San Ramon, summer 1989.

Progeny	Yield (g/plant)	Early blight severity[a] 60 days	75 days	Earliness[b]
DTO-33[c]	475	6.2	7.3	9
Maine-48 x Y84.012	448	4.0	4.8	6
Serrana x EB81-P2.31	44	3.5	5.2	4
LT-9 x EB81-P2.31	443	3.0	4.5	4
Maine-37 x Y84.011	436	e.0	5.2	6
84C46.3 x Y84.012	414	3.7	5.5	4
84C32.3 x YY-9	409	3.3	5.8	5
Maine-47 x 378676.6	395	3.0	5.2	5
Maine-48 x Y84.011	387	3.7	4.5	6
Maine-45 x Y84.012	381	4.3	5.8	6
84C34.4 x Y84.011	379	4.3	5.2	6
84C37.2 x XY.9	375	3.5	5.0	4
Utatlan 69.1 x YY-3	375	4.0	5.5	6
Bzura x EB81-P3.11	365	3.0	4.3	4
LSD (0.05)	162.7	1.0	1.2	2.0

[a] Severity scale: as in Table 3-5.
[b] Earliness scale: 1 = very late; 5 = intermediate; 9 = very early (evaluated 75 days after planting).
[c] Susceptible check.

consistently resistant to powdery scab (*Spongospora subterranea*). These varieties have been adopted for multiplication in areas where this disease is severe.

Fungal wilts and rots. During the 1987-1988 season, a student from the University of Huancayo (UNCP) collected samples from wilting plants and rotted tubers and from healthy tubers in 3 agro-ecological zones of the Peruvian central highlands (Comas, Huasahuasi, and the Mantaro Valley).

The fungi *Verticillium dahliae*, *Fusarium oxysporum*, *Fusarium solani*, and *Fusarium graminearum* were the principal vascular pathogens isolated from wilting plants. Other pathogens such as *Phytophthora erythroseptica* and *Rhizoctonia solani* also were isolated from plants with the same symptoms, but were secondary invaders.

Phytophthora infestans, *Phytophthora erythroseptica*, *Fusarium solani*, and *Fusarium sulphureum* were the principal fungi causing rot of potato tubers in the 3 agro-ecological zones of Peru. A wet rot (*Pythium* sp.) in potato tubers was found, especially in the Comas and Mantaro valleys.

The incidence of wilting plants and tuber rots generally was low in the central highlands of Peru, but varied with the environmental conditions at each location. The pathogens *Fusarium* sp., *P. erythroseptica*, *Verticillium dahliae*, and *Pythium* sp. were found in a latent state in healthy tubers collected immediately after harvest.

Sweet Potato Diseases

Importance of Bacterial and Fungal Diseases of Sweet Potatoes

Little information is available regarding the economic importance of bacterial and fungal diseases of sweet potatoes. Diseases of the foliage appear to be sporadic and generally of minor importance. Soilborne diseases generally are considered to be the major disease constraints, because they cause losses when plants are still in the field or when storage roots are kept for propagation and for future consumption. The most important of these diseases are black rot (*Ceratocystis fimbriata*), charcoal rot (*Macrophomina phaseolina*), foot rot (*Plenodomus destruens*), *Fusarium* root rot, and stem canker (*Fusarium* spp.). All of these diseases cause losses in the field and continue to cause rot in produce during transit, marketing, and home storage.

Where storage roots are kept for use as a source of plantlets and slips for propagation, as in Argentina and Uruguay, the important soilborne diseases include sclerotial blight (*Sclerotium rolfsii*), soil rot (*Streptomyces ipomoea*), and bacterial stem and root rot (*Erwinia chrysanthemi*). Similarly, bacterial wilt (*Pseudomonas solanacearum*) is important in southern China.

Although there are only a few places in the developing world where sweet potatoes are stored for later consumption (a notable exception is China), a number of fungi have often been reported to cause storage root rot; these include *Rhizopus stolonifer* (soft rot), *Diplodia gossypina* (Java black rot), and *Phomopsis phaseoli* (dry rot).

In most developing countries, especially in the tropics, sweet potatoes are consumed soon after harvest, and propagation is by vine cuttings taken from the growing crop. Diseases such as leaf and stem scab (*Elsinoe batatas*) can be transmitted by this propagation.

Surveys in Peru have identified many of the diseases reported worldwide. The diseases are found in sweet potato growing areas of irrigated valleys on the coastal plains and in the low- and medium-elevation tropical forest areas. Assessments are under way to determine the feasibility of screening for resistance to those diseases that are important worldwide, using the extensive germplasm collection at CIP to select resistant accessions for use as cultivars on parental materials.

Screening of the germplasm for disease resistance has begun at CIP, Lima, in association with the UNA. Screening and evaluation methods have been developed and are being used to evaluate 324 entries for Java black rot (*D. gossypina*) resistance, and approximately 200 entries for *Fusarium* root rot (*F. solani*). Both fungi have been isolated from storage roots.

Survey in Peru. Surveys were made to determine the presence of bacterial and fungal pathogens in some of the major producing coastal valleys of Peru (the Rimac, Chillon, Chancay, and Huaura valleys of Lima Department; the Caplina River Valley of Tacna), and at the San

Table 3-6. Stem, foliar, and tuber pathogens of sweet potatoes in areas surveyed in Peru. Presence is indicated by "+" sign.

	Area surveyed		
Disease	San Ramon, Junin Dept.	Four valleys in Lima Dept.	Yurimaguas, Loreto Dept.
Stem rots			
Fusarium sp.	+	+	+
Rhizoctonia solani	+	+	
Sclerotium rolfsii	+		+
Foliar leaf spots			
Albugo ipomoea-panduratae	+	+	+
Alternaria sp.	+	+	
Coleosporium ipomoeae	+		
Cercospora sp.	+	+	+
Curvularia sp.	+	+	
Phyllosticta batatas	+		
Septoria sp.	+		
Stemphylium sp.		+	
Tuber diseases in storage			
Diplodia gossypina	+	+	
Erwinia chrysanthemi	+		
Fusarium sp.	+	+	
Macrophomina phaseolina	+		
Plenodomus destruens	+		
Rhizopus stolonifer	+		
Basidiomycete (unidentified)	+		

Ramon (Junin) and Yurimaguas (Loreto) jungle research stations. Facultative parasites were tested for pathogenicity and identified, whereas obligate parasites were only identified. At San Ramon, 19 diseases were detected, 12 were found in the 4 valleys of Lima Department, and 4 at Yurimaguas (Table 3-6). Soft rot was detected in storage (*R. stolonifer*) at La Yarada in the Caplina Valley of Tacna. All pathogens identified were fungi, except for the bacterium *Erwinia chrysanthemi*. Surveying was limited to one visit late in the growing season, except at San Ramon, where observations were made each week.

Storage diseases. Diseases were studied in samples taken after 2 months of storage from among numerous accessions maintained in CIP stores at both San Ramon and La Molina (the latter is listed under Lima valleys in Table 3-6) and at La Yarada, Tacna. The percentage of infected accessions is shown in Table 3-7. At San Ramon, foot rot (*P. destruens*) also was found to cause disease in the field. Storage diseases were especially severe at San Ramon, where most accessions were diseased, with rotting in more than 50% of their storage roots. At San Ramon, a student from UNCP-Huancayo made a field comparison of 10 cultivars, which indicated some differences in disease incidence among cultivars. Japonés-portugués (RCB 64-IN) had the greatest incidence of *Cercospora* sp.; Paramonguino (RCB-276-IN), and Amarilla de Quillabamba (RCB-173-IN) had the lowest incidence of *Fusarium oxysporum* on tubers in the field, but the latter suffered the greatest losses during storage because of soft rot (*R. stolonifer*) and foot rot (*P. destruens*). Morado (RCB-3-IN), Nemañete (RCB-31-IT), and Desal (RCB-6-IN) showed the greatest losses in storage due to *Fusarium* root rot, charcoal rot, and Java black rot, respectively.

Chlorotic leaf distortion. A research contract with Louisiana State University studied possible relationships of a virus or a viroid with sweet potato chlorotic leaf distortion (CLD). Crystalline nuclear inclusions were shown to occur, but

Table 3-7. Percentage of accessions infected by different pathogens after two months of storage among 108 accessions at San Ramon (Junin); 68 at La Molina (Lima); and 10 at La Yarada (Tacna).

Pathogen	Storage location in Peru		
	San Ramon	La Molina	La Yarada
Diplodia gossypina	42	46	
Fusarium spp.	20	31	
Diploidia gossypina jointly with *Fusarium* spp.	6	9	
Macrophomina phaseolina jointly with *Fusarium* spp.	16		
Plenodomus destruens	4		
Rhizopus stolonifer	3	10	60
Unidentified Basidiomycete	4		
Erwinia chrysanthemi	2		
Undetermined	3	4	

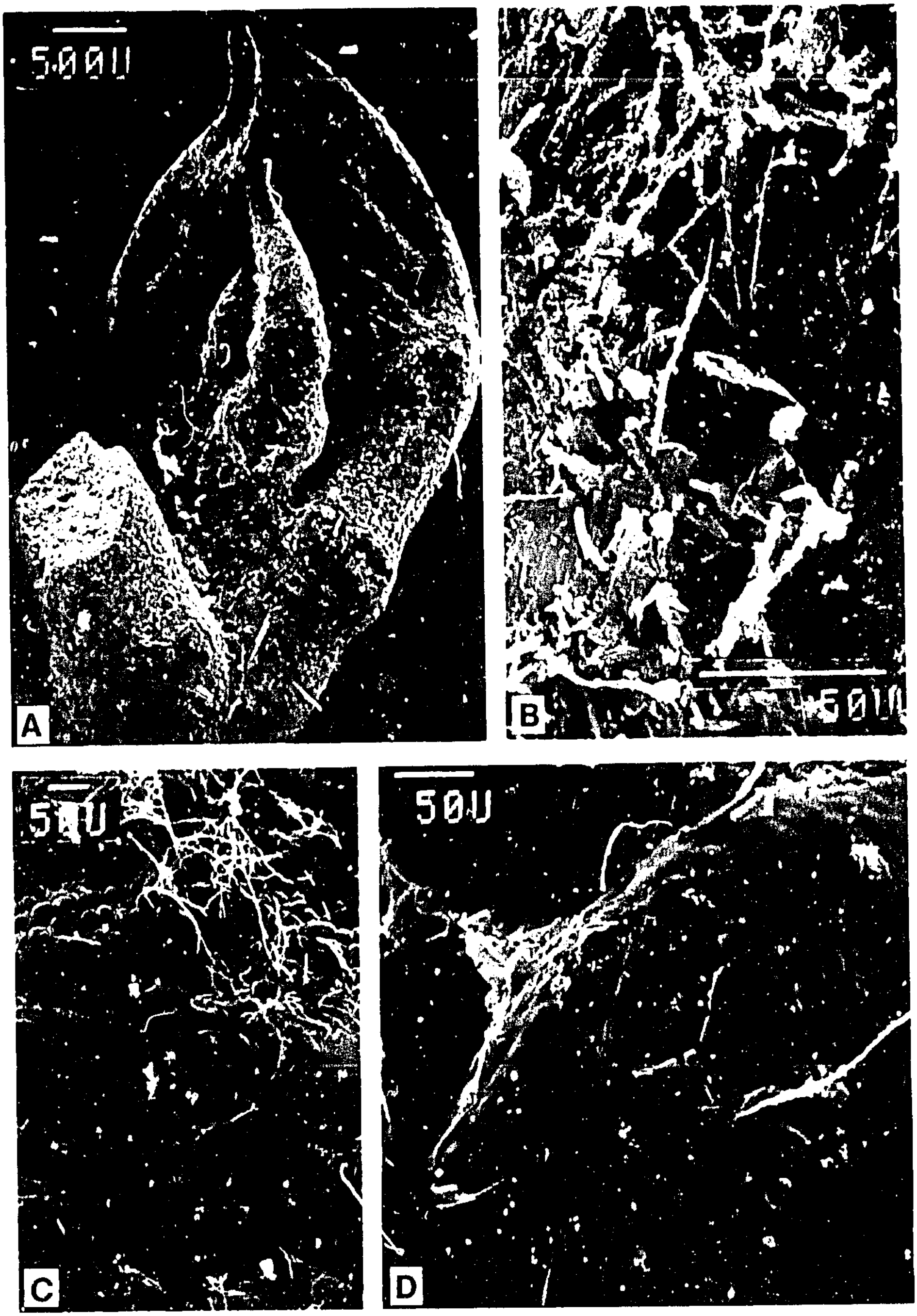


Figure 3-5. Presence and absence of Chlorotic Leaf Distortion fungus on the surface of sweet potato plants: (**A**) shoot tip of clone NC-845 covered with a layer of mucilage and fungal hyphae; (**B**) enlargement of (A) showing the edge of a leaf primordium where the mucilage was rubbed off; (**C**) epiphytic hyphae on a young leaf; and (**D**) developing leaf tip of healthy Beauregard cultivar partially covered by mucilage.

no virus was consistently associated with CLD. Under microscopic observation, the white material that appears on the adaxial surface of leaves with CLD was found to contain fungal mycelia and macroconidia. *Fusarium lateritium* Nees was isolated from all symptomatic plants and from many symptomless plants found in commercial fields; however, it was not isolated from symptomless mericlones grown in the greenhouse or the field. This fungus was isolated from clumps of epiphytic growth on leaves, and from the surface-disinfested tissues taken from stem nodes; leaf segments; leaf primordia; apical meristems; true seed (nonscarified); stamens, pistils, receptacles, and petals of opened flowers; unopened flower buds; and axillary vegetative buds. Inoculation studies demonstrated that CLD is caused by *F. lateritium*.

Because *F. lateritium* was isolated from surface-disinfested apical meristems (0.5 mm to 0.8 mm) and other parts of the shoot tip, a histological study was initiated to determine the location of the pathogen. Scanning electron microscopy (SEM) of the shoot tip revealed that the apical dome, leaf primordia, and youngest leaves that had not yet unfolded, were covered by a continuous layer of mucilage with fungal mycelia on and in the mucilage (Fig. 3-5, a and b). Older leaves showed no indication of mucilage; fungal mycelia were found in clumps that were regularly distributed over the surface of the leaf (Fig. 3-5, c). Examination of sections of these tissues by light microscopy indicated that there was no fungus within the older leaves; however, fungus appeared to be present within the apical meristem or leaf primordia. The presence of the mucilage on the surface of these tissues has interfered with infiltration and embedding, thus hindering efforts to obtain usable sections from them. Examination by SEM of the shoot tips of CLD-free mericlones indicated the presence of the mucilage on healthy shoot tips (Fig. 3-5, d).

Compendium of Sweet Potato Diseases

A Compendium of Sweet Potato Diseases was published by the American Phytopathological Society (APS) in 1988. It has been translated into Spanish by CIP as a joint APS/CIP publication. This comprehensive publication describes the geographic distribution, symptoms, causal organisms, disease cycles, and control of the most important biotic and abiotic disorders.

Effect of virus diseases on sweet potato in Peru **Left** healthy plant, **right** naturally virus-infected plant

Thrust IV

Control of Virus and Virus-like Diseases

Thrust Profile: 1990

The control of virus diseases is based principally on prevention of infection. Thus, in CIP's work with NARS, breeding for resistance to major potato viruses is one of the most effective and inexpensive prevention measures. Breeding for resistance to potato leafroll virus (PLRV) alone, or in combination with potato virus X (PVX) and potato virus Y (PVY) immunities, is one of the major Thrust IV activities. Because the resistance to PLRV is now known to have multiple components, the search for parental genotypes with individual resistance components should facilitate efforts to combine them in later stages. One of these components, aphid antixenosis, was determined in four clones maintained at CIP. Resistance to infection is another important component of the resistance to PLRV. This resistance can be broken down by growing resistant clones under high temperature conditions. For example, of 62 advanced clones that resisted PLRV infection after five field exposures during the winter at Ica, Peru, only 16 showed moderate to high resistance to PLRV in the summer season. These findings indicate that final selections for resistance to PLRV should be done at locations having conditions similar to summer conditions at Ica. Resistance to virus multiplication, although not common in cultivated potato, has two important advantages in controlling the disease. It reduces the severity of the leafroll disease and also reduces the inoculum potential in plants having this type of resistance. Two clones with resistance to virus multiplication, developed through a collaborative project, are now available as parental lines.

Because pathogen variability is a crucial factor in the strategy of breeding for resistance, the variability of PLRV is being carefully evaluated. Monoclonal antibodies were used to examine the antigenic determinants (epitopes) on the protein coat of the PLRV particle, and wide variability was found among 8 PLRV isolates. Studies are now being made of the relationship between serological variability and infectivity of several geographically different PLRV isolates, particularly in resistant genotypes.

Virus-free seed is another important prevention measure in controlling virus diseases. To produce basic stocks free of viruses, however, sensitive methods are needed for virus detection. In addition, virus detection methods should be simple and inexpensive for use in NARS. The serological technique called ELISA is one of the methods that satisfies these three requirements. The antisera, one of the most expensive reagents for use in ELISA, can now be produced in several NARS through CIP advice and training. To facilitate this process, studies are under way of the production of virus antibodies (anti-idiotypes), starting from a small supply of previously produced antibodies, rather than from purified virus.

To increase the pool of virus and viroid detection methods at CIP, complementary nucleic acid sequences have been developed for 8 viroids and 6 viruses and these are available for use as DNA or RNA probes.

Virus research on sweet potato included efforts to detect and identify viruses, as well as a search for resistance genes to sweet potato feathery mottle virus (SPFMV), the most important virus attacking the crop. Antisera and kits for detection of major viruses are now available for distribution to NARS. A mechanically transmitted, unknown virus (code-named C-2) found in the germplasm collection, has been identified and partially characterized. Several other viruses are now being characterized.

Thirteen accessions in the CIP germplasm collection were found to resist repeated SPFMV graft-inoculations; they represent the best available sources of resistance to this virus.

Potato Research

Resistance to Viruses

Some accessions of CIP's germplasm collection have genes for virus resistance, and sensitive virological techniques have now been developed for assessing the presence of viruses. Using these two basic elements, CIP has developed genotypes immune to PVX and PVY.

Previous studies have shown that the genetic resistance to PLRV is more complicated than that to PVX or PVY, because of the multifactorial nature of this resistance and its strong dependence on environmental factors.

Resistance to PLRV multiplication. Resistance to virus multiplication in the plant is one of the most important components of the resistance to PLRV. The level of this type of resistance can be assessed only by determining the virus concentration in plant tissue at different intervals after inoculation and the rate of infection of progeny tubers in inoculated plants.

Two advanced clones (G-7461-1 and G-7445-1) that had shown evidence of genes for resistance to virus multiplication were part of the collaborative research with the Scottish Crops Research Institute. Preliminary inoculations with 9 geographically different PLRV isolates indicated that these clones were infected only by isolate 01 from Peru and were infected at a low rate by an isolate from Nepal. However, infected plants showed only small amounts of virus in the foliar tissue. These results indicate that clones G-7461-1 and G-7445-1 have genes for resistance to virus multiplication, as well as probable resistance to infection. They will be used as progenitors in CIP's breeding projects, and studies will be made of the infection rate of progeny tubers.

Antixenosis and antibiosis. Resistance to aphid vectors is another important component of the resistance to PLRV, and antixenosis and antibiosis are the most relevant factors in this resistance.

In spite of difficulties encountered in maintaining healthy aphid colonies for these studies, tests were made and a high level of antixenosis was found in CIP clones 703314, CIP 703319, F-3, and the cultivar Ccompis. Antibiosis was again confirmed in *Solanum neocardenassii*.

Screening for resistance to PLRV. A total of 112 clones from CIP's pathogen-tested collection were screened for resistance to PLRV under field conditions during the winter season at Ica, Peru. Only two clones, G-4 and Monserrate, showed a high level of resistance to PLRV infection. Another group of 52 pathogen-tested clones that had previously shown resistance to PLRV infection under glasshouse conditions is being exposed to PLRV infection in a field-exposure trial to determine the stability of their resistance. This experiment is being conducted in collaboration with the Universidad San Luis Gonzaga at Ica, Peru. The aphid population during the winter season was measured on plants and in Moericke yellow traps and a moderate count was found at up to 6 weeks after planting (35 to 150 winged aphids per week). However, the count was low (5-18 winged aphids per week) during the remaining period until harvest time.

Sixty-two advanced clones were found to resist PLRV infection after 5 field exposure trials during the winter season at Ica. When these clones were exposed to PLRV infection during the summer season (temperatures from 22C to 38C) in the same location, only 16 clones were selected as moderately resistant and resistant to PLRV infection (Table 4-1). This resistance breakdown under high

Table 4-1. Some characteristics[a] of clones selected for resistance to PLRV after 5 field-exposure trials at Ica, Peru.

Clone	Family	LR	SG	RS	DM	Yield
86007	B-71-240.2 x 7XY.1	R	-	-	-	1171
86061	•	R	1.079	3.66	19.78	960
86023	•	M	-	-	-	713
86001	•	M	-	-	-	650
86008	•	M	1.078	1.66	20.03	622
86002	•	M	1.076	3.00	19.81	600
86010	•	M	1.083	2.00	21.17	515
86059	•	R	-	-	-	513
86015	•	R	1.084	2.66	22.34	433
86058	•	R	-	-	-	390
86014	•	M	1.082	3.00	20.70	386
86060	•	R	1.077	3.33	20.92	339
86017	•	R	1.078	2.33	18.94	317
86099	BR63.15 x 7XY.1	R	-	-	-	294
86095	Mariva x 7XY.1	M	1.080	3.66	20.49	270
86085	B-71-240.2 x 7XY.1	R	-	-	-	150

[a] LR = highly resistant (R) or moderately resistant (M). SG = specific gravity in g/cm^3. DM = dry matter in percentage. RS = reducing sugars using arbitrary scale of 1 (minimum) to 5 (maximum). Yield is expressed in grams per plant.

temperature regimes also has been noted in the field experiments conducted through a research contract in Poland (Institute of Potato Research, Mlochow). Such findings are important because CIP's research objective is to develop genotypes for use mainly in warm climates.

Combination of resistances. The combination of virus resistances (PVX, PVY, and PLRV) with resistance to other pathogenic agents is a key research objective because resistance to only one virus is not enough for good performance of a genotype under field conditions. Such a combination is especially important for PLRV resistance that is broken into genotypes susceptible to PVX or PVY.

Thirty-seven families from crosses between PLRV-resistant clones and PVX- and PVY-resistant clones were evaluated for agronomic characteristics at La Molina. Of these, 17 families (Table 4-2) showing the expected segregation ratio were selected for export to other countries for field evaluation and selection.

There was also an evaluation of another group in which 16 families were obtained from crosses between parents with resistance to PLRV and immunity to PVY, or a combination of immunities to PVY and PVX, and 45 were obtained

Table 4-2. Number of progenies showing the expected segregation ratio (immune: susceptible) by genotype.

Genotype	Virus immunity	Expected ratio	No. of progenies[a]
$Yy_3 \times y_4$	PVY	1:1	9
$Xx_3y_4 \times Yy_3x_4$	PVX+PVY	1:3	1
$Y?y_2 \times Xx_3Yy_3$	PVY+PVX	11:13	2

[a] Of 37 families tested.

from intercrosses of PVX- and PVY-immune clones. From a population of 9,600 plants, 5,600 showed resistance to PVX and PVY and 233 clones (4.16%) were selected on the basis of their good agronomic traits. Future work is designed to produce clones carrying the gene for immunity to PVY in higher frequencies (triplex condition), as well as duplexes for PVX and PVY, and their combination to PLRV resistance. Work is now under way to combine PVX and PVY immunities with resistances to bacterial wilt (*Pseudomonas solanacearum*) and to early blight (*Alternaria* sp.). The objective is to have genotypes carrying all of these resistances available to NARS within the next 5 years.

Variability of PLRV. Studies of the variability of viruses are essential to the production of resistant genotypes, and CIP has made extension studies of the variability of PVX and PVY. Current studies are focusing on the variability of PLRV, and isolates of PLRV available at CIP have been studied to compare infectivity and the symptomatology produced in selected hosts, including *Nicotiana benthamiana*, *N. clevelandii*, *Datura stramonium*, *Gomphrena globosa*, *Physalis floridana*, and *Lycopersicon esculentum*. No significant differences were found among these isolates, indicating that variability of PLRV infectivity cannot be used as a criterion for classification of strains of this virus.

Immunological differences among PLRV isolates were examined, using several monoclonal antibodies derived from a British isolate produced in collaboration with the Scottish Crops Research Institute. ELISA tests were made and the color reactions were quantitated by determining the absorbance values in an ELISA colorimeter. The highest absorbance values in these studies were assigned a value of 10, and the remaining absorbance values were calculated in relation to this value. Table 4-3 shows the results, which suggest that the isotope variability in the PLRV particles ranges widely among the PLRV isolates. Based on these results, PLRV isolates at CIP can be grouped into three serogroups: Group 1 includes the isolates from Korea, from El Salvador, and from Peru. Group 2 includes isolates from China, Kenya, Uruguay, and Britain; however, the Chinese isolate differed markedly from the other isolates in this group, in its reaction to the monoclonal PM-10. Group 3 is represented by isolate 10 from the Peruvian Andes. Serological detection or identification of PLRV can be improved by producing antisera specific for each serogroup and then combining several antisera to obtain a wide spectrum detection system (polyvalent detection).

Techniques for Diagnosing Virus and Viroid Infection with NCM-ELISA

The NCM-ELISA test is the preferred technique for serological detection of viruses because of its sensitivity and ease of use. However, the technique becomes as expensive as DAS-ELISA if all reagents and supplies are obtained from commercial laboratories outside the developing countries. Attempts are being made to reduce the costs by exploring the use of supplies available in the local markets. The goat-anti-rabbit conjugate and the nitrocellulose (NC) membrane are the most expensive items in the tests; however, methods have now been developed to produce the goat anti-rabbit conjugate in each laboratory by injecting goats with purified rabbit gamma globulin (IgG) and then linking the antibodies obtained with alkaline phosphatase. This conjugate showed the same sensitivity as the commercial conjugates at half the cost.

NCM-ELISA has been useful for detecting all potato viruses, except PLRV, which has proved difficult because of the poor attachment of PLRV particles onto the NC membrane. The attachment of PLRV particles on NC membranes has been improved through the use of a special solution (0.2M Tris-borate buffer, DIECA and EDTA). This solution is used to extract the samples;

Table 4-3. The reaction[a] of PLRV isolates (available at CIP) against monoclonal antibodies derived from a British PLRV isolate.

	Monoclonal antibodies					
PLRV isolate	1	4	5	7	PM-6	PM-10
Korea	10	6	6	4	5	2
029 (Peru)	10	6	9	6	8	3
El Salvador	10	5	8	4	5	1
China	7	2	10	1	4	7
Britain	9	7	10	4	1	2
Uruguay	9	5	10	6	2	3
Kenya	8	3	10	1	5	1
010 (Peru)	4	6	7	1	10	2

[a] Expressed as relative values to the maximum ELISA reading (A_{405}=10) in the experiment.

samples are then clarified with chloroform. These measures help to increase the effectiveness of the NCM-ELISA test.

Research on idiotypic antibodies. Idiotype technology is potentially useful to rapidly reproduce large amounts of virus-specific antibodies or to reproduce specific antibodies to an array of antigens. This new technology is designed to produce antibodies (anti-idiotypes) against virus-specific antibodies (idiotypes), as well as antibodies against idiotypes, without the need of the antigen (purified virus).

Following encouraging research initiated last year, additional studies have been made of idiotypic antibodies, and the terminology used in this research has been standardized. In CIP's work, Ab-1 antibodies are the idiotypic antibodies, or virus-specific antibodies. These antibodies may be of monoclonal or polyclonal origin. Ab-2 antibodies are the intermediate anti-idiotypic antibodies produced in an animal injected with Ab-1. In a serological test, Ab-2 antibodies mimic the reaction of the original virus antigen. Ab-3 antibodies are the anti-anti-idiotypic antibodies produced by injecting an animal with Ab-2. In theory, Ab-3 and Ab-1 antibody reactions should be similar to those of the virus antigen.

Ab-3 antibodies to several viruses are produced, with major emphasis on PLRV. Initial findings indicate that Ab-3 antibodies have been produced that have the same reactivity as do PLRV Ab-1 antibodies of monoclonal origin.

Several sources of PLRV Ab-1 antibodies have been examined for production of Ab-3 antibodies (Fig. 4-1). Independently from these sources, however, all PLRV Ab-3 antibodies produced also showed a variable degree of

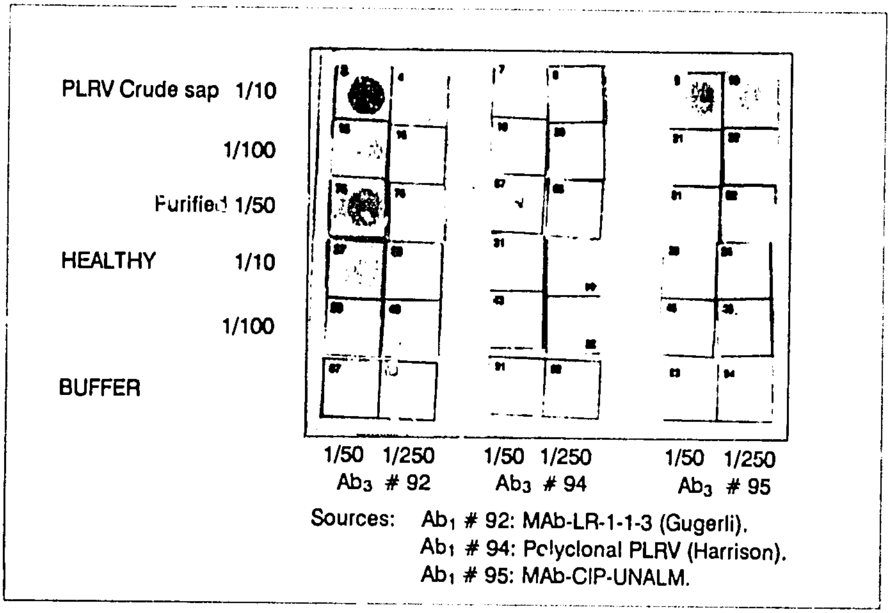


Figure 4-1. Specific detection of PLRV by Ab-3 antibodies produced from three sources of idiotypic (Ab-1) antibodies.

reaction with PVX and PVS. A mixture of spleen-cell fluids from immunized mice containing PLRV Ab-1 antibodies produced Ab-3 antibodies, in which ELISA tests clearly detected PLRV, and almost no reaction to PVX and PVS. Detailed studies are being made of the origin of cross-reactions with other viruses, and of the use of the same animal species for the production of Ab-2 and Ab-3 (syngenic), and use of different animal species (xenogenic animals) in the process.

Viral double-stranded RNA. Virus-specific, double-stranded RNA (ds-RNA) is produced in plants, when infected with RNA viruses. The size and number of ds-RNA bands in electrophoresis are specific for virus groups and have diagnostic value. Thus, ds-RNA technology can be used to detect both known and unknown RNA viruses, and can be especially useful in sweet potato studies, because several viruses in this species have not been identified. In addition, the ability to extract non-genomic, virus-specific RNA provides an excellent tool for virological studies.

Progress is being made in research to extract ds-RNA from luteoviruses using a simplified procedure that CIP has developed, which employs potex- and luteoviruses as models (Fig. 4-2). Further studies are under way to compare ds-RNA from different PLRV isolates and other viruses.

Nucleic-acid probes. Nucleic-acid probes for detection of viroids and viruses have been prepared in collaboration with the Beltsville Agricultural Research Center, Maryland, USA (Table 4-4). These probes are used to detect the agents in potato, sweet potato, or other hosts, as well as to determine relationships among viruses or viroids. Research has concentrated on the analysis and identification of viral cDNA clones. Around 30 different PLRV cDNA sequences, ranging between 100 bp to 1200 bp, can be used to detect PLRV, and with a probe 800 bp long, PLRV can be detected in up to a 1/1000 dilution of clarified sap (Fig. 4-3). However, the concentration of PLRV virions was found to be extremely variable in infected plants of the same cultivar.

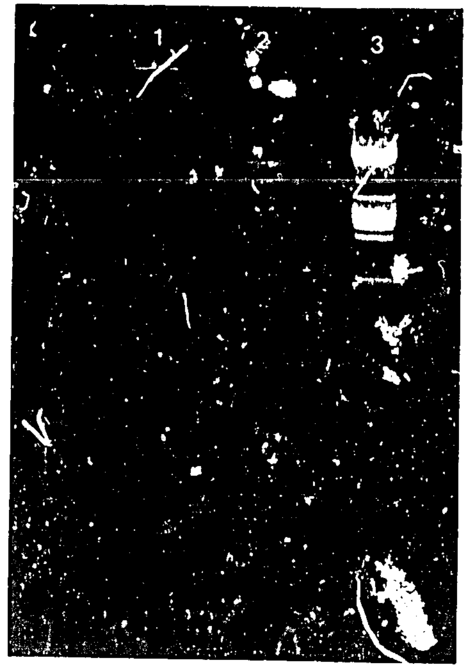


Figure 4-2. Agarose gel electrophoresis of ds-RNA of 1) PVX, 2) PLRV, and 3) DNA-markers.

Because the selection of only one cDNA sequence might yield a probe that is too specific (narrow detection range), it is convenient to select the greatest number of cDNA sequences that can hybridize to one particular virus. Thus, a wide-spectrum probe can be recom-

Table 4-4. Type and sensitivity of nucleic acid probes[a] to detect viruses and viroids.

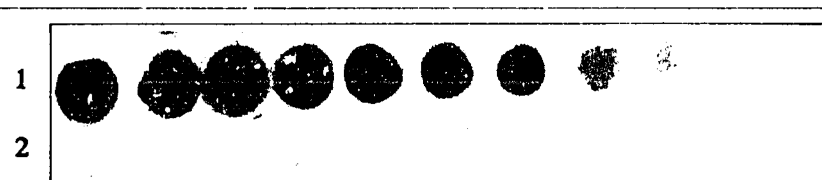
Virus or viroid	RNA probe	DNA probe	Sensitivity
Potato spindle tuber viroid	+	+	1024
Citrus exocortis	+	+	512
Avocado sunblotch	+	+	1024
Tomato Planta Macho	+	+	nt
Tomato apical stunt	—	+	nt
Tomato apical stunt-PSTVd	—	+	nt
Hop stunt viroid	—	+	nt
Crysanthemum stunt viroid	+	+	300
Potato virus X^A	+	+	200000
Potato virus X^O	+	+	1500
Potato virus Y	+	+	10000
Potato leafroll virus	+	+	1024
Andean potato latent virus	+	+	nt
Sweet potato feathery mottle virus	+	+	1280

[a] (+) = available at CIP; (—) = not available. Sensitivity is expressed as the reciprocal of maximum dilution detected of homologous infectious extracts showing positive reaction.

tructed or specific sequences can be used in mixtures (polyvalent detection) to detect all virus strains. On the other hand, highly specific sequences are extremely valuable for strain differentiation and characterization. Therefore, a set of 25 different probes is available for detection of PVY.

Experiments combining several virus and viroid probes in the same hybridization mixture revealed no interference in the detection of individual viruses or viroids. This finding suggests that these probe combinations can be used with a polyvalent method when it is important to know whether the samples are infected, but not the identity of the infecting agent.

Non-radioactive labelled probes can serve effectively to detect viruses or viroids, and such use is now being evaluated.



Note:
1 = PLRV-infected sap dilutions 1/2 to 1/1024.
2 = healthy sap dilutions 1/2 to 1/1024.

Figure 4-3. Detection of Potato Leafroll Virus by Nucleic Acid Spot Hybridization with a 32p labelled probe.

Research on sweet potato viruses has concentrated on improvement of detection methodology, identification of viruses and virus-related agents, and a search for genetic resistance to the most important viruses.

Detection of viruses. NCM-ELISA can now be used to detect sweet potato feathery mottle virus (SPFMV), mild mottle virus (SPMMV), and latent virus (SPLV), using antisera developed at CIP and at North Carolina State University, Raleigh, NC.

Nucleic-acid probes for detection of SPFMV have been developed, and as compared to ELISA, the procedure shows an advantage in detecting the virus long before symptoms develop in infected plants.

Detection of viruses in accessions to be included in the pathogen-tested list follows a protocol that includes several applications of biochemical tests (serology and NASH) and graft-inoculations to *Ipomoea setosa* and *I. nil.* The whitefly-transmitted component (WF) of the sweet potato virus disease is detected by graft-inoculation onto the sweet potato clone TIB 8 that has previously been infected with the RC strain of SPFMV. The synergistic disease caused by SPFMV and the WF on TIB 8 is used as an indication of the presence of the WF. Research is under way to improve this cumbersome procedure.

NCM-ELISA kits for detecting SPFMV, SPMV, and SPLV are being distributed to NARS.

Studies on virus resistance. A search for resistance to sweet potato viruses continued in collaboration with the Volcani Center, Israel. Using the procedure shown in Figure 4-4, 13 clones were shown to have apparent immunity to SPFMV. However, SPFMV was detected in the top of some of these plants when they were grafted with an infected *I. setosa* scion.

Such clones may be truly immune, with the virus moving to the plants passively from the infected scion. To confirm the initial results, stem cuttings from graft-inoculated plants have been excised and they will be tested for SPFMV after development of mature plants. These clones now represent the most resistant material available for SPFMV at present. They are being examined for reaction to other sweet potato viruses, such as mild mottle virus (SPMMV), latent virus (SPLV) and C-2 viruses.

Identification and characterization of viruses. Research is under way to identify the viruses affecting sweet potatoes to prevent inadvertent dissemination and to help eliminate viruses.

Several isolates of apparently unknown viruses have been identified, and the C-2 and C-5 isolates were found to be serologically related to a virus previously reported as SPVC-S in Japan. An antiserum to C-2 has been produced and is being used to study relationships to previously reported viruses in sweet potatoes. C-2 and C-5 have elongated particles (between 750 nm-900 nm) with C-5 having the longest (modal length between 800 nm-900 nm).

C-3 apparently has bacilliform particles, whereas C-4 has isometric particles that are found between chloroplasts in

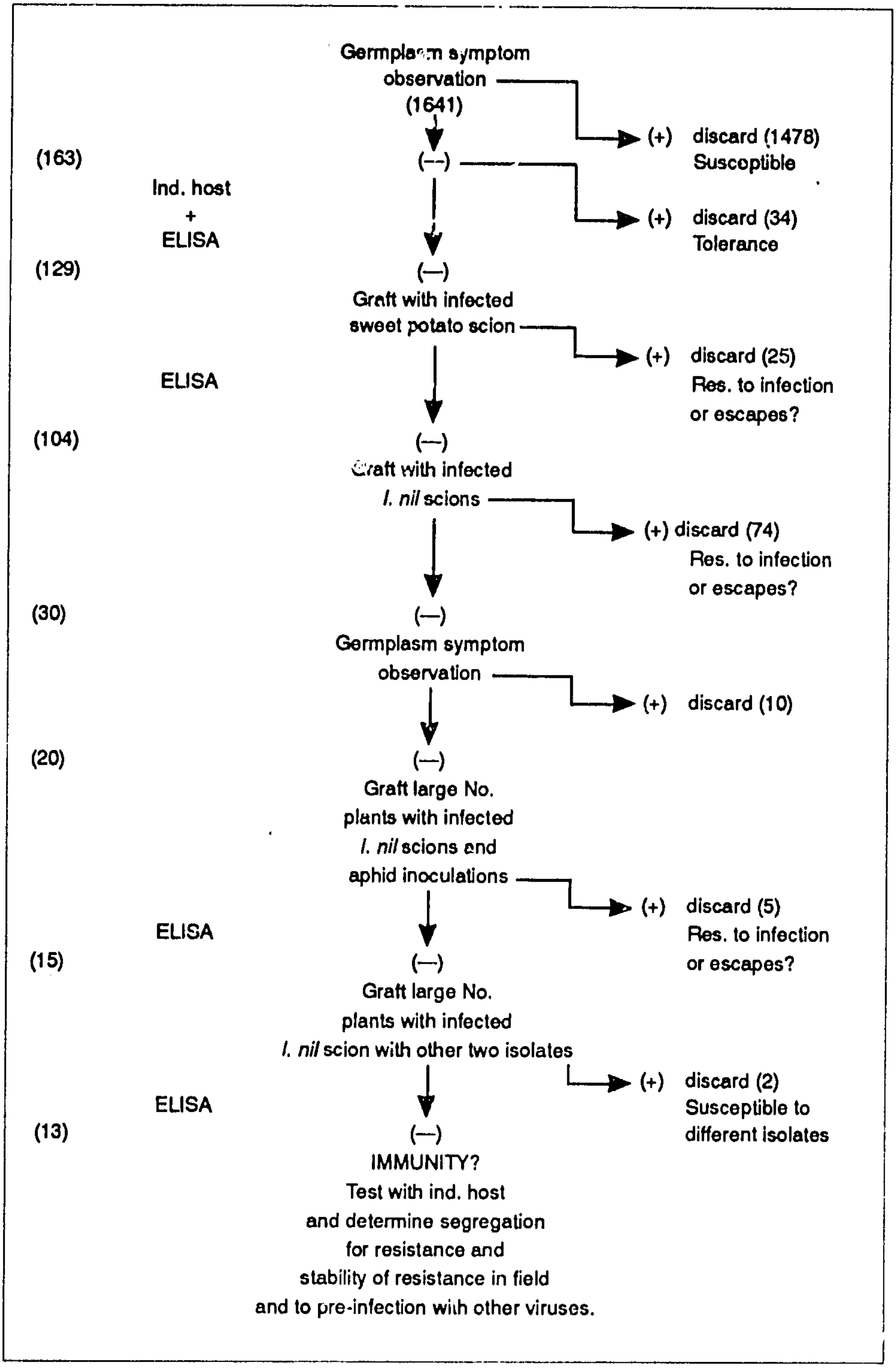


Figure 4-4. Search for genetic resistance (immunity) to SPFMV in CIP germplasm accessions.

thin sections analyzed by electron microscopy (Fig. 4-5). The C-7 isolate induces yellowing; necrosis and dropping of basal leaves; and dwarfing on *I. nil*. This virus also infects *Nicotiana clevelandii* and *Gomphrena globosa*, causing leaf deformation and dwarfing of infected plants. C-7 was experimentally transmitted by whiteflies (*Bemisia tabaci*) and also through the botanical seed of infected *I. nil*.

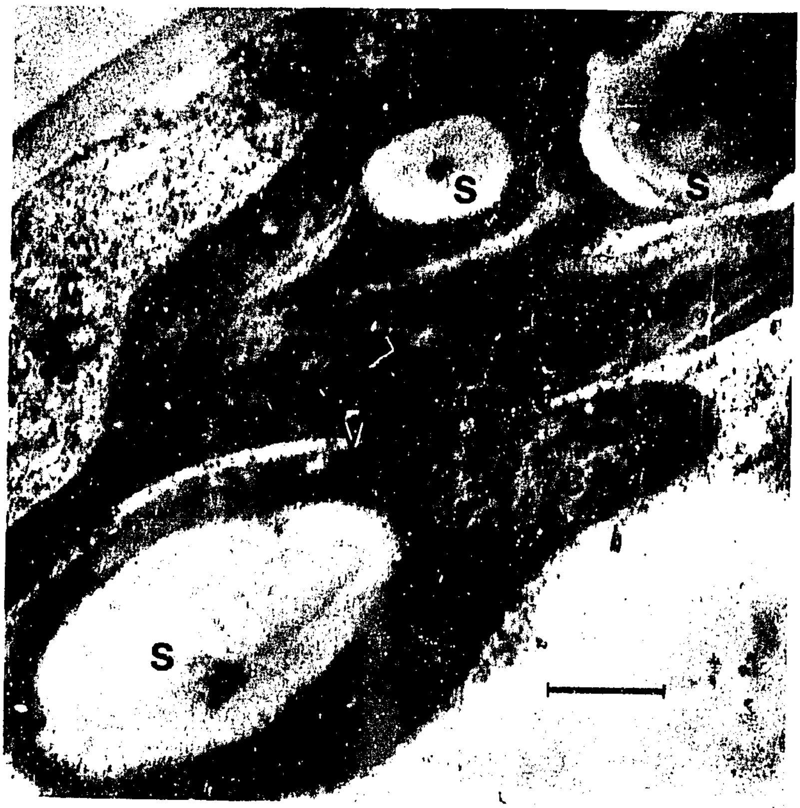


Figure 4-5. Ultra-thin section of phloem companion cell of *I. nil* infected with C-4 isolate. Isometric particles are seen between the chloroplast membranes. C = chloroplast; S = starch grain; V = virus particles. Bar represents 500 nm.

Glandular trichome exudate accumulated on the body, setae, and tarsi of red spider mite (*Tetranychus urticae*), as observed under scanning electron microscope (X 442)

Thrust V

Integrated Pest Management

Thrust profile: 1990

Thrust V research focuses on the identification and use of resistant germplasm, biological control agents, and other non-pesticidal methods to develop the appropriate components for integrated control of potato and sweet potato pests. The potato cyst nematode (PCN) breeding program identified 20 advanced clones, including clone G86056.8, which yielded 2.86 kg/plant, and clone G86147.9, which yielded 2.70 kg/plant. Several advanced clones, tuber families, and true seed with resistance to PCN have been sent to Pakistan, Ecuador, Bolivia, Mexico, Colombia, the Netherlands, Germany, France, and New Zealand for field evaluation and use in breeding. In Ecuador two clones, I 16-10 and G 1-6, have been selected for release. A total of 52 clones have been selected by the national potato program in Ecuador for further evaluations. Resistance to PCN identified in *Solanum andigena* has been transferred to other adapted material. Clones with combined resistances to PCN, late blight, and viruses have been selected. Metabolites extracted from the bark of *Uncaria tomentosa* and foliage of *Lonchocarpus* sp. were toxic to PCN under laboratory conditions.

Root-knot nematode (RKN) resistance was identified in several potato progenies at the diploid and tetraploid level, and additional sources were identified in *S. multidissectum*, *S. bukasovii*, *S. canasense*, and *S. gourlayi*. The fungus *Paecilomyces lilacinus* had a residual effect for RKN control on the sweet potato crop and in the Philippines, this fungus was effective in controlling PCN and RKN. Crop rotation experiments in Burundi identified the most effective cropping sequence to control RKN. In Peru the economic importance of root-lesion nematode, *Pratylenchus* spp, was studied and *P. flakkensis* was identified as the most important. Several new sources of resistance to RKN in sweet potatoes also have been identified. Protein patterns of the false root-knot nematode, *Naccobus aberrans*, have been studied to aid in identification of populations. This technique is useful for identifying races of this nematode. The occurrence of a new nematode damaging to potatoes was studied and its nature of damage on root tissues has been documented. Further research to determine the significance in terms of impact of this nematode on potatoes is under way.

Seven resistant clones with high densities of glandular trichomes type A and B were selected for Potato Tuber Moth (PTM) resistance, and this resistance was reconfirmed in material selected earlier. The granulosis virus was effective after 6 months when stored at room temperatures of 21C ± 2.5C; however, treatment with talc alone was also effective. The biological insecticide *Bacillus thuringiensis* (BT) applied as dust provided good protection in stored tubers. In Colombia improved techiques were developed for mass rearing of the PTM parasitoid *Chelonus phthorimaea*. In Egypt and Tunisia, the use of granulosis virus (GV) and BT was found effective in storage. These components are now being used in integrated pest management. Seasonal occurrence of PTM using pheromone traps was studied in Colombia, Peru, Burundi, and Ethiopia. Highest trap captures of PTM were identified to enable the timely application of control measures.

For leafminer fly, 11 additional clones have been selected. In other studies, clones resistant to Andean weevil, *Premnotrypes suturicallus*, thrips, *Thrips palmi*, and mites, *Tetranychus urticae* and *Polyphagotarsonemus latus* have been identified. The fungus *Beauveria* spp. was effective in controlling Andean weevil. Natural enemies and a host range of thrips and mites attacking potatoes were identified in the lowlands of the Philippines. Sweet potato clones were selected for resistance to the West Indian sweet potato weevil *Euscepes postfasciatus*. In greenhouse tests, the fungus *Beauveria* was effective in controlling the larval, pupal, and adult stages of this pest.

Potato Cyst Nematode

Thrust objectives for potato cyst nematode (PCN) studies are to 1) develop advanced material for varietal selection and parental material with resistance to potato cyst nematode (PCN) *Globodera pallida*, with primary emphasis on Andean countries and secondarily on adaptation to non-traditional tropical highlands, 2) broaden the base of resistance through utilization of cultivated and wild species, and 3) combine resistance to PCN with resistance to virus, frost tolerance, and late blight.

Screening and Breeding for Resistance

One hundred and fifty advanced clones developed by breeders from G 86 and G 85B populations were tested in infested fields at Huancayo, and 62 were selected and sent for regional trials at Huamachuco, Cuzco, and Puno in Peru. Of these clones, 20 outyielded the two check cultivars, and the best clones were G86056.8, with 2.86 kg/plant and G86147.9, with 2.70 kg/plant. Checks were Maria Huanca (1.94 kg) and Tomasa Condemayta (1.54 kg/plant). Yields improved markedly, but there was a decline in resistance to races P4A and P5A, indicating the need to study these races and choose the most appropriate ones to use in screening for the breeding program.

High frequencies of PCN races P4A and P5A were identified. Resistance to race P4A was evaluated in clones G86 and G85B, using pot, petri-plate, and field tests. Results from pot and field tests correlated well. However, numerous clones found resistant in pots rated as susceptible in the petri-plate test. This finding suggests the need for study of a possible second mechanism for resistance related to the hatching and invasion being selected for in the pot test.

Advanced clones, tuber progenies, and true seed were sent to national programs of Pakistan, Ecuador, Bolivia, Mexico, Colombia, the Netherlands, Germany, France, and New Zealand. In Ecuador, 5 clones have been recommended for release, with clone I3-34 (CIP

279023.3) among the best for yield and resistance. However, clone J16-10, which is of CIP origin (377744.2 x Bulk LB), and clone G1-6 are also being considered for release as cultivars. There are 17 selections from the 1988 shipment in yield trials and 35 from the early shipment of 1989. Most genotypes have been rejected because of their susceptibility to late blight. To solve this problem, present breeding efforts are attempting to combine PCN resistance with late blight resistance.

Broadening the Genetic Base

In Huancayo, more than 400 crosses were made using previously identified PCN-resistant material. A total of 200 progenies were tested in the mass seedling screening with 149 rated as resistant to both races of *Globodera pallida*. Ten new *S. andigena* clones rated as resistant were selfed, intercrossed, and outcrossed with I-1039, I-1035, and G3 to evaluate the inheritance of resistance in these potential sources of resistance. The average yield was 1.64 kg/plant, and 1,349 genotype clones (10.8%) were selected as resistant. Of these, 20 genotypes were selected for resistance evaluations to estimate the frequency of resistance. Inbreeding depression was most evident in self crosses of accessions 703990, CCC 4382, 702426, and 703284, whereas the least inbreeding depression was observed in 703430, HJT-15, and CCC 4641. Clone 703430 was also the best parent for yield in this group. The diploid 2n pollen PCN-resistant clone 84-28-58, was used to develop 28 progenies, which were evaluated for resistance to both races; however, this clone contributed little toward resistance. From this population, 476 clones were planted in the field, with 52 selected for further yield trials (mean yields were 1.1 kg/plant at Huancayo and 0.7 kg/plant at Cajamarca). However, of all selected clones, only one originated from the diploid clone as the male parent; thus this clone did not contribute to improved resistance or yield. In other studies conducted at Cornell University, four clones which combine resistance to PCN races RIA with P4A and P5A have been developed. These are lines L114-1, L115-1, L123-1, and L127-2.

Combining PCN Resistance with Virus and Late-Blight Resistance

In studies of PCN/virus resistance, 66 clones with an average yield of 1.6 kg/plant were selected at Huancayo and 9 clones with an average yield of 0.78 kg/plant were selected at Cajamarca. At Huancayo, 60 clones were selected for PCN and late-blight resistance, and 9 clones were selected at Cajamarca. Of the clones at Huancayo, 21 were found susceptible to race P4A, but resistant to P5A; 17 were resistant to P4A, but susceptible to P5A; and 22 were resistant to both races. This finding indicates that the existing genes accumulated for resistance to P4A and P5A can be used effectively to combine PCN resistance with other traits, because the inheritance of double resistance is relatively high. The best strategy to combine these resistances is being investigated. Studies were made of PCN in relation to the nematicidal activity of metabolites extracted from the bark of *Uncaria tomentosa* and from the leaves and stem of *Nerium oleander* from Peru, and from the foliage of *Lonchocarpus* sp. from the Philippines. Diluted aqueous and ethanol extracts of *U. tomentosa* became toxic to *G. pallida* within 24 hours, whereas the aqueous and chloroform extracts of *Lonchocarpus* sp. became toxic to nematodes

48 hours after exposure. *Nerium oleander* extracts were not toxic. Further experiments are planned in the field. If effective, the use of this approach would significantly reduce the need for toxic nematicides.

Root-Knot Nematode (RKN)

The main objectives of our root-knot nematode research are 1) to screen for and utilize resistance to *Meloidogyne* incognita, and 2) to identify the components of integrated root-knot nematode management and interrelationships of this nematode with other organisms.

Screening for and Utilization of Resistance to RKN in Potato

A total of 2,670 seedlings were tested representing 33 progenies produced by crossing 5 *Meloidogyne* susceptible females with 4 resistant 2x clones, 2 susceptible 2x clones and 1 susceptible 4x clone. Few resistant progenies were found. Other tests of resistance were made of 2,580 seedlings representing 35 progenies of 4x-2x crosses, and 1,990 seedlings representing 9 progenies of 4x crosses, which were developed by crossing previously selected resistant material with those developed for adaptation to warm tropics. The frequency of resistant segregating genotypes in these crosses also was lower than expected. However, in other studies involving progeny of 4x-2x crosses, a high level of resistance to RKN has been identified.

In retesting the reaction of 743 previously selected clones (97 from 2x crosses, 213 from 4x-2x crosses, and 433 clones from 4x crosses to *M. incognita*) the lowest incidence of resistance was noted in the clones of 2x crosses. Although clones of 4x-2x crosses retained their high degree of resistance, many clones from the 4x crosses also showed a good degree of resistance.

A total of 81 RKN-resistant clones developed by 4x-2x crossing of susceptible female and resistant male progenitors were retested to confirm resistance. Temperatures were 4C to 6C higher than previously and most of the genotypes became susceptible when retested at this higher temperature. This finding suggests the need for standardization of the temperature regimes during the screening process (see Table 5-1 for temperature conditions and plant reactions). Additional sources of resistance were found in five 2x clones with *Solanum multidissectum, S. bukasovii, S. canasense*, and *S. gourlayi*, thus widening the gene base of the 2x population used in the breeding program.

Components of Integrated RKN Management

In isolated field plots of potatoes planted as a first crop at Ica, Peru, studies were made of the effects on *M. incognita* of one preplant application of *Paecilomyces lilacinus* at 2 x 10^{14} spores/ha; of organic matter (chicken manure) at 6 t/ha; and of Aldicarb at 1.5 kg a.i./ha and 3 kg a.i./ha, when used alone and in combination. The study also investigated the residual effect of these treatments on sweet potatoes planted as the second crop. Although the yields of potatoes in treated plots were higher than in those of control plots, the differences were not significant. For most treatments on sweet potatoes, the yields of *Meloidogyne*-resistant sweet potato cv. Nemañete were generally sig-

Table 5-1. Reaction of some clones selected as resistant to root-knot nematode, *Meloidogyne incognita*, during 1988 and retested in 1989. La Molina, Peru.

1988 evaluation (Av. temp. = 26C)		1989 evaluation (Av. temp. = 31C)					
No. of clones	Root galling index[a]	1	2	3	4	5	6
44	1	12	20	8	4	-	07
31	2	-	11	17	1	2	0
7	3	-	-	2	3	1	0
Total = 81		12	31	27	8	3	0

[a] 1 = highly resistant, 2 = resistant, 3 = moderately resistant, 4 = moderately susceptible, 5 = susceptible, 6 = very susceptible.

nificantly higher than those from the control plots. No differences were noted in the nematode populations for all treatments when measured immediately after harvest of each crop; however, the nematode population at sweet potato harvest was significantly lower than that of the initial population and of that measured after potato harvest. When used in an integrated RKN-management program, the resistant sweet potato cultivars, in combination with other treatments used in this study, will further reduce nematode populations. A single application of any of these components at the beginning of the first crop resulted in a residual effect that contributed to the yield increase of the second crop.

Observations of the effect of these treatments on the third crop (potatoes) indicated a general pattern of decreasing nematode population, which in part may be attributed to the use of a highly resistant rotation crop (sweet potato cv. Nemañete).

Evaluations were made of the effect of 50 isolates of plant growth-promoting *Rhizobacteria* on development of the potato plant and control of RKN. Although the metabolites of all these isolates were toxic to *M. incognita* under laboratory conditions, they were not effective when applied to the soil. All the bacterial isolates (in the greenhouse) increased plant growth, despite nematode infection, and a few showed some degree of nematode control. Most bacterial isolates showed some residual effect as they persisted in the soil; they promoted a better growth of the next crop than did the non-inoculated control. Nematicidal activity of 16 fungal species isolated from cysts of PCN was evaluated on *M. incognita*, *G. pallida*, and *Naccobus aberrans*. These metabolites were very effective in killing the *G. pallida* juveniles; however, they were not effective in controlling RKN, and the metabolites of only 3 fungi killed 90% of *N. aberrans*. The data suggest some specificity in the biocontrol activity of fungi isolated from *G. pallida* cysts. Further studies should be made to identify organisms that produce metabolites with broad-spectrum activity against several genera of nematodes.

Crop rotation influences on RKN control were studied at Gisozi, Burundi. Best results were obtained with *Panicum maximum* as the preceding crop, followed by *Sorghum* sp. and finally *Setaria* sp. and *Triticum* sp. These crops reduced RKN populations in soil.

Sweet Potato

Root-knot nematode (RKN), *M. incognita*, is a major pest of sweet potato in many areas of the warm tropics. A total of 54 clones from the sweet potato germplasm collection were evaluated for resistance to *M. incognita*, and 8 resistant and 4 moderately-resistant clones were identified. At San Ramon, 140 second-generation clones were tested: one clone was found to be highly resistant and 29 were resistant.

Seedlings of 1,113 genotypes representing 11 progenies were tested, and 76 were found to be highly resistant and 106 were resistant.

In a retest of the material previously selected in a seedling screening test, 22 out of 32 clones tested retained their high degree of resistance, while 7 out of 14 were rated as resistant in the retest. Higher greenhouse temperature during the retest, (4C to 6C higher than that of the initial test) may account for this loss of resistance. Nevertheless, results of the above two studies indicate that the seedling screening method is efficient. The resistance of 131 clones of *Ipomoea trifida* was tested in another screening test and 57 highly resistant and 43 resistant clones were identified.

Root-Lesion Nematode

Assessment was made of the distribution of *Pratylenchus* spp. in Peru, and methods for management were studied. A total of 174 root and soil samples were collected from La Libertad, Ancash, Lima, Ica, Cerro de Pasco, Junin, Huanuco, Ayacucho, Cuzco, and Puno. They were analyzed to detect *Pratylenchus* spp., and the following percentages were found: *P. flakkensis* (46%), *P. penetrans* (20%), *P. brachyurus* (12%), *P. scribneri* (2%), *P. zeae* (8%), *P. coffeae* (15%), and *P. crenatus* (3.5%). Small percentages of *P. andinus*, *P. macrostylus*, *P. neglectus*, and *P. vulnus* also were found. Of 50 plant species tested, all *Chenopodiaceae*, *Liliaceae*, *Tropaelaceae*, and *Umbeliferaceae* were resistant. Plant species *Chenopodium ambrosioides*, *Tagetes minuta*, and *Tagetes patula* were resistant and antagonistic to *P. flakkensis*. On the Peruvian coast, sweet potato, cotton, peas, and beans were effective in crop rotation studies and in the Andean highlands, oats, barley, lupine, and wheat were identified as useful crops for rotation to reduce populations of this nematode.

The protein patterns of false root-knot nematode, *Nacobbus aberrans*, were studied to identify races. Electrophoretic studies indicated no differences in protein patterns of these nematodes when grown on roots of potato or tomato plants. However, the protein patterns differed among populations collected from different regions of Peru. Extraction and inoculation methods for this nematode have been developed. The taxonomy of a new plant-parasitic nematode attacking potatoes in Peru also is being studied. Examinations of root sections revealed that these nematodes penetrated and moved inter- and intracellularly along the root axis in the cortical tissue parallel to the stelar region. Necrosis was usually limited to the cells adjacent to the nematode. Further studies to identify this new nematode are in progress.

Insect and Mite Pests

This research identifies useful control components for an integrated pest management (IPM) strategy to reduce injury caused by major insect and mite pests that infest potato and sweet potato.

Potato Tuber Moth (PTM)

Screening for Resistance

In an initial test, tubers of 65 advanced clones with high densities of glandular trichomes types A (4-lobed) and B (long-stalked with sticky droplets) were tested using the closed container test, and seven of these clones were selected as resistant. Of these seven, clones T86H735.8, T86H748.3, and TA14.6 had high levels of antibiosis. In a second test, laboratory and storage tests were conducted to reconfirm resistance in 190 clones from populations P82, P83, P85, OCH6579, in hybrids selected for resistance to Australian PTM population, P87, in clones selected for the Colombian PTM population, and in clones with high densities of glandular trichomes. Emphasis centered on identifying clones with high densities of glandular trichomes and tuber resistance to PTM. In laboratory tests, 32 clones were selected as resistant. In storage tests, 79 clones were selected as moderately resistant (Table 5-2).

Table 5-2. Reconfirmation of resistance to potato tuber moth, *Phthorimaea operculella*, for clones selected between 1982-1987. La Molina and San Ramon, Peru.

Potato populations[a]	Laboratory test				Storage test		
	No. evaluated	No. selected	Resistant (R)	Moderately resistant (MR)	No. evaluated	No. selected	Moderately resistant (MR)
P 82	5	1	-	1	5	0	-
P 83	8	6	2	4	8	8	8
P 85	6	5	1	4	6	5	5
P 87	61	19	3	16	61	21	21
OCH 6579	11	3	-	3	11	2	2
PA LM	31	15	5	10	29	16	16
PA SR	27	15	4	11	27	1	1
PA	34	26	14	12	37	22	22
PC	3	3	2	1	3	3	3
PT	3	2	1	1	3	1	1
Total	189	95	32	63	190	79	79

[a] Acronyms used by breeders. P82-87: PTM population developed in 1982, 1983, 1985, and 1987. PA LM: Hybrids with resistance to Australian PTM selected in La Molina. PA SR: Selected in San Ramon. PA: Hybrids with resistance to Australian PTM. PC: Clones resistant to Colombian PTM. PT: Hybrids developed for glandular trichomes resistant to PTM.

This population has a broad-based resistance to PTM populations from Australia, Colombia, and Peru. In a third test, 401 clones selected in the field from the second clonal generation P87 were evaluated in storage at San Ramon and 75% of the clones were selected for resistance. This high level of segregation for resistance reflects substantial progress in the breeding program. Resistance has now been increased through careful selection, and most of the selected clones are high-yielding, averaging more than 1 kg/plant. Siblings P85072.3 and P85072.4 showed the greatest ability to transmit resistance.

Resistance at the diploid level was studied in 111 clones, and a total of 16 were selected as resistant. In Colombia, tests were made of potato clones obtained from Cornell University and CIP breeders. Pupation in some of these clones was substantially reduced (Fig. 5-1) and a total of 120 clones have been selected and are being screened for resistance to other insect pests. At Cornell University, additional trichome clones have been developed from callus culture: clones 4001, 4029, 4038, and 4040. These clones show promise for transmitting B droplets in backcrosses.

Biological Control

Further evaluations have been made of the granulosis virus (GV), the bacteria *Bacillus thuringiensis* (BT), and the parasitoid *Copidosoma* sp. The formulation of GV plus talc stored at 10C for 6 months was compared with the formulation stored for the same period at 21C ± 2.5C (room temperature), and with the freshly prepared GV formulation. All 3 formulations were effective, indicating that GV does not lose its effectiveness when stored at room temperature. The effect of talc alone was investigated at levels of 1 gm/kg, 3 gm/kg, and 5 gm/kg of stored potatoes. Levels of talc at 3 gm/kg and 5 gm/kg affected larval development and damage; pupation was reduced by

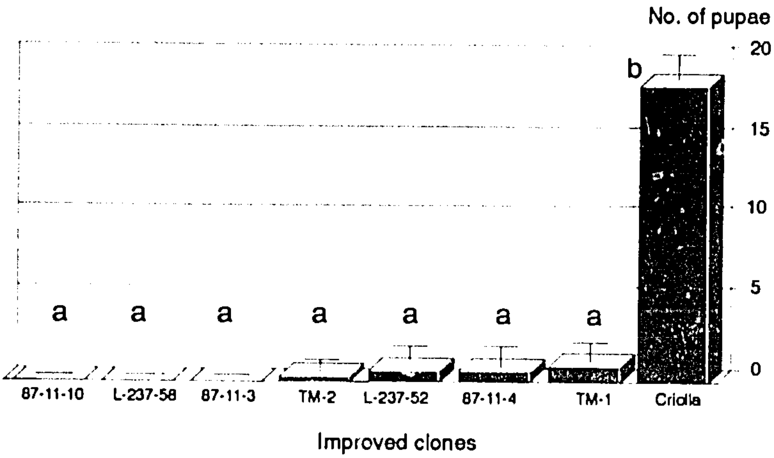


Figure 5-1. Results of a test using the closed container test for resistance against the PTM. All the new clones behaved as resistant when compared with the check Criolla cv. Duncan's Multiple Range Test (P <.05).

59%, and the number of holes in tubers was reduced by 76%. PTM larvae on talc-treated tubers fell off or showed coated blocked spiracles and mouth parts. In tests of formulations of BT and GV in solution and powder form, the most effective were BT applied as dust, BT plus talc, GV plus talc, and talc alone. For all treatments, PTM damage and pupation was substantially less than that of the untreated tubers (Table 5-3).

In studies of the interaction between PTM, the parasitoid *Copidosoma* sp., and GV larvae of PTM emerging from parasitized PTM eggs were placed on GV-treated and untreated tubers. The pupation percentages were: 29.3% for PTM from parasitized larvae, 5.2% for GV alone and 0.4% for both GV and the parasitoid. In storage, GV plus talc and talc alone were tested at rates of 1 gm/kg to 5 gm/kg of potatoes. In comparison with untreated tubers, the 5 gm/kg dose reduced tuber damage by 72%, sprout damage by 59%, and PTM population by 78%, whereas talc alone reduced tuber damage by 49% and sprout damage by 46%.

In San Ramon stores, GV and the insecticide Deltamethrin (Decis) were tested as liquid and dust formulations, and both reduced tuber damage by over 90%, as compared to the check. Deltamethrin E.C. was not effective. In the field, GV was compared with the biological insecticide BT (Bactospeine W.P. 0.2%) and the carbamate insecticide Methomyl (Lannate 0.4%). Both GV and BT were as effective as Methomyl in reducing PTM larval infestation. In comparisons with untreated plants, the reductions were: GV, 61%; BT, 71%; Methomyl, 100%; and GV plus BT, 74%.

Table 5-3. Effect of different formulations containing *Bacillus thuringiensis* (BT) and Granulosis virus (GV) on potato tuber moth damage and development. La Molina, Peru.

Treatments	$\bar{x}$ Holes[a] per tuber	$\bar{x}$ Pupae[a] per tuber	Damage[a] index
Bacillus thuringiensis (BT)			
Bactospeine 0.2% W.P.	2.50 de	0.40 a	1.00 a
Bactospeine 0.2% W.P. (as dust)	0 a	0 a	1.00 a
Bactospeine + talc	0.50 ab	0 a	1.00 a
Granulosis virus (GV)			
+ talc	1.40 bc	0.10 a	1.00 a
GV with water	3.40 e	0 a	1.30 a
Talc alone	1.60 cd	0.70 a	1.10 a
Check	4.40 f	6.80 b	2.50 b
SD	0.35	0.27	0.12
CV %	17.76	9.44	25.47

[a] Means followed by different letters are significantly different using Duncan's Multiple Range Test (DMRT) $P < 0.05$.

Methods to mass rear GV-infected larvae were studied by spraying GV in three concentrations (1,10, and 20 GV-infected larvae/liter of water) in potato plants infested with PTM and maintained in 3m x 2m field cages. The optimum dose for obtaining maximum GV-infected larvae was 10 larvae/liter of water. At this dosage, 91% of larvae in foliage were infected. An average yield of 35 infected larvae per plant was obtained.

In Colombia, laboratory facilities have been established for mass rearing of PTM parasitoids *Copidosoma desantisi* and *Chelonus phthorimeae*. Other parasitoids of *Trichogramma* spp. are also under study. At Kafr El Zayat, Egypt, GV and BT were tested in storage, and tuber damage with the GV + BT + talc treatment was less than 10%, whereas damage in untreated tubers exceeded 60%.

In Tunisia, integrated control studies continued with the evaluation and refinement of control components and techniques and examination of the population dynamics to optimize IPM strategy in storage. The efficacy of GV (Tunisian isolate) and BT (Bactospeine) separately and in combination was studied, using selected dry carriers (talc or lime) at preestablished initial rates of infestation in potato heaps of 200 kgs, which were surrounded by thick straw. Regression analysis indicated that the treatment effects on populations of PTM differed ($P < .05$) at one month after storage. At 3 months, the PTM population stabilized without further increase. Only a slight increase in infestation occurred in the control treatment after the first month. The general lack of infestation was attributed to both good isolation provided by straw and to high populations of predatory mites, beetles, and spiders in the heaps. All treatments provided good control (less than 10% damage compared to 25% to 60% for untreated tubers). Seven treatments were found to be equally or more effective than the chemical insecticide K-Othrine. Of these, the combinations of BT-talc, BT-lime, GV-BT-talc, and GV-BT-lime were the most effective. Both GV and BT were obtained from Tunisian sources: the BT from a commercial producer of Bactospeine ($2.89/kg), and the GV from rearing facilities at INRAT (produced at a cost of $0.03 per diseased larva). The GV-producing facilities at this center are non-commercial. The costs for one-ton storage were: GV-talc, $4.67; GV-lime, $2.17; Bactospeine, $8.67, and the insecticide K-Othrine, $18.33. The production of GV is very economical in relation to the cost of commercially available insecticides.

Sex Pheromone

When 2 formulations of sex pheromone (PTM1, 0.4 mg + PTM2, 0.6 mg; and PTM1, 0.9 mg + PTM2, 0.1 mg) were compared in water traps at La Molina, Peru, no significant differences were observed in trap captures during the first 8 months. However, the PTM1, O.4 mg + 0.6 mg formulation captured more PTM after 8 months. In Tibaitata, Colombia, the triene component of this pheromone attracted more male moths than did the diene ($P < .01$). No differences were observed in trap capture when diene and triene were blended in proportions of 10:40; 20:30; 30:20; and 40:10. However, lower levels of triene resulted in lower trap captures. Such data are useful in identifying the optimum pheromone blend for monitoring PTM.

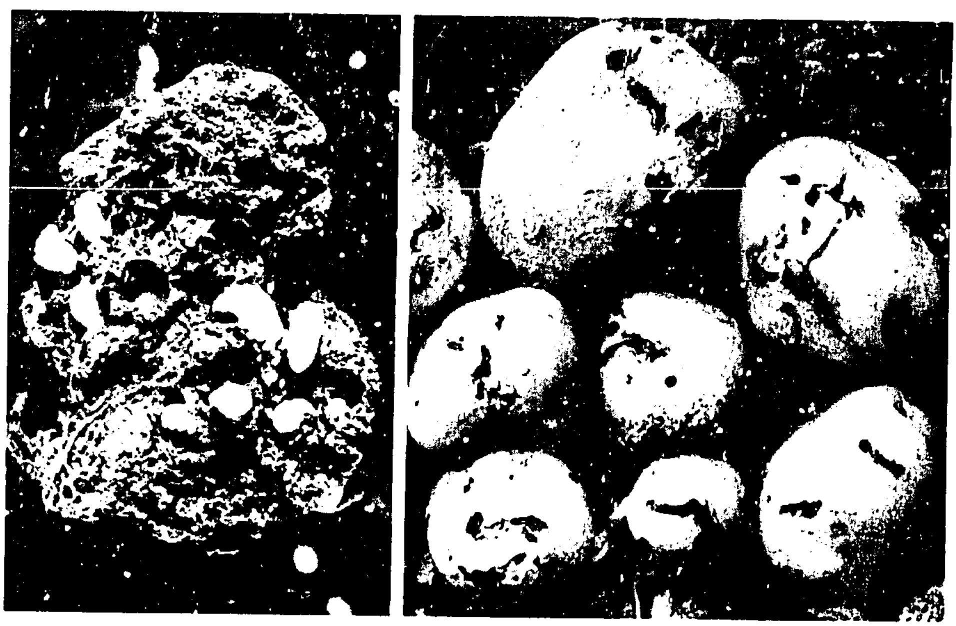
In Burundi, PTM populations were monitored using sex pherome traps at Gisozi, Nyakararo, Munanira, Mwokora, and Mahwa from September 1988 to August 1989. The highest captures of 10 to 14 moths/trap/week were observed between November and December in the fields and stores at Nykararo. In fields at Mahwa, the PTM population was high during May-July (8-20 moths/trap/week). In Ethiopia, trapping counts were made at the Holetta Research Center, where the moth populations were low (month/trap/week). These data help in developing recommendations for timely application of insecticides to control this pest and for adjusting planting and harvesting dates to coincide with low PTM populations. In Egypt, wire-screened stores with pheromone and light traps gave the best protection.

Leafminer Fly

In field evaluations of 137 clones at La Molina, Peru, 11 were selected as moderately resistant to leafminer fly with clones 282 and 220 yielding more than 1.2 kg/plant. In a second test, 10 clones previously selected from the TPS breeding program were reevaluated, and 7 were selected (136, 662, 731, 661, 28, 25, and 33). Clones 136, 661, and 28 yielded more than 900 gms/plant. The clones Monserrate, Kinigi, and Mariva, which had been selected earlier for resistance, were reevaluated and their resistance reconfirmed.

Andean Potato Weevil

In Peru, a total of 26 clones from the population developed for high altitudes was tested for resistance, using the closed-container test, and 15 clones were selected, some of which are resistant to



Left: Andean weevil *Premnotrypes* spp. larvae and pre-pupae found in a potato store. **Right**: Tubers showing Andean weevil damage.

frost and late blight. Of these clones, 85F46.J, 85F108.3, 380495.1, and 85LB70.5 yielded more than 2 kg/plant. A storage trial was conducted at Chinchero, Cuzco, Peru using the fungus *Beauveria* sp. as a biological control agent. This fungus was effective in controlling all stages of the weevils, emerging from the stored tubers. Nine isolates of *Beauveria* sp. have been collected from different locations in Peru and are now being identified. Mass rearing methods for this fungus have been improved, and barley husks have been shown to be the best and cheapest substrate.

In Colombia, physical barriers (use of plastic bands 50-cm high) to prevent access to adults was effective in reducing infestation. Of the insecticides tested, Carbofuran (Furadan) was the most effective as a foliar spray when applied at 60 and 67 days after planting.

Spider Mites and Thrips

Clones segregating for glandular trichome type A and B were evaluated for resistance to *Tetranychus urticae* and *Polyphagotarsonemus latus* in field cages at La Molina, Peru. From the breeding program of Cornell University, clones J108.1, J115.1, J115.2, and *S. neocardenasii* were selected for resistance to *T. urticae*. (See thrust photo for glandular trichome exudate accumulated on body of *T. urticae*). These clones were susceptible when tested for *P. latus*, indicating that resistance to one species of mite may not be correlated to other species. Seven families from Cornell University were evaluated visually and several clones have been selected. A total of 367 clones have been selected from CIP breeding material.

In the Philippines, 30 TPS families from the T88 population were tested for resistance to thrips and mites, and clones T88719, T88764, T88766, T888770, T88810, and T88814 were selected. Several families also were tested in Puno, Peru and 17 were selected for resistance.

The host range and natural enemies of *Thrips palmi* and *P. latus* were studied in the Philippines. These two pests have common host plants: 13 for *T. palmi* and 17 for *P. latus*. Nine natural enemies were identified for *T. palmi* and 8 for *P. latus*.

Sweet Potato Weevil

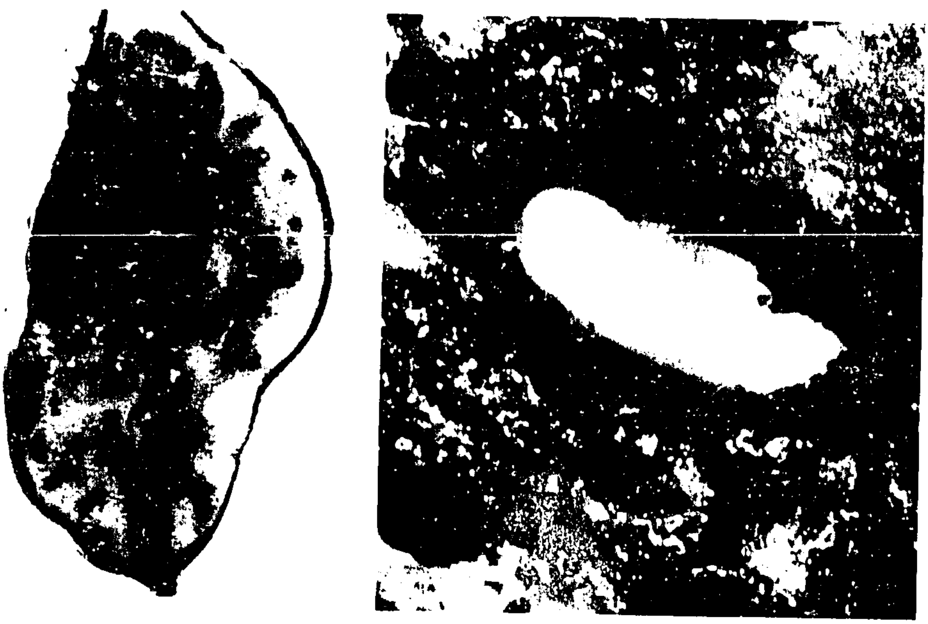
In Peru, previously selected clones and additional germplasm were screened under laboratory and field conditions, and clones RCB 17IN, DLP2173, and DLP2274 were shown to be less damaged in lab and field tests. Scanning electron microscopy (SEM) was used for male and female differentiation of *Euscepes postfasciatus* adult weevils. In the female, the posterior ventral segment was observed to be nearly flat, while in the male it curves upward. For biological control, the fungus *Beauveria* sp. has been isolated from infected adults and mass reared. In greenhouse tests, all treatments with *Beauveria* sp. resulted in higher mortality rates and fewer larvae and pupae.

In the Dominican Republic, 3 trap designs using sex pheromone were field evaluated for *Cylas formicarius*. The water trap was found to be the most effective, and a total of 4,908 *C. formicarius* males were caught in a 40-day period. In collaboration with CARDI (Caribbean Agricultural Development Research Institute), an integrated management program for this pest has been initiated in Jamaica, St. Vincent, and Barbados.

Research Contracts

Research contracts with the Universidad Nacional Agraria, La Molina, Lima, Peru focused on the control of major potato and sweet potato pests. Population dynamics of *L. huidobrensis* have been studied in potatoes, and high infestations were found in September, with parasitism varying from 3.3% to 13.6%. In the laboratory, selective insecticides are being identified through bioassay with leafminer fly parasitoids.

In sweet potato studies, the population dynamics of the sweet potato whitefly *Bemisia tabaci* and its parasitoids have been collected for identification. Seasonal occurrence of other sweet potato pests also has been studied. The Centro de Introduccion y Cria de Insectos Utiles (CICIU) of Peru has collaborated in improving the mass rearing methods for the polyembryonic parasitoid *Copidosoma desantisi* of PTM. In the Philippines, collaborative studies with UPLB have evaluated the fungus *P. lilacinus* for control of potato nematodes. Several isolates were tested and the isolate from Peru at a 2-million spore level gave 68.6% control of *G. rostochiensis*. At the 4-million spore level, this control increased to 73.4%, and at the 8-million spore level, to 78.4%. This fungus was also effective in controlling root-knot nematode infestation in tomatoes at the 4-million spore level. Ultraviolet light and gamma irradiation are being used to enhance the biocontrol efficacy of *P. lilacinus* and *Metarhizium anisoplae*.



Left: Sweet potato root showing damage caused by the sweet potato weevil *Euscepes postfasciatus*.
Right: Sweet potato weevil pupa lodged in the flesh of the root.

Sweet potato harvest in alley-cropping experiment with legume trees. Yurimaguas, Peru.

Thrust VI

Warm-Climate Potato and Sweet Potato Production

Thrust Profile: 1990

Potato clones that yield well under warm climates continue to be selected, and now improvements in sustainability of yields following continuous production and diffused light storage (DLS) cycles have also been achieved in some clones. In the Philippines, clones 384515.9, 385131.52, 385130.8, and 385152.44 have excelled for these characters.

Sweet potato clones were screened for yield capability at all CIP stations, and at salty-environment locations at Tacna, Peru. With the exception of results obtained during the hot rainy season at Yurimaguas, early clones produced acceptable tuberous root yields.

To improve sweet potato yields under hot, waterlogged conditions, a new line of research has begun to examine the physiology of tolerance to waterlogging. Results from the sweet potato drought program have illustrated the importance of maintaining a good foliage cover over the soil and of an early storage-root formation. Drought studies in potato have identified clones that can avoid drought (large root systems, e.g. clones P-3 and P-7) or escape drought (early tuberizing clones, e.g. cv. Berolina). Under conditions of increasing drought, resistance has now been confirmed for the cultivars Huinkul, LT-7, and MS-35.27.R. The relationship between lethal and sub-lethal relative water contents of leaves and chlorophyll fluorescence and the ability of clones to withstand drought is now being studied, to rapidly screen genotypes for drought tolerance. Problems with salinity are often confounded with those of insufficient water supply, especially in marginal desert regions. A series of experiments with the cultivars Atica, Alpha, and Nicola have shown them to be relatively tolerant to saline irrigation water.

Alternative crops to maize (e.g. sunflower) were successfully used to shade the early autumn potato crop in Egypt; shade-tolerant cultivars were identified for strip cropping in China. Additionally, advantages of pest control through intercropping practices have been quantified in Southeast Asia.

Studies of sweet potato clonal response to a range of artificial shade levels have illustrated the shade tolerance present in sweet potato germplasm, and have suggested the possibility of selecting clones specifically for intercropping.

Agronomic and Physiological Research

Drought and Salt Tolerance

Potato. Drought limits potato production in at least 20 of the 44 countries included in the constraints survey (Thrust X), and therefore merits intense research attention. In particular, drought is a serious limitation to winter production of potato in the lowland tropics, where the crop coincides with the dry season. In addition to field selection for yield done in collaboration with national programs, which often takes into account exposure to drought, specific studies have been made of physiological and genotypic responses to drought in Peru and the Philippines, as well as in contract research at the Scottish Crops Research Institute (SCRI), and in collaboration with the Volcani Center in Israel. Data collected will assist CIP and national programs to decide on 1) screening strategies that can confidently identify drought-tolerant genotypes, and 2) irrigation strategies suitable for localized production conditions.

Drought-resistance evaluations based on yield and root-pull resistance (RPR) continued in Peru. Physiological age of the tubers at planting was a major contributor to the location, season, and year effects. Five traits (foliage dry weight, number of nodes and stolons, and root and stolon dry weight) were closely related to RPR (r^2 = 0.765). Additionally, tuber weight was related to RPR in early clones. In these trials, under conditions of increasing drought, resistance was confirmed for the cultivars Huinkul, LT-7 and MS-35.27.R, whereas BR-65.15, Cruza-27, Haille, and MEX-21 were rated as moderately resistant. In a field trial comparing the influence of two subsurface irrigation systems under varying degrees of drought stress, abaxial stomatal resistance increased with stress, while adaxial resistance increased to an even greater extent. Stomatal resistance and stomatal density increased, suggesting a reduction in water loss and a capacity for efficient water use. Measured over time, leaf water potential became more negative, suggesting an increase in the level of tissue stress.

In the lowland Philippines, four clones subjected to drought stress, by withholding irrigation for 30 to 50 days after planting (DAP), showed uniform responses of reduced height, branching, canopy cover, and rooting (weight, length, and number). The two clones with *S. andigena* in their ancestry (P-3 and P-7) produced the most roots, which grew down to 60 cm. However, Berolina, the earliest maturing cultivar (which had a root number similar to that of P-3 and P-7) showed concentrated root growth in the top 15 cm, especially in the drought-stress treatment. This finding suggests that P-3 has drought-avoidance characteristics, whereas Berolina is characterized by drought-escape features.

The response of apical cuttings taken from 10 potato clones and subjected to control and stressed moisture regimes in raised field beds was closely related to field response. This finding suggests that this approach might represent an economy in field space for genotype screening. Reduction in dry matter accumulation was evident at 30 DAP, and tuber yield differences between treatments was evident at 50 DAP. The clones DTO-28 and 380584.3 showed the least tuber yield reduction. Genetic studies must now follow in order to determine the heritability of drought tolerant related characters, before the development of various drought tolerant populations can be implemented.

Related studies continued under contract at the Scottish Crops Research Institute to determine the combination of characters that will improve the exploitation of soil-water resources over the cropping season. Genotypes were grown in vertical pipes, either well-watered or with terminal drought. Yield and dry matter partitioning to tubers varied between genotypes, and rates of leaf growth were related to available soil-water contents. The differences in genotypic response to drought were not associated with differences in osmotic adjustment. Further experiments will determine whether the drought effect can be attributed to water supply due to rooting differences, or to other factors, such as cell-wall extensibility. Minimum leaf conductance (i.e. epidermal conductance to measure minimum water loss) and lethal and sublethal relative water content (RWC) values were studied in subsidiary experiments. Genotypes did not differ markedly in RWC; however, they differed in the leaf number at which lethal RWC values occurred.

Chlorophyll fluorescence shows promise in rapid screening for drought tolerance, whereas the use of rooted cuttings in a polyethylene glycol-graded osmotica was disappointing, due to its uptake and toxic effect on the plants.

In Israel, the decreasing availability of good quality irrigation water, plus the extension of potato production to marginal (often saline) soils, has focused intense research attention on genotypic responses to salinity and irrigation methods. This research, funded by the Ministry of Foreign Affairs of the Netherlands, has been under way since 1986. Comparisons of differing levels of irrigation water salinity (1 dS/m^2, 3.5 dS/m^2, and 6.6 dS/m^2), have shown that yield reduction is less with short (2- to 3-day) irrigation intervals than with longer (7- to 12-day) irrigation intervals, when the same total amount of irrigation water is supplied over the season. Flexibility of the potato root system to search for water appears to be limited, thus subsurface irrigation close to the plant axis seems desirable. Potato genotypes showed differing yield responses to various water salinities (1.4 dS/m^2, 4.3 dS/m^2, and 6.8 dS/m^2). When the potato crop was established with nonsaline, sprinkler-irrigation water and then subjected to a saline drip-irrigation system, the cultivars Atica, Alpha, and Nicola, and the clone LT-4, were shown to be relatively tolerant to salinity, while Baronessa, DTO-28, DTO-33, LT-7, Superior, Désirée, and Cara were susceptible to salinity. Sprinkler irrigation with differing treatments of saline water (1.4 dS/m^2, 3.8 dS/m^2, 5.6 dS/m^2, and 9.3 dS/m^2) did not significantly reduce tuber yield of potted plants, whether grown in saline or nonsaline nutrient solution. However, in another experiment, the amount of foliage covered with necrotic lesions of *Alternaria solani* was found to increase with an increase in salt concentration in the sprinkler-applied irrigation water. It appears that this disease, in combination with *Verticillium dahliae*, can enhance the salinity-induced decline in plant survival, and therefore emphasizes the need to incorporate resistance to these diseases in genotypes adapted to North African and Mediterranean conditions.

Results from an additional experiment indicated that the physiological age of seed tubers at planting could influence genotypic response to salinity. Manipulation of the physiological age of seed tubers could minimize the effect of salinity on growth and yield, and this will be studied in future experiments. Results, to date, on the use of saline irrigation water illustrate the potential that the potato crop has to adapt to marginal desert lands where supplies of nonsaline irrigation water are not available.

Sweet potato. Line-source and drip-irrigation systems were used during the summer in Lima to effect varied irrigation levels, applied at similar frequencies, once the crop had been established under favorable water conditions. Under the line source system, in which irrigation ranged from 260 mm to 363 mm during the 4-month season, significant yield reductions were noted with less irrigation water (Table 6-1). It was also found that clones producing high yields generally had higher leaf-water potentials. Water use efficiency (WUE, weight of storage root per unit volume of water received by the crop) and storage root dry-matter contents were greater in drier treatments. As in the previous year, there was no clone with irrigation treatment interaction for storage-root yield, or for WUE; therefore, selection for high yield under well-watered conditions would permit simultaneous selection of drought-tolerant cultivars.

Table 6-1. Effects of a line-source irrigation system on root yield (kg/m^2) of 14 sweet potato clones. La Molina, summer 1989.

Clone name	Clone code (RCB-)	Water application rate (mm)				Mean
		363	317	283	260	
Chiappe	94-IT	1.29	0.86	1.08	0.92	1.04
Paramutai	24-IT	1.07	0.95	0.79	0.87	0.92
De Armero	125-IT	0.88	0.84	0.95	0.79	0.86
Centennial	20-IF	0.74	0.88	0.53	0.49	0.66
Guiador	120-IT	0.93	0.50	0.40	0.65	0.62
Paramonguino	276-IN	0.78	0.77	0.10	0.59	0.56
Super Star	38-IT	0.68	0.48	0.30	0.26	0.43
Buen Pobre	72-IN	0.50	0.43	0.36	0.21	0.37
Maleno	44-IN	0.39	0.33	0.33	0.28	0.33
San Pedrano	28-IN	0.12	0.40	0.00	0.04	0.14
Morado	3-IN	0.08	0.14	0.04	0.13	0.10
Japonés Portugués	64-IN	0.07	0.05	0.08	0.15	0.09
De Sal	6-IN	0.11	0.09	0.03	0.03	0.07
Amarillo de Quillabamba	173-IN	0.06	0.05	0.01	0.06	0.04
Mean		0.55	0.48	0.36	0.39	
SED clone mean	0.14			p = <0.001		
Treatment mean	0.05			p = <0.05		
Clone x treatment	0.18			ns		

Table 6-2. Storage root yield, yield components, foliage yield, and expansion rate of leaves and petioles (mid-season), for six sweet potato cultivars in four irrigation treatments: 1 = 100% (477 mm), 2 = 80% (405 mm), 3 = 60% (325 mm), 4 = 40% (249 mm) of estimated evapotranspiration. Total evaporation during season = 871 mm.

Clone	Treatment	Fresh storage root yield (kg m^{-2})	Fresh foliage yield (kg m^{-2})	Total dry weight (foliage + root g; m^{-2})	Expansion rate (cm d^{-1})	
					Petiole	Lamina
RCV 31 IT Nematode	1	1.36	3.14	941	1.13	0.89
	2	1.12	3.55	859	1.05	0.91
	3	0.63	3.41	705	0.86	0.79
	4	0.92	1.91	669	0.80	0.69
RCB 120 IN Guiador	1	0.39	6.24	1035	1.39	1.12
	2	0.38	6.02	975	1.17	0.97
	3	0.16	3.12	563	0.76	0.69
	4	0.17	3.43	563	0.90	0.80
RC 146 IN Negrito de Huanco	1	1.39	8.82	1312	-	-
	2	0.87	5.39	950	1.60	0.84
	3	0.83	4.67	833	1.30	0.56
	4	0.52	2.83	616	1.31	0.68
RCB 146 IN	1	1.30	3.00	872	1.32	1.01
	2	1.32	2.77	819	1.09	0.88
	3	0.67	1.79	510	1.03	0.82
	4	0.35	2.28	619	0.83	0.75

With the drip system, amounts of water varying from 250 mm to 477 mm were applied to 6 cultivars during the 5-month season. The well-watered treatment did not invariably produce the greatest fresh storage-root yield, but it did produce the greatest total dry-matter (foliage plus roots) yield (Table 6-2). Petiole and leaf laminae extension rates were sensitive to water deficit; however, for all clones, the average reduction in extension rate for well- and poorly-watered plots (25%) was proportionally less than the reduction rate for the plots with applied irrigation (48%).

Irrigation levels of 160 mm, 360 mm, and 580 mm were applied to plots of 5 sweet potato cultivars in the lowland Philippines. Drought sensitivity was observed only during the early vegetative stage, and storage-root yield was significantly reduced only at extreme moisture stress. As at Lima, Peru, irrigation greater than 400 mm seemed to be detrimental to root yield. The results from the Philippine study indicate that genotypic ability to tolerate water stress depends more on the earliness of storage-root formation and bulking rate than on crop cover and root growth attributes.

Data generated in contrasting environments on the physiological response of sweet potato genotypes to drought are unique, and provide a base upon which to develop breeding and screening strategies to improve and exploit drought tolerance in the sweet potato. The greater ability of the sweet potato over that of other crops to prosper under drought conditions will favor its extension to marginal lands.

In vitro screening of sweet potato germplasm for salt tolerance has continued, but several anomalies remain for study. For example, the clone with best fresh and dry weight production under mildly saline conditions (174 mg NaCl/l) was characterized by the lowest number of roots, and of nodes with roots.

Heat and Shade Tolerance

Potato. Additional data have been analyzed from controlled environment studies at Nova Scotia Agricultural College (NSAC), Canada, and from contract research at Cornell University, U.S.A.

At NSAC, combinations of low irradiance (250280/mol/m^2/s) and high temperature (33C/25C day/night) – as found in shaded intercrops of potato – significantly reduced net assimilation rates for the two clones studied, as shown by comparable rates obtained under high irradiance, cool-temperature conditions (430-450 mol/m^2/s and 20C/10C). Respiration following 16 h at 30C was greater in plants grown under high-light and low-temperature conditions, suggesting a greater pool of assimilates under the more favorable conditions. Data on rates of carbon fixation suggest that leaves adapt to higher temperatures: the net photosynthetic rate at 30C was 9.19 mol CO_2/m^2/s for leaves produced under hot conditions, compared to 7.25 mol for leaves produced under cool conditions. Terminal and variable (peak-minus-initial) fluorescence values were closely related to total dry weight production and growth parameters, and may act as indicators for tolerance to high temperature and low irradiance. At the relatively higher temperatures tested at Cornell University (40C/30C), heat sensitivity was associated with a complex of responses: increased senescence, a greater chlorophyll a:b ratio, inhibition of dark reactions in photosynthesis, and reduced stomatal conductance. These data support the hypothesis of a causal link between photosynthesis and shoot growth at high temperature, while countering the evidence of a relationship between heat tolerance and dark respiration. Incorporation of a high photosynthetic rate appears to be the next step in the implementation of these results to improve productivity under high-temperature conditions. This incorporation might be estimated by measuring non-photochemical quenching of fluorescence, which correlated closely with CO_2-saturated rates of O_2 evaluation at 25C and 40C in heat-tolerant and heat-sensitive accessions.

Research continued on intercropping as a technique to reduce heat stress for potato, particularly at planting and/or close to harvest. In Egypt, follow-up studies built upon previous successes with relay cropping of an early autumn potato crop into an existing maize crop. This work includes use of sunflower as the shade crop and earlier (July 12) potato planting dates. Relay cropping of potato into either the maize or sunflower crops (established 45 days earlier) resulted in significant improvement in percentage emergence measured at 45 DAP, as well as 6.1 t/ha of maize grain or 2.1 t/ha of sunflower seed.

The widespread practice of strip cropping potato with maize is important in southern and central China. Research on this topic continues under contract with CIP at the Southern China Potato Research Center, at Enshi in Hubei Province. Studies involving variations in spatial distribution and population of both crops confirmed the advantages of 2:2 and 2:1 row ratios of maize:potato, as compared to results obtained with 3- or 4-row strips. In comparisons of maize planting dates, the mid-April planting proved best in terms of total yield (potato plus maize dry yields). Total yield was not influenced by nitrogen rates of 160 kg urea/ha when applied to each crop grown at three altitudes (460 m, 1,180 m, and 1,700 m). In measurements of the response of 16 potato clones to strip cropping (1:1 rows at 3.6 plants/m^2 for each crop), clones 694-11, 684-1, and Xinyu 4 produced yields greater than that of the control cultivar, Mira. Maize yield was significantly reduced by a delay in potato maturity (Fig. 6-1), which was associated with greater potato plant height and increased competition with maize for light. New potato and maize genotypes must minimize interspecific competition. Further research is necessary to determine whether competition is solely for light, or whether root competition for water and nutrients also exists.

Other trials conducted at Kunming, Yunnan Province, compared potato yields as a strip or sole crop in a 2:2 arrangement. Of 20 clones, seven (Serrana, Achirana *Inta*, 381064-7, MEX-32, Kufri Jyoti, Primicia INTA, and Yunnan Purple) produced greater potato yields when strip cropped. Several medicinal and vegetable crops were studied to determine their suitability as crops with which potato can be intercropped. Intercropping potato and spinach increased net returns by 8% to 48% above those obtained with potato alone, with the variation in returns dependent upon the potato cultivar. Potato yields were low when grown

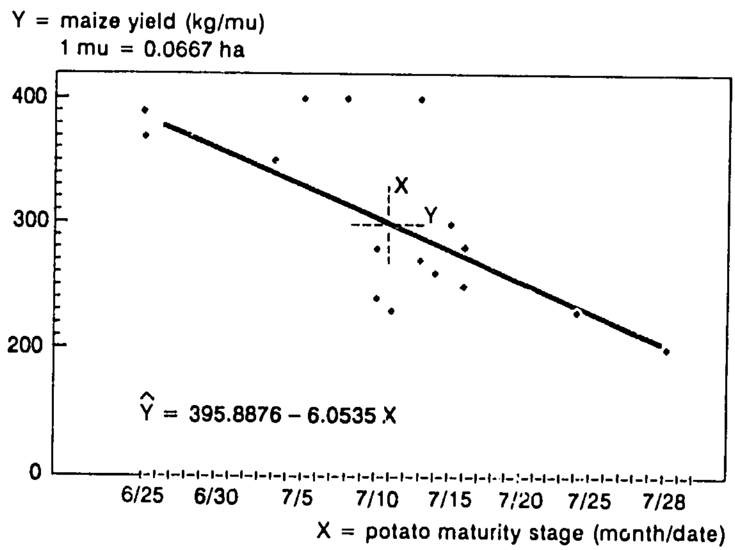


Figure 6-1. The relationship between maize yield and potato maturity date for 16 potato cultivars when planted as a 1:1 strip crop, Enshi, China.

with the other crops (rhubarb, figwort, tobacco, duhuo, and rue). In a rotation trial, the findings (5.1 t/ha vs 4.1 t/ha, LSD = 0.8 t/ha) indicated the benefits of reversing the strip rotation (i.e. planting maize in the second year, where potato had been planted previously, and potato where maize had been planted). However, yields were not as high as those obtained when the strip cropping followed a lone maize crop (8.3 t/ha) or an autumn vegetable crop (8.2 t/ha).

New varieties and agronomic procedures introduced to existing intercropping practices could have important compensatory consequences for overall yield and stability of the crop associations. However, the research under contract in China has introduced new innovations in isolation (e.g. changing planting dates, varieties) without detrimental effects, and these must now be fully tested by farmers.

To take into account the difficulties of acquiring adequate supplies of seed potatoes in Maharashtra State in India, collaborative work with the National Agricultural Research Project in Aurangabad has recently focused on the use of seedling tubers as planting material in the intercropping of potato and preseasonal sugarcane. Intercropping treatments tested four hybrid populations of seedling tubers, three tuberlet sizes (5 g-10 g, 10 g-20 g, and 20 g), and two intra-row spacings (7.5 cm and 15 cm). None of the treatments significantly influenced cane growth characters and sugar production, and tuber yields (10.2 t/ha to 12.1 t/ha) were similar to those of the cultivar Kufri Chandramuki (12.3 t/ha). During the two years of experiments, the best monetary returns were obtained with the largest seed tubers and closest intra-row spacing. Approximately 16 g of TPS was necessary to produce 550 kg of seedling tubers on 156 m^2 of nursery beds, which is sufficient for planting a 1-ha field of sugarcane.

In the Philippine lowlands, variable planting dates of sweet corn after potato (0 to 30 days), at a constant population of 5.6 plants/m^2 for each, did not influence early potato growth or reduce tuberization. However, the resultant severe shading of up to 70% during the later part of the crop significantly reduced potato yields. The square plot planting arrangements for maize planted simultaneously with potato (5.6 plants/m^2 of potato and 2.8 plants/m^2 to 8.5 plants/m^2 of maize) increased shading and reduced tuber yields compared with yields from plantings arranged in rectangular plots. Data from various experiments in which maize was the shade crop indicated that daily radiation levels of MJ/m^2 in shaded potato plots were insufficient to sustain rapid tuber bulking.

Sweet potato. Sweet potato is frequently intercropped in tropical farming systems, often with low populations of maize. An experiment in the Philippines investigated varietal suitability for intercropping with maize. A sharp yield decline of tuberous roots was not evident within the sweet corn populations tested (8:1 and 4:1 ratio of sweet potato:maize plant populations) which suggests that sweet potato genotypes are uniformly tolerant to low shade levels. Sweet corn yields (< 1 ears per plant) were low, however, which may be due to severe competition by the sweet potato, and to the lack of adequate nitrogen.

At Yurimaguas, Peru, in intercropping trials of sweet potato and maize that maintained the single-crop sweet potato population, while planting maize at populations ranging from 0.62/m^2 to 1.85 plants/m^2, a significantly greater dry yield of tuberous roots was obtained, as compared with that obtained with sweet potato grown alone. Of the 30 clones tested under these varied shade intensities, few outyielded the control clone Jewel. Relay cropping of a full-population maize crop into a full-population sweet potato crop (45 days after planting sweet potato) reduced tuberous root yield of 30 clones by an average of 35%, mainly due to reduced individual storage root weights. Dry weight of foliage was reduced to a greater extent (47%). However, some clones suffered less yield reduction than did the control clone Jewel, and might represent potential sources for shade tolerance.

In an experiment in the lowland Philippines, with artificial shade applied from date of planting, an interaction was noted between shade treatments (0% to 70% reduction in solar radiation) and genotypes, suggesting that clones may be specifically selected for their performance as shaded intercrops. Experiments are under way to determine the feasibility of field and laboratory screening for shade tolerance, and of the potential for sweet potato as an agroforestry cover crop.

Agronomic Practices to Alleviate Other Stresses

Potato. In Southeast Asia, the production of good quality seed in the highlands is limited by the presence of soilborne pests and diseases. Opportunities to exploit new highland areas are limited. Thus research is emphasizing the production of seed tubers in rice paddies, despite the contingent production problems. Restricted root growth has been alleviated by turning under the rice stubble before forming the traditional beds for potato production: yields were 1.26 kg/m^2 as compared with 0.85 kg/m^2 obtained without stubble incorporation. Plant population densities influenced yield significantly, with yields ranging from 1.17 kg/m^2 at 4.6 plants/m^2 to 1.53 kg/m^2 at 6.4 plants/m^2. High rates of nitrogen fertilizer application (120 kg/ha to 480 kg/ha) are being studied as a follow-up to findings that dosages (600 kg/ha) typically applied to shallots (*Allium cepa*) can vastly improve foliage growth and crop cover.

Pests and diseases seriously limit ware potato production in the warm-climate cropping systems of Southeast Asia. The stabilizing effect of intercropping on pest incidence has been recommended to reduce pesticide usage. Intercropping in close proximity with shallots reduced insect populations (particularly aphids) in the potato crop in both 1988 and 1989, but also led to an increase in the population of thrips. Combinations of intercropping and pesticide usage are now being studied to provide better control of persistent pests.

Pests, in particular white fly (*Bemisa* sp.) and thrips (*Thrips tabaci*), are also important in the lowlands of the Dominican Republic, where potato is a newly introduced crop. Intercropping is being studied as part of an integrated control program. Where pests are not a problem, yields with readily available cultivars (e.g. Red Pontiac, Désirée, Achirana INTA) reached a maximum of 24 t/ha, with average yields ranging from 9 t/ha to 20 t/ha. Interest in development of a chipping industry prompted experiments financed by Frito Lay (FL), using the clone Atlantic and two FL clones. The yields obtained were equal to, or better than, those of the control cultivar Kennebec, and were unaffected by fertilizer composition (15:15:15 vs 12:30:12 N:P:K) or within-row spacing (31 cm vs. 23 cm). This finding suggests that traditional farmer practices do not have to be greatly adapted to accommodate the new cultivars.

In India, studies were made of potential for use of plant-growth hormones to improve tuber yields and stress tolerance of potato. During 1987-1988, sprouted tubers of Kufri Bahar were treated with two concentrations of GA_3, CCC, S3307, and Triadimefon (TFN). Yields from tubers treated with CCC (25 ppm) and TFN (5 ppm) outperformed the control yield (20.5 t/ha) by 3 t/ha to 5 t/ha. The yields from seed tubers retained and stored after harvest also benefited from applications made in the previous seasons. In 1988-89, direct application of TFN to sprouted tubers did increase tuber yield; however, the application stimulated an increase in tuber number per unit area. Further studies are being made of the interaction between environment and seed treatment.

Sweet potato. Sweet potato is often grown on marginal soils and the crop is subject to stresses other than drought. Inorganic fertilizer is seldom applied to sweet potato. In Peru, a free-living, nitrogen-fixing bacteria, *Azospirillum*, was shown to significantly increase tuberous root yields of sweet potato (by up to 200%), when grown in pots containing 3 kg of sterile coastal soil. In a field experiment at San Ramon, the effects of inoculant *Azospirillum* were compared, using two cultivars at three N fertilizer rates (0 kg, 80 kg, 160 kg N/ha). The cultivars differed in their N requirements, and even at high inorganic N application rates, yield benefits from *Azospirillum* were still evident. Inorganic N fertilizer applications, much of which pollutes the environment, could be reduced through leaching or utilization. Further research is under way to quantify the N contribution of various *Azospirillum* accessions.

Twelve experiments were run in coastal Peru, under contract with the National Agrarian University, to study the nutrient requirement for sweet potato. Coefficients of variability were high, ranging from 15% to 30%, as is common in sweet potato experiments. On the slightly alkaline loamy soils (which have low levels of organic matter and total N, high levels of P and K, and no salinity problems) application of 5 t/ha of farmyard manure provided sufficient nutrients to sustain yields of 20 t/ha to 30 t/ha. Responses to formulation or dosage of N (0 Kg to 120 kg N/ha), P_2O_5 (0 kg/ha to 180 kg/ha), or K_2O (0 kg/ha to 200 kg/ha) did not differ significantly. At the lowland Amazon site of Yurimaguas, sweet potato yields on limed soil did not respond to N application rates of greater than 30 kg/ha. These results on contrasting soils confirm the efficient nature of the sweet potato crop in exploiting the soil for nutrients, and the need for minimum inorganic fertilizer application. The role of *Azospirillum*, or other non-associative N-fixing rhizobacteria in providing N to the sweet potato crop, cannot be discarded.

During the tropical rainy season, sweet potato is often subjected to waterlogging, a stress for which it is poorly adapted. This characteristic limits the year-round availability of sweet potato and other tuberous root crops in many tropical areas. Therefore, research is under way to assess the physiological response of young sweet potato plants to waterlogging, and to develop suitable techniques to help identify tolerant genotypes. These studies show that leaf abscission was enhanced after longer periods of waterlogging (up to 6 days), while stem extension was promoted, and foliage dry matter content (%), and tuber dry weight were reduced. Response trends for other variables (e.g. shoot dry weight) measured on the five genotypes were not well expressed, and genotypes did not differ significantly among themselves. CIP's aim is to identify tolerant genotypes within the germplasm collection that can be used for crop improvement or for immediate field production under waterlogged conditions.

Although the sweet potato crop is robust at the time of planting, unfavorable conditions (e.g. lack of soil moisture) at planting can seriously delay establishment and reduce plant stand. A series of short-term experiments (terminated 30 days after transplanting), suggested the following recommendations. When drought-stressed, a stem length of 30 cm (vs. 15 cm, 20 cm, or 25 cm), with 10 cm to 15 cm covered by soil, produces the most vigorous growth, an important asset in combating early-season weed competition. Advantages of dipping cuttings in a dissolved root hormone (NAA and IBA) were cultivar-dependent, but use of prerooted cuttings was of no benefit to any cultivar when planted under stem water conditions. Drought during establishment significantly reduced stem weight, and leaf weight and area. Root number and weight showed similar, but non-significant, trends.

Clonal Selection

For potato and sweet potato, earliness is an important character that gives both crops the flexibility to adapt to the range of cropping systems found in the tropics. This character, in combination with the maintenance of high cooking quality, has received much attention in the past in potato selection. Intensive selection pressure for this character is being applied in the sweet potato program.

Potato

Peru. Bacterial wilt at San Ramon seriously affected survival and yield of a set of clones (20 tubers/clone) planted during the rainy season of 1989. As in previous years, some clones (e.g. CFK-69.1, 377250.7, LT-7, and Atlantic) were prevalent among the parents of selected clones. Favorable temperatures (31.8C day/16.8C night, average) and planting on clean soil promoted high yields for clones of CIP's pathogen-tested list during the dry season at San Ramon. The data for the past 5 years' testing of pathogen-tested clones have been summarized, and clones adapted to the mid-elevation tropics have been designated on the pathogen-tested list. Some of the clones adapted to San Ramon were tested at Yurimaguas during the dry season. Bacterial wilt was found at 40 DAP and later, leading to yield reduction in some clones. However, some clones (e.g. I-822, CFS-69.1, and 379686.3) produced yields in excess of 1,000 g/m^2, and all 30 clones evaluated are being retested in 1990.

At Tacna, in southern Peru, salinity is a stress additional to that of high temperatures. Of 350 PVY + PVX-resistant clones screened, 5 gave yields of 1,000 g/m^2. During the winter season in Lima, PVY + PVX-resistant clones produced high and early yields (with resistance mostly in the duplex condition). These clones will be used as parents for further breeding efforts.

The Philippines. All germplasm evaluations in the lowlands were conducted at Canlubang Sugar Estate, Laguna, and were intercropped with sugarcane. In the third field evaluation of clones that had been repeatedly produced and DLS-stored, clones 384515.9, 385131.52, 385130.8, and 385152.44 showed 50% survival rate at harvest, a per-plant yield of 500 g, and an absence of virus symptoms. These clones show potential as cultivars that could sustain lowland tropical potato production, without frequent recourse to multiplication in traditional seed areas. Screening for tolerance to early blight was ineffective, because only a slight infection was observed during the latter part of the growing season. Gray mold disease (*Botrytis cineria*) was prevalent following one week of continuous rain, and significantly lowered yields. Nineteen tuber families from local crosses were tested in the field, but they did not outperform clone LT-7, or the local check clones. Clone LT-7 yields surpassed those of a group of clones planted to evaluate their processing quality, and it showed equal quality.

Vietnam and the South Pacific. Further evaluation is under way for promising clones in Fiji (377850.1) and in Vietnam (Achirana INTA and I-1039). Good storage characteristics and virus resistance are emphasized in selection to avoid dependence upon sources of imported seed tubers.

Burundi. Promising results were obtained from exploratory evaluations to determine whether available clones would adapt to lowland (800 m) conditions. During the dry season (following maize), irrigated and mulched plots of potato clones yielded from 8.9 t/ha to 18.2 t/ha in a region close to the capital, Bujumbura. Pest and disease incidence was minimal.

Sweet Potato

Peru. Harvests were made at 90 DAP in Yurimaguas, or 120 DAP at other sites in Peru, to select early-bulking genotypes. Of a total of 60 clones, 5 second- and third-generation clones yielded 1,500 g/m^2 during the summer season at Lima. Similarly, 7 second-generation and 10 third-generation selections produced yields of 1,500 g/m^2 in an autumn crop at Tacna. Yields were equal to or greater than those of advanced clones from other breeding programs, which had been grown under the same conditions in Tacna. Yields at Yurimaguas were low (< 1,000 g/m^2, with the exception of one clone), which may reflect the lack of earliness and/or the poor adaptation to the ambient stresses (flooding, low radiation, acid soils, etc.) encountered there. Because these adverse conditions are typical of areas where sweet potato is not yet exploited as a low-input crop, an intense effort is now being made through the population breeding approach, to raise actual sweet potato yields under these conditions.

Egypt. Traditional sweet potato cultivars in Egypt are low-yielding, in part due to heavy virus incidence. Two virus-free cultivars were received from NCSU in 1988 along with true seed of 5 hybrids. The cultivars (925 and 1135) outyielded local cultivars by 200% to 300%, but it is unclear from the findings to what extent this yield advantage was due to lack of virus infection. Nevertheless, this exercise has shown a potential improvement in yield, and healthy cuttings have been distributed to growers in areas important for sweet potato production. Three-month storage of roots in improved nawalla (rustic, dried mud-brick–adobe–structures with thick straw roofs) resulted in a 20% total weight loss (rottage plus respiration) for the more storage-tolerant cultivar 925, whereas in unimproved nawalla, storage losses reached 55% for the cultivar 1135.

India. Comparative agronomic evaluations of selected sweet potato varieties were initiated by CIP in 1989. Monthly plantings are being made to determine optimum planting dates, along with studies on spacing, fertilization, and planting techniques to provide agronomic recommendations. Similar experiments are also in progress in other important sweet potato production areas worldwide.

A healthy nursery of sweet potato in India.

Researcher from INIA, Chile evaluating tuber production of clones grown under suboptimal temperature conditions

Thrust VII

Cool-Climate Potato and Sweet Potato Production

Thrust Profile: 1990

A multidisciplinary approach is used to develop technology to improve potato and sweet potato production in cool environments of developing countries.

Improvement of potato breeding populations to provide potential cultivars for these environments focuses on limiting stress factors, on major disease and pest resistances, and on developing agronomic characters to meet farmer and consumer needs. The two main target areas for such improved germplasm are 1) the Andean region, covering mainly the South American highlands and, 2) the non-Andean region, including cool-environment lowlands and highlands of tropical and subtropical latitudes. During crop growth frost, suboptimal temperatures, and drought are the major abiotic stresses that limit potato production in these regions. Reduction of the effects of these stresses increases the potential for potato production in cool environments both by raising productivity and by expanding the area available for cultivation.

Agronomic and physiological studies are focusing on cultural practices to improve potato production and to develop methods to screen genotypes for their efficiency in the use of nitrogen where there is poor nitrogen content in the soil.

The sweet potato crop in cool environments of developing countries is playing an increasingly important role in both human and animal diets, with plantings gradually expanding to wider environments because of the crop's great plasticity for adaptation to unfavorable conditions. Improved germplasm is better adapted and fitted to farmer and consumer needs.

Potato research last year included: field testing and selection for frost tolerance in collaboration with the National Potato Program of Peru INIAA, at Illpa, Puno (3,850 m). One-fifth of all clones tested were selected for their tolerance to frost, earliness, desirable agronomic characters, and high yields despite severe drought and incidence of frost. The outstanding clones were chosen by the station for multiplication and potential variety releases.

Collaborative projects with the Potato Program of INIA, Chile. Clones selected for long-day adaptation from CIP's improved germplasm produced up to 30% greater tuber yields than did locally grown cultivars. A second project developed simple technology for potato production that is easily adaptable for use by farmers.

Contract research with INIA, Chile. In selection of potatoes for suboptimal temperatures, the early sprouting CIP clone DTO-33 showed the most promising performance. Short tuber dormancy, early tuber initiations, and a fast bulking rate appear to be the most important characters for successful adaptation to suboptimal conditions.

A collaborative project in Burundi. Timing of fungicide applications was shown to be of critical importance in helping to control late blight in varieties with different degrees of horizontal resistance. The resistant variety Sangema was severely infected when fungicide spraying was delayed until 8 weeks after plant emergence. Apparently, the level of horizontal resistance in this variety is not sufficient to withstand the effects of this fungus at this stage, without previous spraying.

Improved agronomic practices for potato production in Cameroon. Findings indicated that poultry manure applied at a rate of 5 t/ha gave the best results when compared with other locally available fertilizers. Reports on the use of TPS for potato production from Ethiopia and Cameroon indicated that a threshold for resistance to late blight in the segregating progenies is necessary for the success of this technology. In potato production for human consumption, seedling tubers derived from TPS offer greater advantages for plant survival and growth.

Collaborative project in Paraguay on the use of TPS for commercial potato production. Seedling-tubers of cross Serrana x LT-7 showed better performance than transplants of this cross. Tuber production of this cross (in both seed beds and the field) was the highest among those tested.

Field screening of 400 sweet potato clones for adaptation to cool environments in two coastal locations in Peru. In research conducted during the winter, approximately 90% of all clones had large roots and 69% yielded more than 0.5 kg/plant. Selected clones are being tested in mid-elevation cool environments (2,000 m - 2,500 m) for performance and adaptation.

Potato Populations in Cool Environments

Potato

Improvement of potato populations by selecting cultivars for cool environments has concentrated on limiting stress factors such as frost tolerance, production under suboptimal temperatures, and (more recently) drought tolerance. Agronomic characters suitable to meet farmer and consumer needs in a wider range of environments are also being considered.

Breeding for Stress Tolerance

Frost. Two parallel potato breeding populations are under improvement for frost tolerance as the primary crop protection character and the gradual addition of resistances to diseases and pests important in cool environments, such as viruses, late blight, and cyst nematodes.

One population is targeted for the Andean highlands, where frost incidence is a major limiting factor and cyst nematodes are causing increasing damage. The required crop characteristics are similar to those of the native primitive cultivars that are highly appreciated by farmers and consumers.

A second population is being improved for use in the non-Andean cool environments (highlands and lowlands) of tropical and subtropical latitudes, where early- and late-season frosts are limiting. This population will eventually have resistance to late blight, and will be adapted to long days. Crop characteristics required in this area are similar to those of *S. Tuberosum* cultivars, which have been long adapted by farmers and accepted by consumers.

Testing and selection of clones was done in collaboration with the Peruvian National Potato Program, at their Southern Altiplano Experiment Station at Illpa, Puno (3,850 m). Frost damage is the most limiting factor in this area, which is the largest potato-production region in Peru. Periodic droughts are the second limiting factor.

Of the 600 clones tested at this location during the year, 110 were selected for their tolerance to frost and for yield and other agronomic characters (Table 7-1). Despite the four-week drought that followed planting, and the incidence of frost 87 days after plant emergence, average yields were high. The outstanding clones were chosen by the local station for multiplication of clean seed stocks and for further evaluation in regional trials. Potential variety releases are planned by the national program to help overcome frost damage.

Under non-frost conditions (CIP's Huancayo Station), replicated trials of the most advanced frost-tolerant clones from both populations produced tuber yields as high as 2.6 kg. per plant at a plant density of 44,444 plants/ha (Fig. 7-1), indicating their high yield potential under optimum field management.

Table 7-1. Tuber yields of top-performing clones with tolerance to frost at Illpa Station, Puno (3,850 m).

		Frost damage after planting[a]		
Clone number	Yield kg/10 hills	87 days -1.8 C	112 days -2.5 C	125 days -4.5 C
87 F172.9	19.8	4	1	6
85 F124.1	19.4	3	3	9
381128.5	18.9	4	3	7
384025.1	17.9	4	5	8
85 F65.4	17.9	2	2	9
84 FF111.2	17.2	3	1	4
Local checks				
Andina	14.5	2	2	8
Rukii	4.6	1	1	1

[a] CIP scale derived from % of foliar damage: 1 = 1%-10%, 9 = 81%-90%.
Plant density: 33,333 plants/ha.

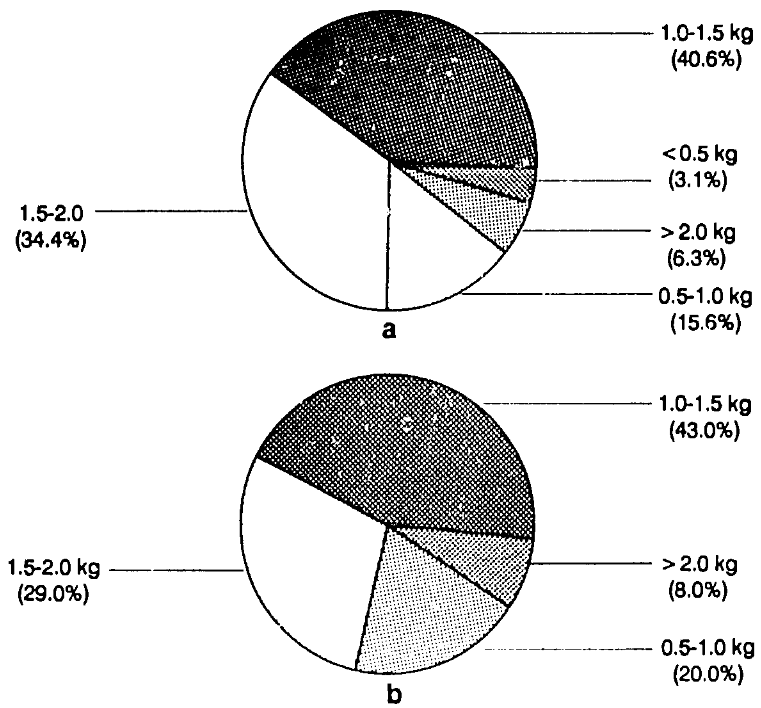


Figure 7-1. Tuber yields in kg/plant of frost-tolerant clones at CIP-Huancayo Station, 1989. **a)** clones for Andean region; **b)** clones for non-Andean region.

Long-day adaptation. The Potato Program of INIA (Osorno, lat. 40° S) tested 30 selected clones from the non-Andean potato population previously introduced in Chile for adaptation and tuber yield performance under long days. Total tuber yields were reported to be as much as 30% over the local checks (Table 7-2). There has been progress in adapting cool-environment populations to long days for selection of potential cultivars.

Suboptimal temperatures. Contract research was begun with the Potato Program of INIA, Chile to breed and select potatoes adapted to suboptimal temperatures (low-temperature profile). Two distinct seasons were chosen for screening and selection of potato germplasm: 1) a fall-winter season with mild low temperatures and short days (Santiago Valley, lat. 30° S), and 2) a winter-spring season with low temperatures through most of the growing season, and increasing day-length (Osorno, lat. 40° S).

Findings from a preliminary trial of a sample of locally available clones planted at the end of August (a month earlier than the normal season) indicated that early tuber sprouting may be one of the key requirements for fast plant emergence and rapid plant growth under these conditions. Of all the clones tested, the early-sprouting clone DTO-33 (from CIP origins) was the first to emerge from the soil and develop a larger canopy. Similarly, when clones were harvested 90 days after planting, DTO-33 had the

Table 7-2. Tuber yields of top-performing clones selected for adaptation to long days (Osorno, Chile, lat. 40° S).

Clone number	Yields (t/ha)		Specific gravity
	Marketable	Total	
383125.82	60.6	61.1 a[a]	1.102
383151.57	37.5	59.6 a	1.103
383136.47	55.9	57.7 ab	1.106
383142.62	52.2	54.2 b	1.109
383144.67	52.2	54.2 b	1.106
383144.49	51.9	54.2 b	1.109
Local checks			
Ultimus	40.6	43.1 c	1.106
Desirée	41.2	41.6 c	1.100

[a] Means followed by the same letter are not significantly different (P < .05).

highest yield (Fig. 7-2). However, when harvested at 114 days, yields of other clones were similar or higher, Ultimus and Remehue-10 being particularly outstanding. Further experiments are under way at other locations to examine tuber sprouting, plant emergence, tuber initiation, and tuber bulking rate, and to confirm the value of characters needed to select materials for this type of environment.

Successful results of this research will have two direct benefits for clients in sub-tropical latitudes, where there is an increasing expansion of potato production during mild winters and where low temperatures are a limiting factor. First, the research will select cultivars

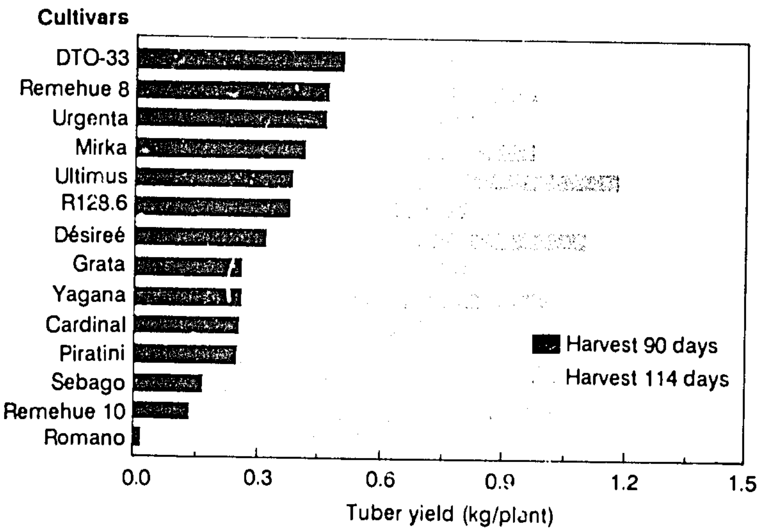


Figure 7-2. Tuber yields of cultivars planted under suboptimal temperatures in southern Chile. Experiment Station at Remehue (INIA), 1988.

best suited to suboptimal conditions and to low-temperature profiles in particular. Secondly, because when conditions are favorable, the incidence of major diseases and pests is negligible, and the potatoes produced under these conditions are healthy and of high quality for use as seed and for human consumption.

Agronomic and Physiologic Research

Peru. No field studies were made of the efficient use of nitrogen (N) during the 1988-1989 season. However, data from previous field, greenhouse, and laboratory experiments were further analyzed in the search for simple root morphological characters that would predict 1) yield ability on soils with low N, and 2) the ability to respond to added N as inorganic fertilizer. In tests of clones grown under low N in the field, both the fresh weight of the root system (averaged over values measured on in vitro plants, rooted cuttings, and rooted sprouts) and the average length of secondary roots were significantly and inversely related to the yielding ability. The ability to increase tuber yield in response to added N was inversely related to the diameter of secondary roots (measured either at the basal or apical extremes) and positively related to the apical diameter of the root hairs. These relationships were maintained in all vegetable material evaluated and will be verified in tests of another set of potato clones. Investigations are under way to assess non-linear relationships between tuber yield and yield increase due to added N, and root morphological characters.

Burundi. A series of agronomic experiments during two growing seasons in the Crete region of Burundi investigated liming and fertilization to improve potato production and application of fungicides to control late blight.

Tuber yield responses to liming and NPK fertilization were not statistically significant. Acidic soils (pH: 4.7) and low solubility of the source of liming, as well as its application rate, may have prevented the response to the treatments studied. Further studies on application rates of lime as well as other sources of NPK are planned within the context of limited-resource farming systems.

During two consecutive seasons, the experiments were conducted on the effect of fungicide applications in controlling late blight in three varieties with different degrees of resistance. The results indicated that when spraying started 8 weeks after plant emergence, Sangema variety had the highest rate of foliar infection, as compared with Uganda-11 and Ndinamagara. Yields were significantly reduced in Sangema and less affected in the other two. The resistance in Sangema apparently could not withstand the high infection pressure of the fungus when additional protection was delayed; however, the other two varieties showed higher levels of resistance. As an additional protection measure, further experiments will attempt to determine optimal frequency and timing of fungicide applications.

To control late blight under high inoculum pressure, a more integrated approach earlier in the season may be necessary. No horizontal resistance to late blight alone would stand such a pressure without adequate additional protection measures.

Cameroon. Preliminary fertilization trials in Cameroon to determine sources and applications of fertilizer to improve

Advanced clones selected in the high hills of Rwanda from CIP's genetic material.

potato yields, indicated that poultry manure applied at a rate of 5 t/ha gave the best result. The manure is locally available and cheaper than chemical fertilizers. Other agronomic practices for crop improvement, such as intercropping potato with corn and chemical control of late blight, are being studied.

Chile. A collaborative project with the Potato Program of INIA, Chile (Osorno, lat. 40° S) reported that when comparing applications of technology between the experiment station and the farmers' fields under both irrigation and rainfall conditions, there is a significant yield gap in favor of the technology as applied by the station. This gap can be narrowed by identifying the factors involved and correcting measures developed for an easy adoption by the farmers.

Ethiopia TPS. Reports from Ethiopia indicated that trials conducted during the rainy season at Holetta Research Center, which included the international, regional, East African, and open-pollinated TPS trials, were almost completely lost to late blight. Future TPS trials during the rainy season will include progenies of late blight-resistant parental clones, known to transmit high levels of resistance to their offspring. Seedling tubers from selected pedigrees also will be considered for testing the feasibility of using TPS as an alternative potato production method.

Cameroon TPS. Previous experiences have shown that seedling tubers rather than TPS transplants may be the most appropriate technology for seed-tuber production. Sixteen progenies were evaluated in nursery beds this year for seedling tuber production at Mfonta (1,300 m). The highest yielding progenies for tuberlet production included the pedigrees CIP 98004 (CFK 69.1 x DTO-

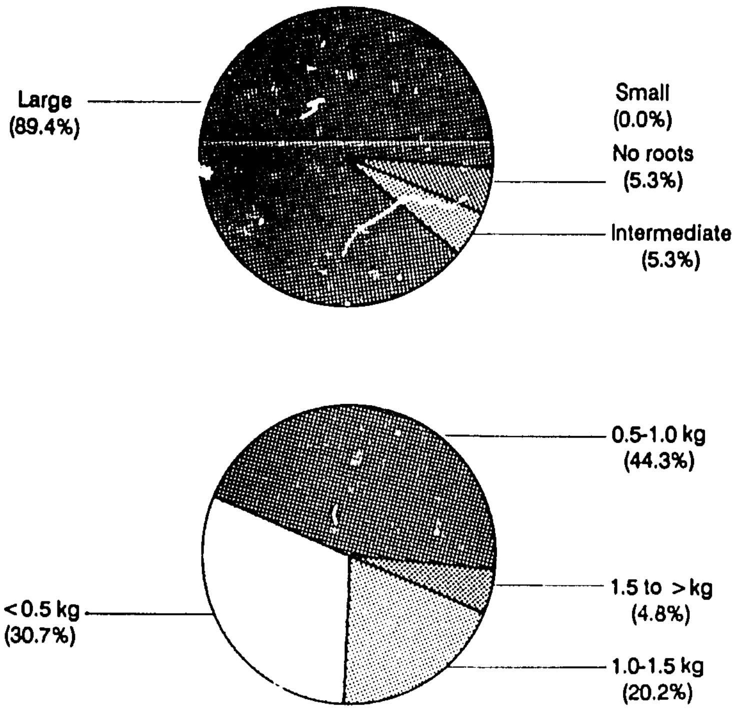


Figure 7-3. Performance of a sample of sweet potato clones from germplasm in cool winter season, Lima, 1989. **a)** root enlargement; **b)** root yield kg/plant.

28) at 6.0 kg/m^2 and CIP 978001 (Atzimba x R128.6), at 4.3 kg/m^2. Seedling-tuber performance for consumer potato production was compared with that of commercial Dutch varieties in trials (at 2,000 m) in which plants were sprayed once against late blight. Six of the progenies outyielded the three commercial varieties and showed resistance to late blight.

Paraguay. Tuber production from seedling tubers of pedigree Serrana x LT-7, in both seed beds and the field, was significantly higher than the three other pedigrees evaluated during March-June 1989 at the IAN-Caacupé Experiment Station.

Shortly after being harvested the Serrana x LT-7 tubers were treated for sprouting and planted in selected farmers' fields during July-November of the same year. However, yields were rather low as a result of poor emergence and overall plant stand.

The short period between planting seasons may result in a serious limiting factor if short dormancy is not bred into segregating progenies; however, if cycles are reversed so that tuber multiplication is done during July-November and consumer potatoes are produced during March-June, a solution may be found to the tuber-sprouting problem at planting time. Additional studies are under way.

Sweet Potato

Evaluation in Cool Environments

Evaluations were made of 400 sweet potato clones from the germplasm bank maintained at CIP to examine their performance in cool environments during the winter season at two coastal locations in Peru. Preliminary data on plant growth, root enlargement, and yield at harvest (150 days after planting) indicate that much of the material performed well and showed some ability to adapt for production under cool temperatures. Yields were as high as 2 kg/plant at a plant density of 35,000 plants/ha (Fig. 7-3). These clones will be further evaluated to determine their range of adaptation in cool environments, and at higher altitudes.

Collecting sun-dried potato chips in India.

Thrust VIII

Postharvest Technology

Thrust Profile: 1990

A recent survey of national program leaders identified constraints in the postharvest phase as among the most important in production and use of potatoes and sweet potatoes. Interdisciplinary research and training activities in Thrust VIII help develop and deliver storage and processing technology in collaboration with national programs. During 1989, this work included 20 projects, 4 contracts, and 4 theses under way in more than a dozen countries in Latin America, Africa, and Asia. Past work has emphasized potatoes, but sweet potatoes are now receiving increased research attention.

Building on the successful extension of diffused-light storage for seed potatoes, recent storage research has focused on consumer potatoes. Evaporative cooling techniques were studied in Peru, Kenya, and India, and forced-air techniques were studied in Pakistan. Simple rustic stores were tested in India and Thailand. Household storage in bamboo baskets and sacks was analyzed in Burundi. In Peru, clones were evaluated for storage characteristics. Seed storage under rustic versus refrigerated conditions was studied in Egypt. Rustic storage of seed was evaluated in Cameroon. Storage in sand of tubers produced from true potato seed was examined in India. A storage workshop was held in Malaysia. Successful storage trials for consumer potatoes in several countries suggest that interdisciplinary research on adoption of these techniques would now be useful.

Potato processing research has focused on clonal evaluation (Peru, Thailand); on continued testing and evaluation – including costs and returns – of rustic processing techniques (India); and on marketing and demand for processed products in selected countries (India, Thailand). Additional activities included a survey of postharvest practices (China), backstopping of ongoing research involving simple processing in selected countries (Colombia, Guatemala, Peru, and Zaïre) and thesis work (Kenya).

Sweet potato research has drawn upon baseline surveys of postharvest practices and constraints carried out as part of a diagnosis of sweet potato food systems (see also Thrust X). This work is being conducted in Peru, China, Vietnam, and the Philippines; similar research is under way in Indonesia, Thailand, Taiwan, Argentina, and Uruguay. Results of these surveys emphasize the importance of interdisciplinary research involving biological and social scientists to identify, evaluate, and improve existing technologies.

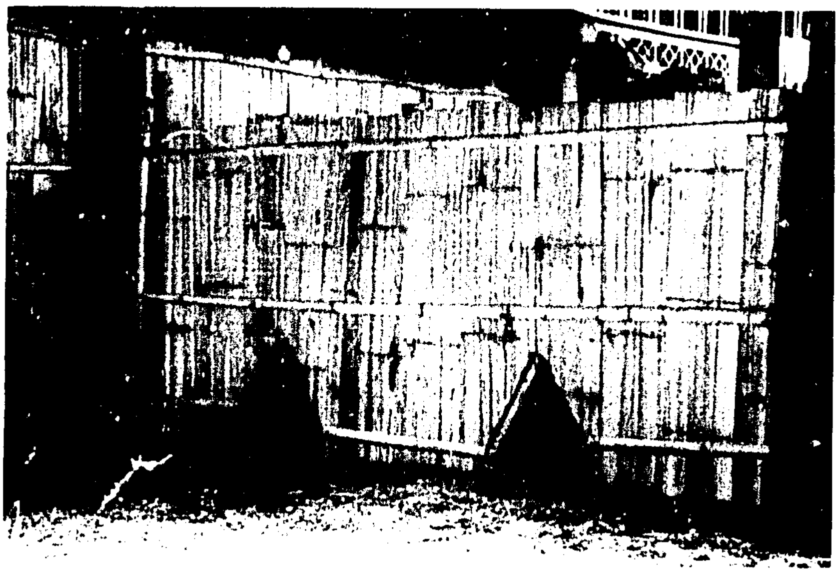
Sweet potato studies have been included in the experiments using village-level, rustic processing techniques in India. Clonal evaluation for processing has begun in Lima, with thesis work on the nutritional and chemical characteristics of CIP's sweet potato germplasm collection. Similar work is now under way in Thailand. Sweet potato storage research using rustic stores has begun in India and Kenya.

Potatoes

Consumer Potato Storage

Technology continues to be developed for short-term storage of both consumer and seed. potatoes in warm-dry and warm-humid climates, with experiments in Peru, Kenya, Burundi, Cameroon, Egypt, India, Pakistan, and Thailand. These and other activities seek to develop low-cost alternatives to established marketing and utilization patterns. Successful trials in several countries point to the need for interdisciplinary research on factors that influence adoption of improved storage practices for consumer potatoes.

Peru. A total of 18 clones were tested for storability under rustic storage conditions at ambient temperatures in Huancayo and San Ramon. A cold store set at 4C was used as a control. Total tuber weight losses after 6 months of storage ranged from 6.5% to 20.1% at Huancayo, from 12.9% to 41.9% at San Ramon, and from 5.1% to 11.8% in the cold store. Clones Capiro, Yungay, CEW-69.1, and 69-56-52 (Table 8-1) showed excellent storability or keeping quality for consumer potatoes. Results of these experiments indicate that clones with a long dormancy period do not necessarily have good keeping quality.



Boxes with ventilation ducts for storage of consumer potatoes in Thailand.

Table 8-1. Observations on storability for seed and consumer potatoes in a range of clones at Huancayo and San Ramon, Peru.

Clone	Tuber weight loss (%) 6 months			Dormancy (days)[a]		Incubation period[b]	Storability index[c] 6 months	
	4C	Hyo	SR	Hyo	SR	(days)	Hyo	SR
DTO-33	10.2	18.6	31.8	48	34	354[d]	0.95	0.78
DTO-28	11.0	20.1	29.0	76	41	357[d]	0.83	0.65
LT-2	11.8	9.2	41.9	111	48	317	0.90	0.55
B71-240-2	7.0	13.3	27.2	97	62	327	0.96	0.86
LT-5	8.8	11.8	26.0	118	76	317	0.98	0.83
Serrana	8.9	11.4	21.2	139	62	337	0.95	0.92
Revolucion	9.0	11.0	23.3	111	43	337	1.04	1.09
Rosita	9.1	15.3	26.0	97	69	327	0.99	0.88
Saturna	9.3	14.3	23.3	139	62	317	0.98	0.75
I-822	8.3	13.2	31.5	84	35	330	0.90	0.68
CEX-69.1	7.1	11.1	21.1	70	28	360	1.08	1.00
I-931	9.1	13.4	25.8	63	28	350	1.05	0.92
69-56-52	6.6	9.2	12.9	133	78	310	0.95	1.00
MEX-32	7.4	10.0	18.2	119	55	360	1.16	1.16
CEW-69.1	5.5	7.9	16.5	91	48	370	1.08	0.96
Huancayo	5.1	6.5	17.9	105	62	330	1.21	1.46
Yungay	7.2	9.0	15.9	98	55	340	1.08	1.37
Capiro	8.7	11.7	14.1	133	83	330	0.88	0.97
Mean	8.3	12.1	23.5	102	54		0.99	0.94
Mean		14.6						
LSD 0.05		2.2						
CV %		7.6						

[a] Days between harvest and sprouting.

[b] Days between harvest and tuber formation on sprouts.

[c] Storability index: yield from DLS stored tubers (Huancayo and San Ramon) as a proportion of yield from seed tuber stored at 4C.

[d] No tuber formation on sprouts.

At San Ramon, research on integrated control of storage losses of potatoes in the warm tropics has shown consistent results over several storage seasons (see Annual Reports 1988 and 1989). Low-cost storage of locally produced potatoes over a 4-month period is clearly feasible under warm (20C to 30C), rustic conditions, without significant loss of quantity or quality. Two storage treatments were highly effective: 1) a single selection of the most suitable proportion of the crop (undamaged, healthy tubers) for storage, following a 2-week holding period after harvest, effectively reduced losses, and 2) soaking the charcoal store walls with water twice daily to induce evaporative cooling reduced tuber weight loss and infestation by the potato tuber moth. Application of CIPC effectively inhibited sprouting, as did use of thiabendazole or sodium hypochlorite dipping treatments to control pathogens causing rotting (*Fusarium* and *Erwinia* spp.). Neither sprouting nor rotting caused serious losses, until after the 4-month storage period.

At North Carolina State University, a Ph.D. thesis confirmed previous findings that repeated selection during the storage period increased storage losses, due to tho higher levels of mechanical damage caused by additional handling (see Annual Report 1989). During 4 months of rustic storage at San Ramon, losses in 14 cultivars adapted to the warm tropics were associated with their relative susceptibilities to the pathogens *Erwinia carotovora* ssp. *carotovora*, *E. chrysanthemi*, *Fusarium solani*, and *F. oxysporum*.

Kenya. Research continued to develop low-cost consumer potato storage for low altitudes. Storage experiments on the Kenyan coast used the variety Roslin Eburu, harvested at medium altitude. Different types of naturally ventilated stores were compared during a storage period of 33 days. Preliminary results showed that total weight losses ranged from 21.8% to 51.9%, with lower losses for the naturally ventilated store without evaporative cooling. High losses were mainly due to soft rot caused by *Erwinia carotovora*, which in turn was induced by skin damage from harvesting immediately after crop maturity. A thesis summarizing this research is being prepared for the Cranfield Institute of Technology. Storage technologies developed for cool highland areas in previous years continue to be evaluated with farmers, in cooperation with an FAO project.

Burundi. Prices for consumer potatoes increase by 30% to 50% between the harvest in January and the seasonal shortage in May. Storage of consumer potatoes was tested with 4 varieties using 3 types of naturally ventilated storage techniques. Storage capacity ranged from 500 kg to 1,000 kg. The maximum possible storage period was defined as the period without significant sprout development, since sprouted tubers can only be sold as seed. Bamboo baskets, positioned on stones so as to allow ventilation from below, provided the longest storage period: 31 days for cv. Ndinamagara, 71 days for cv. Muruta, 61 days for cv. Kinigi, and 101 days for cv. Uganda.

India. Storage trials using consumer potatoes were conducted at Athgara in collaboration with the Central Potato Research Institute. Tubers were stored in sand for 80 days, with losses of 10% by weight and 5% by number; these results impressed local farmers unfamiliar with this traditional procedure.

Thailand. In cooperation with the Horticultural Research Institute and the Agricultural Engineering Division of the Department of Agriculture at Fang (northern Thailand), 4 different types of low-cost, naturally ventilated stores were tested at the experiment station using two commercial cultivars, Fang-60 and Spunta. After 7 weeks of storage, total weight loss ranged from 13.8% to 18.9%. During storage, average outside minimum temperature was 21.4C and average maximum temperature 34.6C; temperatures in the potato pile ranged from 23.2C to 26.5C. Farm-gate prices for potatoes rose from 5.5 to 7 baht per kg over the storage period. This increase was sufficient to generate positive economic returns as a result of potato storage in each of the experimental stores.

Need for Adoption Research

Recent experiments in warm climates in several countries have identified suitable methods to store consumer potatoes for periods up to 2 months. These methods include appropriate designs for stores, as well as integrated methods to control storage diseases and pests. Interdisciplinary research is now needed to evaluate the user's perspective of these storage technologies and to identify factors that influence adoption (e.g. availability of credit).

Seed Potato Storage

Cameroon. Two diffused-light seed storage trials were conducted at mid-elevation sites (1,300 m and 2,000 m) using the local varieties Kijam and Tibati. One treatment was with sodium hypochlorite, another with CIPC. The controls were tubers that had not been chemically treated. Each trial had subtreatments with and without Lantana, and lasted for 240 days. Initial findings indicate that potatoes can be stored successfully for the 240-day period, but the physiological condition of the tubers is better after 180 days (Table 8-2). Although the CIPC sprout inhibitor prolonged dormancy, it became less effective after 90 days. Sodium hypochlorite had a negligible effect, perhaps because soils in the region are relatively clean. At lower elevations, rotting was more pronounced for tubers stored after the rainy season than after the dry season. The percentage of rotted tubers, the sprout lengths, and the weight losses were greater at lower than at higher altitudes. Tubers from each of the treatments have been planted to evaluate their yields.

Egypt. Four hybrids and 4 commercial varieties from certified seed imported from Europe were placed in storage (in early June) for 3 to 5 months inside a cold store at 4C to 5C, and in a non-refrigerated store (Nawalla). Tubers from the two stores were presprouted under diffused light for 2 weeks, then planted at the end of September 1988. The experi-

Table 8-2. Percentage rotted sprout lengths and percent weight losses of tubers stored under diffused- light rustic stores at Mfonta, Cameroon, in 1989 ([illegible]300 m.a.s.l.).

	% Rotted tubers			Sprout length (mm)			% Weight loss		
Treatment[a]	90 days	180 days	240 days	90 days	180 days	240 days	90 days	180 days	240 days
1	1.4	4.3	6.8	12.3	20.1	20.2	10	29	39.7
2	1.8	2.8	5.4	11.4	20.5	19.9	9	27	38.3
3	2.2	6.9	11.1	13.4	21.8	24.3	10	30	41.7
4	1.6	4.2	6.5	13.1	21.6	21.9	12	29	39.3
5	0.4	4.1	6.1	8.4	20.9	24.0	9	27	36.3
6	1.6	3.6	4.5	9.0	18.8	22.4	9	27	37.5

[a] Treatments:
1 = Lantana but no chemical treatment.
2 = No Lantana, no chemical treatment.
3 = Lantana and 0.5% Sodium Hypochlorite.
4 = 0.5% Hypochlorite but no Lantana.
5 = CIPC (20 ppm) and Lantana.
6 = CIPC (20 ppm) no Lantana.

Table 8-3. Comparison between varieties of different sources and seedling tubers from TPS in cold store and non-refrigerated store (Nawalla), Egypt.

	Nawalla				Cold store				
	Germ. %				Germ. %				
Variety/progeny	30 days	45 days	Stem No.	Harv. (t/ha)	30 days	45 days	Stem No.	Harv. (t/ha)	Mark. %
Alpha	74	49	2.9	23.4	86	89	3.2	32.4	85
Serrana x DTO-28	75	93	1.9	31.2	83	96	2.4	33.0	80
Claudia	88	91	2.6	24.7	77	95	2.1	27.1	70
CFK 69.1 x DTO-33	85	97	2.8	29.1	89	95	2.9	36.8	80
Spunta	95	97	2.8	28.5	89	91	1.9	30.0	90
Atz x DTO-28	80	98	2.9	30.3	86	99	3.0	33.9	80
Draga	84	96	2.8	27.9	48	88	2.0	29.0	85
Atz x DTO-33	81	95	2.7	30.8	91	99	3.2	36.5	75

Planting date: Sep. 18, 1988. Harvesting date: Feb 1, 1989. Plot size: 9.4 m^2. Reps.: 3.

ment was harvested in early 1989. Comparable yields for the hybrids and commercial varieties kept in a rustic store indicate that expensive refrigeration is not necessary for seed potatoes under Egyptian conditions (Table 8-3).

India. A previous storage design for consumer potatoes was modified to accommodate seed potatoes. During the first 3 months after harvest, consumer potatoes were stored in darkness. They were subsequently exposed to diffused light by opening the windows and placing the tubers in thin layers on shelves. After 70 days, total weight losses were 11.5% for cv. Kufri Bahar and 4.4% for cv. Kufri Jyoti. Tubers of 13 different genotypes – including 9 TPS families – also were stored in sand, which is a traditional storage method used by farmers. After 6 months of storage, average weight losses were 52.5% and average loss of tubers due to rotting was 38.6%. No significant differences were found in storability between genotypes.

The Philippines. Non-chemical methods to control sprouting of potato tubers are being developed in a collaborative project with the University of the Philippines at Los Baños. In preliminary experiments, plants of the *Liabiatae* family were screened to identify natural sprout inhibitors. Species presently being evaluated are *Coleus amboinicus Lour.*, *Mentha cordifolia Opiz*, *Ocimum basilicum* L. and *Ocimum sanctum* L.

Potato Processing

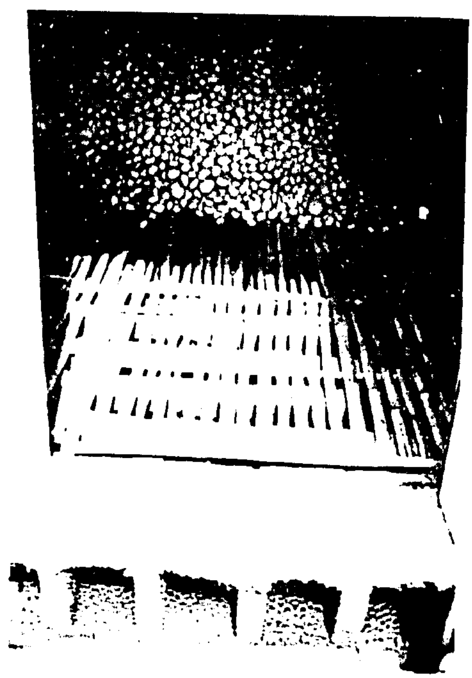
Thailand. The demand for processed potato products is growing rapidly in many Southeast Asian countries. In Thailand, about 5,000 t/yr of potatoes (about 30% to 50% of national production), are processed into snacks and convenience foods. Most processing is carried out by local companies. Research has emphasized evaluation of clones for processing quality. In cooperation with the Agro-Industry Section of the Agricultural Chemistry Division of the Depart-

Low-cost store for consumer potatoes in Thailand.

India. Low-cost, village-level techniques for processing of potatoes are being developed by CIP and SOTEC, a non-profit development organization based in Bareilly. Seven village processing units are currently operating under the supervision of SOTEC. These units process an average of 550 kg of potatoes per day. The main products made are dehydrated strips and chips, part of which are ground intc flour. Conversion rates for strips and chips (raw material to processed product) range from 14% to 16% for medium-sized to large tubers. Product quality, including moisture content and uniform size and color of the chips, is being stressed, and guidelines are being developed to standardize product quality. Processing equipment has been further improved, as well as the economic efficiency of the processing methods.

ment of Agriculture, 40 clones and cultivars were evaluated for use in processing into chips and french fries. In addition, clones are being evaluated for domestic cooking quality.

Results of a joint study of marketing, consumption, and demand for potatoes and potato products in Bangkok have been published by the Department of Agricultural Economics of Kasetsart University, the Horticultural Research Institute of the Department of Agriculture, and CIP. These findings highlight the potential for increased consumption of fresh and processed potatoes, as population growth and rising incomes generate greater demand. The methodology developed for this study should be useful for similar research in other countries.



Raised slatted floor. India.

SOTEC assists the processing units in securing funds for initial investment and in marketing of the processed products. Numerous recipes have been developed and are being demonstrated to rural and urban consumers. The processing units have generated substantial employment opportunities for rural women.

Table 8-4. Variable costs of simple potato processing in India.

	Amount of fresh potatoes processed/day (kg)			
	200	400	600	1,000
Variable cost/ packet (US$)	.099	.086	.079	.074

Socioeconomic backstopping of the processing research at SOTEC included 1) estimates of the cost of production based on technical coefficients and estimated prices for inputs and outputs (Table 8-4), and 2) contract research by an economist at the Agro-Economic Research Centre, Himachael Pradesh University, who studied the marketing of processed potato products in New Delhi. The cost estimates include various simulations of prices for fresh potatoes as well as processed products (Table 8-5). These calculations indicate that processing of more than 500 kg of raw product per day was barely profitable; they also demonstrate the importance of the price of potatoes and labor in determining unit production costs. Although more detailed information is needed on conversion rates, these findings provide an economic justification for combining rustic storage with simple processing and for beginning with the former to eventually finance the latter.

Studies of the marketing of processed potato products in New Delhi found a much wider variety of products than had been supposed. A total of 15 products are currently available, differentiated on the basis of form, package, weight, and price. Solar-dried chips produced with rustic techniques represent half the volume sold. Most sales are to middle-income consumers. The majority of the retailers contacted (82.6%) felt that demand for processed products could be increased by reducing the price and introducing more attractive packaging (see Thrust X for additional details).

Peru. Since 1987, CIP-Lima scientists have been evaluating clones to emphasize processing potential for chips and french fries, using CIP's germplasm

Table 8-5. Economic feasibility of producing dried potato chips in India (90 work days, 3 and 5 years credit).

	Amount of fresh potatoes processed/day							
	200 kg		400 kg		600 kg		1,000 kg	
	3rd year	5th year	3rd year	5th year	3rd year	5th year	3rd year	5th year
Total annual cost/packet	.18	.18	.17	.16	.16	.15	.15	.15
Annual net revenues/packet (US$)	(.12)	(.02)	.14	.21	.21	.30	.33	.40

Table 8-6. Yield and processing attributes of eight advanced clones.

Clone	Pedigree	Yield (kg/pl)	SG	RS	Use	Observations
377219.18	N568.7 x DTO-28	1.19	1.081	low	Ch	LT parent
377838.2	BR63.65 x N522.22	1.30	1.080	low	Ch	LT parent
E86.011	(377835.9 x PI/PS BK) x 378015BK	0.84	1.084	low	Ch	Warm, cool climates
E86.692	CFS69.1 x Atlantic	1.20	1.078	low	Ch/ff	Warm, cool climates
E86.695	CFS69.1 x Atlantic	0.72	1.088	low	Ch	Warm, cool climates
86LM 235	Aphrodite x LT-7	1.25	1.083	low	Ch	TPS parent
86LM 320	CEX69.1 x Atlantic	1.05	1.097	low	Ch	TPS parent
86LM 614	BL2.9 x 378015.3	1.10	1.094	mod.	Ch	TPS parent

with multiple resistance or tolerance to different biotic and abiotic stresses. Eight clones have been identified as good chip and/or french fry producers (Table 8-6), following experiments with some 400 clones in different environments (La Molina, San Ramon, and Huancayo), with testing for yield, specific gravity, and reducing sugar content. Future studies will test an additional 1,000 clones for yield and processing attributes, to identify progenies for processing quality.

Sweet Potato

Baseline surveys to document and analyze existing forms of sweet potato utilization for human consumption and animal feed are under way in China, Viet-nam, Indonesia, Thailand, and Peru. These studies are in response to national program leaders' opinions about constraints and opportunities for expanding sweet potato production (see Thrust X). Field studies on these issues also are under way in Argentina, Uruguay, and the Dominican Republic, as part of a broader diagnosis of the food system for sweet potatoes in those countries. Other research is designed to upgrade and increase the economic efficiency of traditional processing. New processed sweet potato food products are being developed, using a consumer-oriented approach.

Sweet Potato Processing

The Philippines. Processed sweet potato food products for low- and middle-income urban groups are being developed by scientists at Visayas State College of Agriculture (VISCA) at Leyte. Consumer surveys indicate that research should focus on chips, noodles, and cubes for traditional food dishes, and flour for hot cakes and baby food. Experiments on the standardization of processing techniques for sweet potato chips showed that a slice thickness of 1.5 mm to 2 mm was most suitable for producing a crispy (when fried) final product. Various pre-frying treatments also were tried with sweet potato cultivars having white, yellow, and orange flesh colors. However, sensory scores were about the same for the fried chips and for the control.

Sweet potato flour has the potential to be used as a substitute for wheat flour in the preparation of popular noodles in Philippine markets – without affecting the texture and general acceptability of the noodles. An acceptable level of substitution was found to be 25% for **odong** noodles (dried type) and 50% for **canton** noodles (fried type). In the formulation of **miki** noodles (fresh type), 25% sweet potato flour produced an unsatisfactory product. Of the sweet potato varieties screened for use in noodle processing, Miracle, Karingkit, VSP-3, VSP-6, and UPLSP-5 were the best performers.

China. With 6 million ha of sweet potatoes, China has a rich tradition of village-level processing. CIP is working with the Food Science Laboratory of the Sichuan Academy of Agricultural Sciences at Chendu, Sichuan Province, to document and improve established processing techniques for sweet potatoes in China and other countries. Sichuan is the largest sweet potato producing province in China, and local farmers and rural entrepreneurs have considerable experience in sweet potato processing utilizing labor-intensive techniques. The principal products are starch, noodles, and dried chips. Major constraints identified in a recent baseline survey included low starch recovery rates due to inefficient processing equipment and non-availability of high-starch cultivars. Research to increase the economic efficiency of processing methods is under way to increase income from sweet potato processing. Semi-mechanized processing is being developed and evaluated at the village level.

Thailand. In collaboration with the Department of Agricultural Extension, a baseline survey is being carried out on production and utilization of sweet potatoes. Preliminary findings indicate

Products made from sweet potatoes are highly nutritious. In the developing world, sweet potato flour is being used as a substitute for cereal flour in bread making.

that sweet potatoes are used predominantly for fresh consumption, with only a small proportion being processed into sweets and snacks. Processing for starch also has potential, if prices for fresh roots can be reduced.

Indonesia. A baseline survey carried out by the Central Research Institute for Food Crops identified a total of 10 different sweet potato products in various retail outlets in West Java. However, these products account for only a very small proportion of total sweet potato production. Most sweet potatoes are consumed when fresh or are used for animal feed. Existing processing methods are being documented and evaluated. Future research will identify additional market opportunities for sweet potato products used for human consumption, as well as for animal feed.

Peru. A pilot survey of sweet potato consumption and processing at Lima found that processed products for human consumption included flour, starch, chips, and bread, with the foliage being used for animal feed. Preliminary results of the consumer interviews indicate a limited use of these products (e.g. starch is used only as an ingredient in a traditional dessert). The available information is meager, however, and other recent studies suggest considerable potential for substituting sweet potatoes for imported wheat flour in bread making (see Thrust X). As higher-income consumers use sweet potato products more frequently, a lower price might well expand the market for both fresh and processed products. More information is needed regarding the influence of government policies, in the form of subsidies for wheat-based products, and how this may hamper the development of sweet potato products in Peru and elsewhere (e.g. the Philippines).

At the Universidad Nacional Agraria-La Molina, in a Master's thesis project, the chemical and nutritional characteristics of sweet potato cultivars in CIP's germplasm collection are being evaluated for possible use in bakery products. Of 150 cultivars evaluated, only 15 were identified as having low values of reducing sugars. Flour of suitable cultivars will be used to evaluate nutritional quality of bakery products, particularly bread, when 30% of the wheat flour is replaced by sweet potato flour.

Pollinated inflorescences in the field, identified for TPS production experiments.

Thrust IX

Seed Technology

Thrust Profile: 1990

Worldwide collaborative research focused on improving agronomic characteristics of selected TPS progenies intended for seed production and use in warm climates. Several parental clones were identified with acceptable berry-setting capacity that produced TPS with tolerance to bacterial wilt infection and transplant shock, tuber uniformity and quality, and high yield stability.

Techniques for increasing the efficiency of hybrid TPS production were tested in Chile, India, Italy, and Peru. Supplemental N applications were found to increase the production of TPS, but may reduce tuber production of the mother plant. In soils of medium P and high K content, additional doses of up to 160 ppm (P) and 240 ppm (K), were found to be optimal for increasing flowering and TPS weight. Berry weight was increased by preplanting incorporation of farmyard manure, and by the addition of foliar fertilizers. The transformation of fertile clones into cytoplasmic male sterile lines to increase the efficiency of hybrid TPS production was successful in six clones and their crossing ability is being tested.

Additional research emphasized postharvest handling of TPS. Seed-vigor losses following harvest of the TPS were shown to progress at a slower rate during storage, when the seed had been produced with high N. The storability of TPS was better maintained in a dry environment, as compared to when exposed to ambient air. Seedling-vigor testing of selected TPS progenies at various periods of storage demonstrated that the seed must be after-ripened at about 5% to 7% moisture content (dry-weight basis) and under moderate temperature (20C) conditions for at least 12 months, before the seed can be sown effectively in high-temperature environments. Presowing of TPS in a solution of KNO_3 + K_3PO_4 followed by seed drying (osmotic priming) was an effective treatment for enhancing seed vigor at supraoptimal (30C) temperatures.

The efficiency of seedling-tuber production techniques was further improved in extensive studies conducted in India and Peru. Collaborative projects continue to expand successfully in Paraguay, Venezuela, Cameroon, and Indonesia. The studies investigate the technical problems and develop modifications needed at each site for optimal use of TPS in a seedling-tuber production system.

CIP has increased the extent of its collaboration towards strengthening or developing seed-tuber propagation systems in Bolivia, Burundi, Colombia, Venezuela, Kenya, Myanmar, the Philippines, and Peru. The objectives of these projects include: the analyses of limiting factors of potato production and of traditional seed-tuber distribution systems; the transferring of information such as simple positive selection of healthy plants and advanced rapid multiplication and diffused-light storage techniques; and the development of simple flush-out basic seed systems. Farmer participation is an integral part of the process in all projects. A case study exploring the strengths and weaknesses of local seed systems was completed in Kenya.

Research on the improvement of sweet potato propagation techniques was conducted under a wide range of environments. Agronomic and climatic factors affecting flowering and seed production were identified. The use of in vitro-propagated plantlets, larger unrooted cuttings, and rooted cuttings was shown to result in a faster establishment and growth, and increased flowering. Increased plant N uptake and root yields were obtained by the incorporation into the soil of various *Azospirillum* strains.

TPS Progeny Evaluation

The International Progeny Evaluation Trials were conducted at 14 locations representing a wide range of environments worldwide. In Peru, progeny performances in these trials generally differed at San Ramon and Lima, which represent a humid and a dry tropical environment, respectively, and for the two seasons of evaluation. Some progenies, however, showed relatively stable production in all environments. These include Maine x C83.119, Serrana x LT7, C83.174 x C83.119, C83.119 x AVRDC1287.19, and C83.119 x Y87.013. In these trials, the parent C83.119 transmitted high yields and stability levels to its progenies.

In evaluations of advanced progenies in Lima, the treatments included two irrigation systems and two transplanting methods. The plants of progenies Y84.027 x 377964, LT-9 x AVRDC-1287.19, and YY-7 x LT-7 showed high tolerance to transplant shock, as the vigor and potato yields were unaffected in those treatments in which bare-rooted seedlings were transplanted to the field.

Sixty selected progenies from new parental lines of improved agronomic and reproductive characteristics were evaluated under cool (Huancayo) and warm (San Ramon) conditions. Most of the progenies outperformed the controls for most of the agronomic traits evaluated (which included tuber characteristics). At San Ramon, 15 progenies selected from a population adapted to warm climates were evaluated during the hot, rainy season, under conditions of severe bacterial wilt infection. Several progenies yielded well, confirming their potential for use in those conditions.

A sample of 45 families was evaluated at San Ramon (dry season) and La Molina (winter season) to determine the genetic parameters for this population. The North Carolina design I used a sample of 15 male clones and 3 female clones per male in 3 sets. Parental clones that transmit their good agronomic and reproductive characters to their progenies have been identified and will be used as TPS parental lines.

At San Ramon, 220 clones previously selected for adaptation to warm climates were evaluated for their flowering and fruit-setting capacity during both the dry and rainy seasons. Several clones were identified as having suitable reproductive characters (Table 9-1) and will be used in the TPS program as parents to further assess their potential.

Protoplast fusion was used to transform clones for cytoplasmic male sterility (CMS). Using pollen of known TPS male parents, such as 7XY.1, LT-7 and Atzimba, these clones were crossed to assess their efficiency as progenitors and the segregation of their progenies. Two of these clones produced tetrad CMS pollen, but only Y245.7 showed good agronomic performance and potential for use as a parental line in TPS production. Over 300 genotypes were evaluated as potential TPS parents and screened for tetrad CMS at Huancayo, San Ramon, and La Molina. Of the population, six clones were identified as having tetrad CMS pollen: C386LM87-B, C116LM87-B, C137LM87-B, 382301.1, 382302.2, and 382291.1. Tests of their crossing ability are under way.

A general scheme for agronomically evaluating TPS progenies was tested for a second year at two locations in Peru. In this approach, evaluations are made of a set of advanced progenies from the TPS breeding program at CIP, using 2 methodologies: 1) direct production of consumption tubers by transplanting seedlings to the field, and 2) use of seedling tubers. The seedling tubers are produced in beds under controlled irrigation in the highlands. Tubers 3.5 cm to 5.0 cm in diameter are planted at Lima and San Ramon the following season, along with transplants of the same progenies. New improved TPS progenies are being incorporated into this evaluation scheme each year.

In India, locally developed hybrid progenies were evaluated in Modipuram and Tripura. In Modipuram, 13 hybrid

Table 9-1. Evaluation of advanced TPS parents for various reproductive characters in warm environments. San Ramon, Peru, rainy season.

Clones		Yield/pt	Earliness	Characters							
				DFI	FI	FD	F/I	SL	AT	BA	PP
Clone 42	LM88 B	1.24	5	40	7	6	5	5	2	2	3
Clone 43	LM88-B	1.08	5	45	7	6	5	5	2	2	5
Clone 152	LM88-B	1.00	7	38	5	6	5	4	2	2	5
Clone 61	LM88-B	1.00	7	45	7	7	7	4	2	2	5
Clone 44	LM88-B	0.94	5	38	7	7	5	5	2	2	5
Clone 18	LM88-B	0.90	6	38	5	5	5	4	2	2	5
Clone 45	LM88-B	0.90	5	39	6	5	5	4	2	2	5
Clone 517	LM88-B	0.71	6	39	7	6	5	5	2	2	5
Clone 339	LM88-B	0.70	7	39	7	7	5	7	1	1	5
Clone 39	LM88-B	0.70	5	46	3	3	5	4	2	2	5

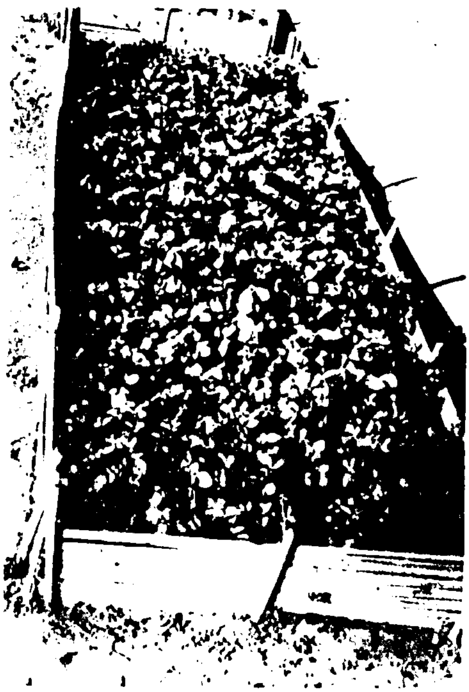
families: HPS-I/III, HPS-I/13, HPS-I/67, HPS-2/67, HPS-2/III, HPS-2/13, HPS-7/III, HPS-7/PPS, HPS-24/III, HPS-25/30, HPS-27/III, HPS-26/PPS and HPS-(II x I) were evaluated for seedling-tuber production in nursery beds. One to two seeds were sown at depths of 1/2 cm to 1 cm, with 10 cm x 10 cm spacing. After 2 weeks of germination, the seedlings were thinned down to a desired level of 100 plants/m^2. All populations had an optimum plant density, except HPS-26/PPS, which had approximately 50 plants/m^2. The crop was dehaulmed after 90 days of seed sowing and at harvest, observations were recorded on total tuber yield, number of different sizes of seedling tubers, and segregation.

At the same location, the field performance of 17 hybrid families transplanted to the field was evaluated for consumer or seed production. Also evaluated were 11 families of which different sizes of seedling tubers had been used for planting. In the trial of the 17 hybrid families, percentage of seedling survival recorded 45 days after transplanting was above 75% in all progenies (Table 9-2). Except for HPS-2/13 and HPS-10/III, the tuber yield produced by TPS families was more than 20 t/ha. HPS-12/13 gave the highest tuber yield, but it showed poor tuber uniformity. TPS families HPS-7/III and HPS-25/13 gave 31.7 t/ha and 33.2 t/ha tuber yields, respectively, which is as good as or better than the best cultivars being used by the farmers. Percentage of marketable sized tubers of TPS families ranged from 55.1% to 88.7%. Some of the hybrids had over 80% marketable yields. In general, the number of tubers produced per unit area by TPS families was much higher compared to that of the cultivars.

Table 9-2. Evaluation of TPS families as transplants at CPRS, Modipuram, India (1988-89).

TPS family	Survival %	Yield (t/ha)	Marketable yield (%)	Tubers (no./m^2)	Av. tuber wt. (g)	Tuber uniformity
HPS-I/III	85.8 ab	26.7 cd	84.7 ab	114.3 cd	23.7 bc	5.0
HPS-I/13	86.3 ab	25.3 d	88.6 a	98.7 cd	27.3 ab	5.0
PS-I/67	95.9 a	23.3 cd	79.5 abc	139.7 abc	20.0 cde	5.0
HPS-2/III	92.1 ab	23.8 de	83.7 ab	110.0 cd	21.7 bcd	5.0
HPS-2/13	85.4 ab	19.1 ef	85.6 ab	76.7 d	24.7 bc	4.7
HPS-II/III	90.0 ab	28.3 bcd	87.6 a	109.0 cd	26.0 bc	4.5
HPS-7/III	91.3 ab	31.7 abc	75.1 abc	173.3 ab	20.7 cde	5.0
HPS-7/67	92.9 ab	25.2 d	63.9 cd	145.0 abc	16.7 def	4.0
HPS-7/PPS	84.6 b	23.9 de	68.4 bcd	190.7 a	12.7 f	3.0
HPS-8/PPS	85.4 ab	23.6 de	55.1 d	169.3 ab	15.0 ef	2.0
HPS-10/III	86.7 ab	15.6 f	70.9 abcd	112.0 cd	14.0 f	3.3
HPS-12/III	90.0 ab	22.5 de	73.0 abc	107.3 cd	21.3 cd	3.0
HPS-12/13	90.0 ab	37.5 a	87.1 a	111.3 cd	32.3	3.0
HPS-25/III	75.0 c	26.0 cd	86.4 a	101.0 cd	25.3 bc	4.0
HPS-25/13	88.8 ab	33.2 ab	87.3 a	123.3 bcd	27.3 ab	5.0
HPS-26/PPS	89.2 ab	27.1 cd	75.2 abc	138.3 abc	20.3 cde	3.0
HPS-27/III	87.1 ab	23.1 de	84.0 ab	95.3 cd	24.3 bc	4.0

Duncan's Multiple Range Test at $P < 0.05$.
Tuber uniformity (shape, size, and color).



Seedling tuber production in nursery beds, India.

Average tuber weight of all TPS progenies was between 12.7 g and 32.3 g; however, some of the TPS families had poor tuber uniformity (a score of 3 or lower).

In the seedling-tuber evaluation, tubers of 2-5 g, 5-10 g, 10-20 g, and >20 g of 11 TPS families were evaluated for their field performance at Modipuram during 1988-89. The same-sized seed tubers of cultivar Kufri Bahar were also planted for comparison. The crop was dehaulmed after 90 days of maturity. Tuber yield (t/ha), marketable yield (%), tuber number of tubers/m^2, and average tuber weight (g) were recorded at harvesting. Hybrid HPS-I/13 produced higher tuber yield than did cv. Kufri Bahar. But the marketable yield produced by Kufri Bahar was higher than that of all other TPS families. TPS families produced more tubers per unit area than did the cultivars. Average tuber weight of cv. Kufri Bahar was superior to that of all other TPS hybrids.

In comparative field trials using second- and third-generation seed tubers of TPS families, the yield potentials of seed tubers of both generations were similar. After 90 days of maturation in the field, the crop was dehaulmed and the yields of both generations of plants were compared to that of locally grown cultivars. Thus, the farmer could use part of the produce from each generation to plant his next crop without substantial loss of yield. In Tripura, completely opposite findings were obtained in a trial using 5 hybrids, 1 OP, and the cv. Kufri Jyoti as control. Similar-sized seedling tubers were used, after 1 or 2 field propagations. The results showed significant yield differences for both generations.

Seedlings of 11 hybrid and two open-pollinated (OP) TPS families were transplanted to the field at a spacing of 60 cm x 15 cm, and survival percentages of all families ranged from 74% to 92%. HPS-I/67 had the highest survival rate. Hybrid HPS-7/III produced the highest tuber yield, and OP TPS-2 was the poorest yielder. Tuber yield of some of the TPS families equalled that of cv. Kufri Jyoti, but the average tuber weight in all TPS families was much lower.

In a comparative field trial using seedling tubers graded as 5 g, 10 g, and 20 g, that were produced in beds in the previous season, HPS-7/13 was the highest yielder and TPS-2 (OP) was the lowest. The crop was dehaulmed after 96 days of planting. Plants from seedling tubers of the three sizes had statistically similar yields. Seedling tubers of 5 g and 10 g produced maximum number of tubers per unit area and had the lowest average weight.

In another experiment, using 20 g, 40 g, and 60 g seedling tubers produced from transplants during the previous season, and dehaulming the crop 96 days after planting, the different sizes did not differ in yields or number of tubers/m^2. This finding suggests that the farmer could sell those tubers larger than 20 g for consumption and use the non-marketable produce as seed for his next season's crop, without loss in yield.

One of the best performing progenies in several Asian countries, HPS-I/13, was compared for three consecutive seasons to the locally grown cultivars (Fig. 9-1) at three locations (Modipuram, Deesa, and Agartala). The marketable yields for HPS-I/13 were generally lower as compared to those of cultivars. But the proportion of market-sized tubers in this progeny was higher than 60% at all three locations during the three seasons. Because seedling tubers from transplants of this progeny normally have produced higher yields, the finding that they have approximately 40% non-marketable tubers (ranging from 10 g to 20 g) can be considered as an advantage, because this fraction could be ideal for use as seed in the next season. Furthermore, an economic analysis of the data indicated that the cost of production of this fraction for HPS-I/13 was about US$38 per ton, as compared to regular market prices of approximately US$152 per ton of seed tubers. Also, instead of the 2.5 t of commercial seed tuber normally used to plant one hectare, the farmer would require only 1.7 t of seedling tubers obtained from the 10 g-20 g portion.

Generally, the average weight of tubers from HPS-I/13 transplants is lower than that of the cultivars. Further hybrid progenies are being screened to improve this characteristic.

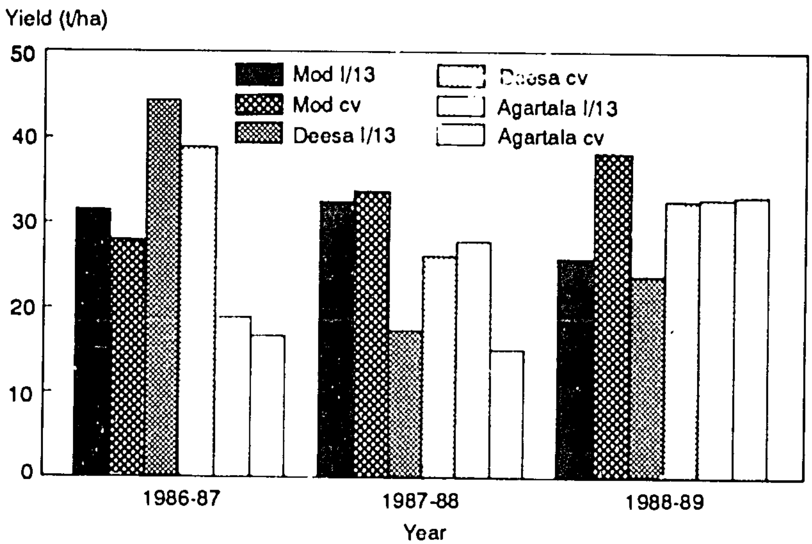


Figure 9-1. Comparative yield (t/ha) of seedling transplants of HPS I/13 and locally grown cultivars.

In the Philippines at Canlubang, new progenies of locally selected parents were evaluated for yield and other desirable characteristics. The hybrid LT-7 x LBB is a promising progeny, having high yields, tubers of uniform shape and color, and large size.

At two locations in Italy, Marigliano, near Naples, and Camigliatello, in the Calabrian region, seedlings of 28 hybrid TPS families were transplanted at both locations, using 2 seedlings per hill and 10 hills per plot. Best results were achieved by the progeny UP 88201 x AVRDC-1287.19, with total tuber production of 5˙6 t/ha. Chiquita x AVRDC-1287.19 had the best tuber uniformity and excellent tuber quality, as well as good yields.

At Camigliatello, hybrid families producing encouraging results included: UP 88.201 x AVRDC 1287.19, UP 88.201 x W 842, Spunta x CFK69.1, W842 x AVRDC 1287.19, W 842 x R 128.6, UP 88.202 x AVRDC 1287.19, UP 88.203 x AVRDC 1287.19. They produced excellent yields and high tuber quality that compared very well with results obtained from commercial varieties used in the region.

CFK69.1 and AVRDC 1287.19 were the best male parents for transmitting good traits for tuber yield quality to their progenies. The best female parental lines were UP 88-201, UP 88-202, UP 88-203, UP 88-204, and UP 88-205.

At Marigliano, the best results for yield and quality were achieved by Morene x BR-63.15. Progenies OP of the CIP clone LT-5 produced excellent yields, with a total tuber yield of 57.1 t/ha. At Camigliatello, Morene x BR-66.15 provided the best combination for yield and quality, and LT-5 OP again performed well.

Production of Hybrid TPS

Seed Production of Selected Hybrids

In Lima, 9 female and 11 male progenitors were crossed to produce TPS for distribution and regional evaluation of 38 new hybrids and 2 OP progenies. All parental material came from transplanted in vitro plants. Sufficient quantity of seeds was obtained, except when pollen of TS-1 and TS-2 was used. Crosses made with those two male parents were affected by the low viability and rapid loss of germinability of the pollen after short periods of storage. Similarly, little or no flowering was observed in LT-9 and Atlantic female progenitors. The plants were drip irrigated, fertilized with supplementary nitrogen, and treated with a 3-hour night break.

In Italy, a diallelic crossing block involving 7 progenitors (V-2, R-128.6, LT-5, I-931, I-1062, CFK 69.1, and AVRDC 1287.19) was used to produce hybrid TPS for local testing and for distribution in CIP Region IV. The TPS was produced on 2-stem plants grown under screenhouse conditions with high rates of N fertilization applied at weekly intervals. The fruits were left to mature on the plant for about 10 weeks before extracting the seed.

Eight kilograms of seed of advanced CIP hybrids were produced under contract with INIA in Osorno, Chile. Variable amounts of hybrid seed have been produced through this contract in the last five years (Table 9-3). Production in Chile highlighted the importance of maintaining high pollen viability, using plants of high sanitary condition, and using efficient hybridization methods.

In Kothi, India, attempts were made to produce substantial quantities of TPS of 8 hybrids for large-scale on-farm evaluation. The 8 hybrids were HPS-I/13, HPS-I/67, HPS-7/13, HPS-7/67, HPS-2/13, HPS-2/67, HPS-25/13, and HPS-25/67, chosen on the basis of their performance in the previous years at different locations. In total, 4.58 kg of hybrid TPS was obtained from these hybrids. In addition, approximately 1 kg of TPS was obtained from 54 different test crosses, when 27 new hybrids developed as female lines were crossed with two elite male testers (TPS-13 and TPS-67). These newly generated TPS families are being analyzed for TPS quality, germination, field establishment, yield potential, and plant and tuber characteristics. A standard procedure for extracting and processing TPS developed in CIP Region VI was followed for extracting the seed of this year's production.

Soil Nutrients and Flowering

Several experiments on fertilizer application and rates were conducted on different soils from various regions of Peru. Higher doses (240 ppm) of N significantly increased flowering and TPS setting, but reduced tuber production on Atzimba potatoes in a sandy loam soil, with neutral pH, low in organic matter and N content with medium levels of available P and K. The sources of N urea, ammonium nitrate, and ammonium sulfate did not differ in their effects on flowering and fruit production.

In soils with medium content of available P (6 ppm to 8 ppm by Olsen), doses of 80 ppm to 160 ppm of P_2O_5 increased TPS production significantly, but higher rates affected TPS weight.

The use of simple and triple superphosphate, and of ammonium phosphate, had a similar effect; rock phosphate (30% of P_2O_5) was shown to be a good source of P for soils that had a pH level of less than 6.5 and little available phosphorous.

In alluvial soils from the Peruvian coastal valleys of Cañete and Chincha, characterized by a high content of available K, the addition of fertilizers increased flowering and berry formation;

Table 9-3. Area, number of female and male plants, berries, and hybrid TPS produced in Osorno, Chile, over 5 seasons.

Year	Area (m^2)	Number of plants M	F	Berries (kg)	Seed wt. (kg)
1984/85	818	781	383	372.4	5.4
1985/86	2,743	2,411	1,420	1,140.34	13.2
1986/87	2,655	2,414	1,215	481.20	5.8
1987/88	3,669	2,870	2,610	2,835.15	32.4
1988/89	2,766	2,158	2,294	687.36	8.0

Hybrid TPS production at the La Pampa Station (INIA), Osorno, Chile, 1988-89.

however 240 ppm of K_2O reduced berry set and 100-TPS weight. A formulated fertilizer mix of K_2SO_4 and $MgSO_4$ performed better than did formulas containing only K.

Applied at weekly intervals before flowering, 2 foliar applications of fertilizer containing macro- and micronutrients increased the number and size of berries and the 100-TPS weight; however, there was no improvement in the rate of TPS germination and vigor of potato seedlings during the first 20 days.

Light Duration

In Lima, Peru clones DTO-28 and LT-7 were studied under greenhouse conditions to determine the effects of daylength on flowering. The daylength treatments were increasing, constant (15 hours), and decreasing. Decreasing daylengths caused a significant increase in pollen production on the DTO-28 clones but not in LT-7. Flowers produced on LT-7 in plants subjected to the constant daylength treatment had pollen of lower viability. Neither clone produced flowers on control plants grown under 12 hours of light.

TPS Physiology

TPS handling. The performance of seed when sown has been demonstrated to be strongly affected by general conditions during the seed development phase, and after harvest. Periodic high applications of N following pollination improve performance and this practice is routinely used in TPS production.

To investigate the effects of moisture conditions in storage on seed germination and seedling vigor, TPS of the cross

Table 9-4. Effects of N applied during seed production and moisture conditions during seed storage on the coefficient of velocity (CoV) and percentage of germination, after 7, 11, and 14 months of storage.

Storage		Coefficient of velocity				Percent of germination			
period	Nitrogen:	Low		High		Low		High	
(months)	Moisture:	Amb	Dry	Amb	Dry	Amb	Dry	Amb	Dry
7		14.0	16.0	13.4	18.9	80	75	68	95
11		17.8	29.3	16.7	25.2	100	99	98	95
14	2	15.0	31.6	15.0	30.2	57	99	99	99
Linear	R	ns	**	ns	.98**	ns	**	ns	ns
Quadratic	R	.98**	.99**	.97**	**	.90**	.80**	.89**	ns

Atzimba x DTO-28 was grown with high and low nitrogen fertilizer applications. The TPS was stored at room temperature in ambient air (9% to 12% seed moisture) and dry (5%) conditions. Germination tests were performed under favorable conditions after 7, 11, and 14 months of storage (Table 9-4), and seedling vigor was tested after 14, 20, and 23 months. The rate and percentage of germination (0 to 8 days after sowing) were more strongly influenced by the moisture conditions during storage than by fertilizer application: dry seed germinated more quickly and at higher rates than did TPS stored in ambient air. The rate of germination showed a linear association with time in storage and the percentage was high (≥95%) in dry seed produced with high N (Table 9-5). The responses for other treatments were curvilinear; germination potential began to decrease by the 14th month in storage. Seedling vigor parameters were shown to be influenced more strongly by N treatments during seed production. High-N seed had much higher rates and percentages (0 to 10 days) of emergence and seedling dry-weight (17 days) levels than did low-N seed, particularly when stored dry. In storage, low-N seedling emergence parameters decreased linearly with time, whereas high-N seed showed linear increases in rate of emergence and the percentages were high (95%). These findings suggest that TPS should be

Table 9-5. Effects of nitrogen applied during seed production and moisture conditions during seed storage on the coefficient of velocity (CoV) and percentage of emergence, after 14, 20, and 23 months of storage.

Storage	Nitrogen:	Low				High			
period	Moisture:	Amb		Dry		Amb		Dry	
(months)		CoV	%	CoV	%	CoV	%	CoV	%
14		10.8	68	10.9	71	13.1	97	14.1	100
20		3.8	2	0.0	0	13.0	78	14.7	95
23		.0	0	2.5	1	14.3	96	14.9	98
Linear 2		-.74	-.90	-.52	-.88	.29	.04	.55	.14
Signifi. (R) **		**	**	**	*	ns	**	ns	

produced with high N and stored dry for sowing under favorable conditions.

Presowing TPS treatments. Presowing treatments were compared for seedling-stand establishment under screenhouse conditions with old (>18 mo) and new (<6 mo) seed for 3 potato crosses. The treatments consisted of soaking the seed in solutions of KNO_3m + K_3PO_4 at 1.0 MPa (priming) and gibberellic acid at 1,500 ppm (GA1500). Evaluations of emergence and seedling growth parameters were performed within the first 17 days after sowing under mean (max.) air temperatur s of 29C and 34C. Seedling vigor levels were lower in the second test (34C) than in the first (29C). In both tests, overall seedling performance was highest in seed of the cross Atlantic x LT-7. Old seed was more vigorous than new seed, particularly when the crosses Atzimba x R128.6 and Serrana x LT-7 were tested at 34C. Priming increased early emergence over the other treatments at 34C and increased seedling dry weight in both tests (Figs. 9-2 and 9-3). GA1500 generally increased final emergence in Serrana x LT-7. It was concluded that for sowing TPS at high temperature a) the genotype is a crucial factor, b) sufficient seed

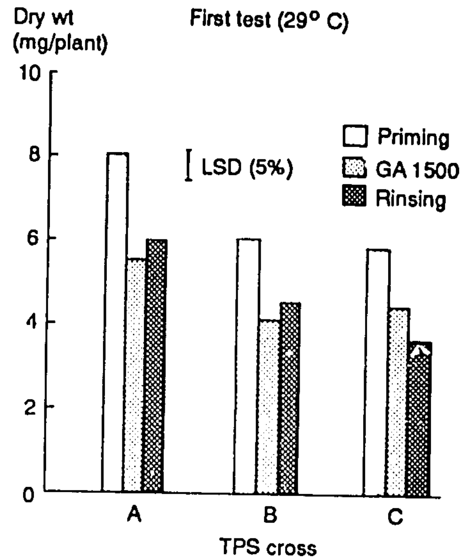


Figure 9-2. Mean seedling dry weight as affected by presowing treatments.

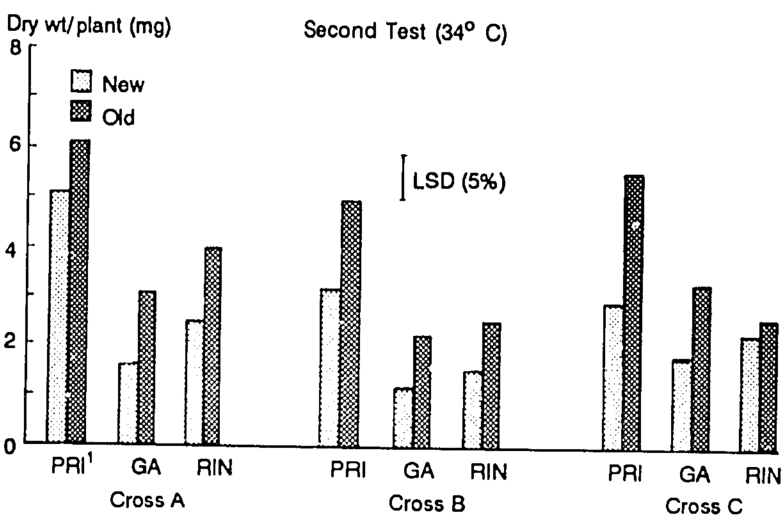


Figure 9-3. Effect of presowing treatments and seed age on seedling dry weight. (PRI[1] = Priming; GA = GA 1500; RIN = Rinsing.)

storage (> 18 mo) may be essential, and c) seed priming is more effective than the standard GA1500 treatment.

Storage of treated TPS. The preservation of the effects of various seed treatments during storage at two temperatures was evaluated, using TPS of Atlantic x LT-7, Atzimba x R128.6, and Serrana x LT-7 that were produced in 1987 and 1988 in Chile. The TPS treatments were a priming solution (KNO_3 + K_3PO_4 at 1.0 MPa), gibberellic acid (1,500 ppm), and rinsing (water for 5 min). The treated seed was stored for 4 months at 2 temperatures: 5C and 22C. The priming effects were preserved better at 5C than at 22C. Seedlings produced with the priming treatments showed a higher coefficient of velocity and greater dry weight than did those with the rinsing treatment. Priming of seed stored at 5C produced the highest seedling vigor and dry weight/plant. In general, the priming treatment produced better performance than did the standard gibberellic acid and presowing rinsing treatments.

In India, studies using freshly extracted seed of 4 sizes showed that a solution of 10% HCl can be safely used to soak seed for up to 80 min. to remove the mucilage and to clean fungus or bacteria from the seed coat. The effects of seed size were also studied in another experiment to determine the proportion of different embryotypes and their relationship to seedling vigor. Seedlings from large seed with embryotype A, i.e. fully developed embryos, were shown to be more vigorous than those from seed with embryotype B.

TPS Agronomy

TPS in Seed-Tuber Programs

South America. A collaborative project between the Ministry of Agriculture (MAG) and CIP was initiated in Paraguay to produce large volumes of seed tubers of 2 selected TPS progenies: Atlantic x LT-7 and Serrana x LT-7. These seed tubers will be used as the basis of a system to supply local farmers with high quality seed tubers. The tubers were produced by transplanting seedlings into 600 m^2 field beds, at a rate of about 50 per m^2, at 2 different experiment stations. The plants were harvested 3 months after transplanting and the tubers stored for 3 months, before planting in February for further multiplication. The tubers of 4 progenies produced last year also were planted in plots at both stations to assess the best adapted progenies. They were also planted in a large production field at the experiment station. In addition, some of the tubers were distributed to farmers to obtain their help in identifying potential problems that may need further research.

In four farmers' fields in Venezuela (states of Trujillo and Merida), seedling tubers were produced in beds and planted in the field after the regular storage period. (One of these farmers has been growing potatoes from seed tubers that originated from true seed sown in beds on his farm about 5 years ago. He obtained 20 t/ha last season). Due to the potential for adoption of this method of potato production in those regions, two methods of seedling-tuber production in seedbeds were evaluated by the national scientists: direct sowing and transplanting seedlings into the seedbeds. The transplanting method showed better plant establishment, higher yields, and improved tuber-size distribution. Of the different progenies tested, Atzimba x 104.12 LB showed the most promising results, with yields of more than 9 kg per m^2 of seedbed.

Africa. In Cameroon, preliminary evaluations have indicated that seedling-tuber production in nurseries can be an appropriate method for providing quality-protein planting materials to farmers at low cost. When seedlings are transplanted to the field under the high-stress conditions of the production sites, they traditionally have shown poor field establishment; however, this limitation can be overcome by nursery production of seedling tubers. In Mfonta (1,300 m) 16 progenies were evaluated in nursery beds, at a plant density of 100 plants/m^2. Seedling tubers were harvested 90 days after transplanting and the highest yielding progenies were CFK69.1 x DTO28, Atzimba x R128.6, Atzimba x 104.12-LB, and I-931 x AVRDC 1287.19. On the Upper Farm, crop production from seedling tubers of 13 progenies was compared with that of three commercial varieties. Six of the progenies outyielded the three varieties and had greater resistance to late blight. The three highest yielding progenies were CFK 69.1 x 104.12LB, CFK 69.1 x DTO28, and Atzimba x 104.12LB.

In Sri Lanka, progenies are being adapted to the local conditions. Improved TPS parents were identified from locally-selected clones and large quantities of hybrid TPS are being produced to replace the less productive progenies used in the past.

Trials for agroeconomic evaluation of the use of TPS continued at a number of locations in India. Economic studies have demonstrated clear advantages of TPS use in many areas; thus, TPS is attracting increasing interest by farmers (see Thrust X).

A very active TPS agronomy program is under way in the Patna region, under CPRS supervision. Seed of the best progenies have been selected through systematic evaluation in India and have been distributed to Bangladesh, Nepal, Sri Lanka, and the Philippines.

TPS progenies that have shown promising results at specific growing locations were distributed to farmers to be tried on-farm.

TPS technology was introduced at 2 isolated growing areas of the Philippines (Canlaon, Negros and Lantapan, Bukidnon). In Canlaon, farmers have successfully sustained TPS production 3 years after its introduction, with most TPS now grown with seedling tubers.

In Lantapan, where bacterial wilt is a limiting factor for potato production, TPS was introduced to provide clean seed. Twenty interested farmers were provided with TPS, and instruction on production; they are now obtaining 1.7 kg-3.8 kg per m^2 from their beds. Seedling tubers of the first generation were planted in June 1989. In September 1989, TPS was distributed (sold) to various farmers in Mindanao along with careful instructions on how to grow the crop from TPS.

True seed production continues in Dalat, Vietnam, where hybrid TPS production was initiated in 1989 at the Potato Research Station and 200 g of hybrid seed were produced. Generally, plants were staked and allowed to maintain 5 flowers resulting in 3 fruits per stem. On average, 100 seeds were obtained per berry. The female parent was CFK69.1, while male parents included LT-7, 38.6, 7XY.1, 88.14, 88.8, and I-1039. Production is expanding for 1990.

In the Red River Delta (RRD) area, during the 1988-89 season, only 10 kg of TPS (OP) were utilized for transplanting in 6 cooperatives (Haihung 2, Langson 2, and Hasonbinh 2). Approximately 700 ha of potatoes were grown from the tuberlets during the 1988-89 season. Extensive adoption has been limited by technical problems: too wet or dry conditions in the seedbed and after transplanting, and poor adaptation of existing progenies to short-day conditions. In the RRD, the breeding work is now focusing on the selection of TPS parental lines that will produce tuber yields of good quality and large size under cool short-day conditions.

Seed-Tuber Propagation

Bolivia. A 12-year research project funded by the Swiss Development Agency has been started by the Bolivian Agricultural Research Institute (IBTA) and CIP to analyze the limiting factors of potato production and to strengthen the national program by developing and transferring appropriate technologies. An intensive workshop was conducted with key organizations participating to define the objectives and activities to be implemented by the project.

Burundi. CIP is collaborating with the Burundi National Potato Seed Project to produce large quantities of prebasic seed for wide distribution and to develop technical information aimed at promoting on-farm seed reproduction systems. A greenhouse and an in vitro laboratory were completed and equipped, with assistance from Belgium. In vitro-derived tubers produced in Gisozi were planted on 1 ha at Mwokora, and on 18 ha at Munanira. The seed tubers harvested will be distributed to rural projects and farmers. At Mwokora, seed quality has been further improved through an innovative integrated approach for bacterial wilt control. Thirty farmers have participated in these trials, and 15 have replanted the seed produced in their own fields.

Colombia. In collaboration with CIP scientists, a project was started by ICA in Boyaca and Cundinamarca to 1) produce large amounts of prebasic seed using advanced rapid multiplication techniques, and 2) diffuse the technology among farmers. An aphidproof screenhouse (120 m^2) was completed in April at the San Jorge Station. CIP has provided crude antisera against PVY, PVX, PVS, APMV, and APLV for processing and distribution to PRACIPA members. A study of the adoption of appropriate diffused-light stores for small farmers (previously promoted by ICA/CIP) has indicated that these stores are well accepted by the farmers.

Peru. The third phase of CIP's collaborative project with the Peruvian National Potato Program is designed to strengthen the capacity for self-sustainability of four major facilities for basic-seed production. The La Molina facilities continued prebasic-seed production and distribution to the other units and basic-seed revenues from the year's sales have generated a reserve fund in addition to covering the operational costs of 1990.

The traditional seed-tuber distribution systems of Peru were analyzed to develop an effective decentralized strategy for distributing basic seed to widely dispersed communities of small farmers. Basic-seed dissemination through rural development projects has continued in Cuzco, Huancayo, Cajamarca, and Puno. Information also was gathered to help increase the efficiency of distribution of high quality seed to small farmers, focusing on the Cajamarca, Cuzco, and Puno areas. In Cuzco, a survey dealing with principal potato diseases covered approximately 20% of the crop production area. In Cajamarca, 500 small farmers were surveyed and 250 seed producers were identified. Survey findings show that this broad-based traditional seed system handles 80 varieties of potatoes that are in daily use: 25 are improved varieties and 55 are native. The farmers identified bacterial wilt as the principal production problem, which is of increasing concern. Tests were made of new approaches for a basic-seed distribution with farmer participation. Community assemblies selected the individual farmers who would receive 50 kg of basic seed, on condition that at harvest each would give 12.5 kg to four other farmers. Thus, with 500 kg of basic seed, 400 farmers obtained high quality seed. The demand for such small quantities of high quality seed far exceeded the supply.

Other strategies to increase the efficiency of basic-seed distribution to the informal markets of small farmers also were investigated. The most promising strategies were:

- Selling allotments of 20 kg of basic seed at the weekly community fairs.
- Selling allotments of 100 kg to 500 kg to communities.
- Selling larger quantities to rural development projects.

At Puno, a similar survey involved 419 small potato producers and 30 units of peasant cooperatives. In the Puno area, farmers reported that they grew 109 varieties, of which only 19 were improved varieties. Their preferences for varieties do not differ, for production intended for home consumption or for market. Only 9% of the Puno farmers were seed producers. Although potato growing is widely diffused in Puno, individual plots are small and the average farmer uses 147 kg of seed tubers.

Venezuela. Socioeconomic studies are being conducted to assess the importance of prebasic seed-tuber production in Venezuela and the efficiency by which the technical information is developed and diffused. Research to assess the importance of vectors of virus and viroid diseases is also under way. In the potato growing area of the Caragua state, aphid vectors of the species *Myzus persicae* were more prevalent than were *Brevicoryne brassicae*, and populations increased near the end of the season, when rainfall decreased. At Trujillo, both species were important. At Monagas, *A. citricola* was predominant, and a fourth species, *M. euphorbiae*, was found. New materials for seed production have been introduced from CIP, and a popular variety (Andinita) was cleaned and returned to Venezuela to be propagated using in vitro techniques. The viroid PSTVd was not detected. A similar project will start next year in the Dominican Republic.

Kenya. A new basic seed production approach proposed in 1987-88, has been implemented. The Agricultural Development Cooperation will produce clean in vitro plant materials at the Plant Quarantine Station at Muguga; mother plants and prebasic seed at the National Potato Research Center in Tigoni; basic seed at Marindas; and certified seed at Molo. Research at Tigoni has focused on increasing the efficiency of mother-plant use for producing cuttings, tuberlets, and tubers.

The Philippines. In Benguet Province, a survey was conducted as a follow-up to the 1987-88 on-farm trials that introduced new cultivars through apical cuttings. This study assessed the potential for use of apical cuttings, as well as the farmer's acceptance of CIP clones. Of 64 farmer cooperators, 50 grew CIP clones and shared with neighbors. The clones I-1035, P-7, and P-3 were the most popular. The area planted to these clones increased substantially over that planted last year. The clone B71-240.2 (locally named Dalisay) also was widely grown, while the clones I-1035 (released as Montanosa) and I-1039 are becoming important.

The study findings indicate that cuttings are a viable tool for potato production, as demonstrated by high potential yield in farmers' fields. This practice can boost seed production by providing a source of clean planting materials. Tubers produced from these materials can then be used for large-scale production.

Myanmar. Since the variety Up-to-date was introduced in 1914, only a few small quantities of imported seed have been received (all before 1935); UTD continues to be grown from locally produced seed. Studies were begun in 1984 to evaluate the need for a seed program. Using simple selection (positive selection of healthy plants), farmers started to improve their seed stocks. CIP also arranged to import seed tubers from the United Kingdom, and to have the local UTD cleaned of all pathogens at the Plant Research Institute in Australia. Results of trials conducted during the summer season using seed from the UK, from Australian (positively selected), and from local unselected seed, showed that yields did not differ among crops. Yields during that season were less than 20 t/ha for all seed used. For the spring crop, irrigated local seed produced slightly lower yields than did the other seed. In virus testing with ELISA, all seed stocks (including the local seed) were shown to have been positively selected, and imported seed, even after 4 generations, are still totally virus free. Local unselected seed showed low levels of PVX, PVY, and PLRV.

These findings indicate that the Shan Hills of Myanmar are well suited for seed-potato production, and that virus levels remain low and can be eliminated by simple selection techniques.

Case Studies on Seed-Tuber Systems

The Kenya seed-potato system case study was completed as a part of a series that includes the Philippines (Annual Report 1988), Ecuador (Annual Report 1989), Canada, the Netherlands, and the United Kingdom (Annual Report 1988). A comparative report is being prepared. Major findings of the Kenya case are described below.

Potato production in Kenya is dominated by small-holder production dispersed in highland areas that grow a large and changing mix of varieties. Production is mostly market-oriented, and the seed-potato system is dominated by farmers who grow their own supplies. Government participation in certified seed production has received a low level of funding and has been ineffective, providing less than 1% of the total seed needs. Seed production and distribution activities are dispersed among institutions associated with the National Potato Research Station, which initially assumed responsibility for the seed program. The study conclusions note that the research stations are fundamentally service institutions, whose research objectives are to develop and disseminate technical information that can be used in producing potato seed. Thus, this research carries no direct responsibility for efficiently producing potato seed according to farmers' needs.

A private firm has now become interested in producing potato seed efficiently, according to farmer demand, and is planning to promote the use of certified seed.

Sweet Potato

Environmental Effects on Flowering

Experiments were conducted at several locations to determine the basic environmental conditions that promote flowering and seed production of sweet potato. The studies were based on the developmental responses of 150 sweet potato cultivars selected as representative of the CIP germplasm, which included cultivars that flower prolifically, as well as those that had not flowered previously. A wide

Potato seed in market at Mwokora, Burundi.

range of environments was studied over a 12-month period.

The basic field-study findings indicate that the flowering and seed production of a sweet potato cultivar can vary considerably from one location to another or according to the method of cultivation utilized (Fig. 9-4). The response differences suggest that the developmental stages of sweet potato may have a wide range of environmental requirements. The flowering and seed production of sweet potato has also been observed to be affected by an unidentified species of fruit fly that feeds on the anthers, causing up to 100% of the buds to abort. This pest has been found in Lima, Chincha, Cañete, and Tacna, but not at other experimental locations in Peru.

Cultivation Procedures and Flowering

Several cultivation procedures were tested to further define the factors that control the developmental stages of sweet potato. In addition, the developmental responses of standard unrooted sweet potato cuttings were compared with those of potted rooted cuttings, as well as with responses of in vitro-propagated plant material.

Procedures were compared for training the plants onto individual stakes and trellis supports, and for plants growing on the ground, without support. Flowering responses ranged widely among the cultivars compared. For example, training individual plants onto a single stake did not induce non-flowering cultivars to flower; nor did this method increase the flowering of a cultivar, when compared with that of the same cultivar growing on the ground without support.

When plants were grown on individual stakes, the entire bulk of a plant was tied onto one stake, thus limiting light and ventilation in the center of the plant mass.

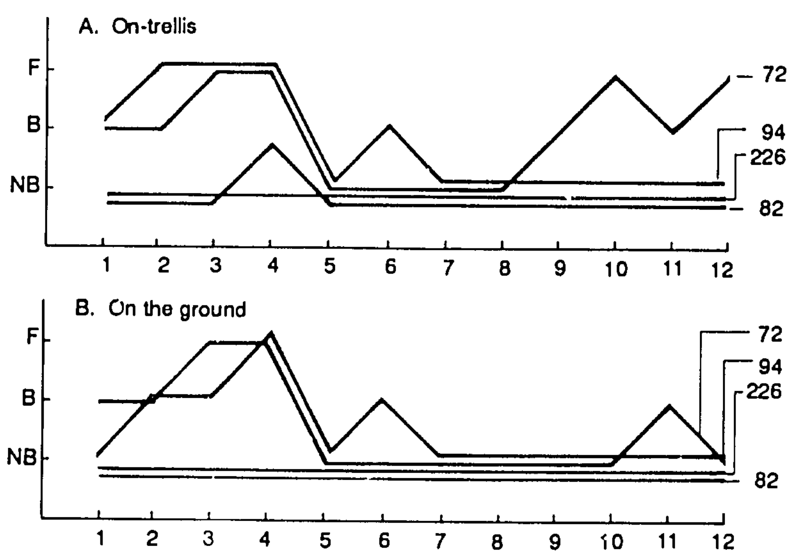


Figure 9-4. Effect of cultivation methods, A) on-trellis; B) on the ground, on flowers (F), buds (B), and no-bud (NB) formation in the sweet potato clones 72, 94, 226, and 82.

On the other hand, training plants onto a trellis (5 plants per 3-meter trellis) induced some non-flowering cultivars to flower and set seed. This method increased the flowering of all flowering cultivars in all of the locations in which the trellis system was tested. Some non-flowering cultivars showed an extreme sensitivity to light quality and quantity, beyond the photoperiod requirement. For instance, cultivar 226 produced flowers only on the portion of the branches along the top of the trellis, whereas no buds or flowers were produced on the portions of branches between the top of the trellis and the ground.

In the Philippines, 12 sweet potato cultivars were grown on stakes or on the ground without support and were evaluated for flowering and fruit set. The cultivars VSP-3, Miracle, and G113.2b were the most prolific in flowering and seed production. The cultivars showed different responses to the two planting methods. In general, the use of stakes enhanced fruit and seed production; however, the degree of influence varied among the cultivars. Cultivars such as Miracle and VSP-3 were slightly affected by the cultivation method, whereas cultivars such as Tipipay, Sinuksuk, and VSP-4 never flowered when grown on the ground.

Sweet Potato Planting Materials

Trials were conducted throughout Peru to compare the growth and development of standard unrooted cuttings, of potted rooted cuttings, and of in vitro-propagated plant material. Plants grown from potted rooted cuttings established more quickly, and grew and flowered more rapidly than those grown from standard unrooted cuttings. However, in general, plants grown from in vitro-propagated plantlets outperformed both standard unrooted cuttings and potted rooted cuttings, in establishment, vigor, rate of growth, flowering, and storage-root yield.

In Kenya, a collaborative project with the Kenyan Agricultural Research Institute (KARI) has begun to develop suitable propagation methods that could increase a multiplication rate that favors the rapid establishment of high-quality, locally-grown sweet potatoes. Initial efforts are primarily at the Katumani National Dryland Farming Research Center. Research will later be expanded to Mtwapa on the coast and Embu in the central region of the country, where sweet potato has shown potential as a crop with tolerance to drought. In arid areas, sweet potato production constraints include the lack of vines to plant at the beginning of the rainy season, thus slowing plant establishment.

Experiments in the Philippines have examined several factors influencing rooting and growth of sweet potato cuttings. Data collected at 30, 60, and 90 days after planting (DAP), indicated that plant survival and growth was enhanced by planting bigger cuttings including apex + 4-nodes, and 4-node cuttings (Table 9-6); storage-root formation was faster and better with these materials. The number of nodes (which is correlated with plant age) also influenced growth. Survival and growth rates were lowest, when the youngest node was used for planting.

In single-node cuttings SNC excised from different segments of 5- to 6-month-old plants, nodes from the middle por-

Table 9-6. The influence of size and origin of sweet potato cuttings on growth on a per-plant basis, at 30 days after planting.

Size of cuttings	Survival (%)	Shoot Length (cm)	Shoot Weight (g)	Root Length (cm)	Root #	Root Weight (mg)
Apex + 2 nodes	50	11	6.5	10.4	5.3	344
Apex + 4 nodes	81	19	12.1	8.9	3.6	1463
1 node (mid-portion)	88	12	6.0	9.9	3.4	358
2 nodes (mid-portion)	91	21	9.5	9.9	5.5	716
4 nodes (mid-portion)	100	19	15.7	10.4	6.9	616
LSD (0.05)		NS	2.7	ns	ns	456

tion showed the fastest shoot and root development, and produced vigorous plants. Shoot tips showed poor initial growth, but had the highest rate of shoot growth at 90 DAP. Nodes from the middle and basal portion produced more storage roots.

Depth of planting did not influence the growth of cuttings; however, at any depth, nodal cuttings grew better than did apical cuttings (Table 9-7).

In another experiment, the potential of SNC as planting material was compared with that of the vine. Single node cuttings were taken from the pathogen-tested mother plants and rooted for 3 weeks prior to planting. The vines were from 5-month-old plants grown in the field, but were initially from single-node plantings. Survival was excellent for both SNC and vines, and yields ranged from 705 g to 970 g/plant for the SNC and 715 g to 925 g/plant for the vines. Single node cuttings produced larger (60 mm) but misshapen roots, whereas vines produced medium-sized roots of normal appearance. Slightly higher yields were obtained with SNCs of all cultivars, especially those of TN-57.

In Peru, samples of sweet potato roots obtained from farmers' fields in two irrigated growing regions on the Coast

Table 9-7. The effect of depth of planting of apical and nodal cuttings on growth, as measured at 30 and 60 days after planting.

Type of cutting/ Planting		Survival (%)	Shoot Length (cm)		Shoot Weight (g)		Root Length (cm)		Root Number		Root Weight (mg)	
			Depth at planting									
		60	30	60	30	60	30	60	30	60	30	60
Apical	Bud exposed	16	6.2	25	2.7	14.2	7.9	22.5	3.5	3.1	22	1912
	Bud buried	19	4.0	10	2.4	6.6	6.0	14.8	2.4	2.7	17	115
Nodal	Bud exposed	84	14.0	28	5.8	10.8	10.9	18.8	6.2	4.7	437	1598
	Bud buried	84	14.5	28	7.6	11.9	11.5	19.0	8.2	4.5	464	1165
LSD (0.05)			ns	7	ns	ns	2.4	ns	2.4	ns	260	ns

(Huaral and Cañete) and from the rainfed area of San Ramon were used for screening *Azospirillum* populations. A total of 26 strains were isolated, 3 having a high nitrogen-fixing capacity as shown in the corresponding laboratory tests. When these selected strains were used in controlled inoculation of potted sweet potato plants of cultivars Jonathan and Paramutai, a two-fold increase in foliage fresh weight was observed in the Jonathan cultivar, when fertilized with 80 ppm N, without inoculant, whereas Paramutai showed a three-fold increase with the same fertilizer application, but was inoculated with the bacteria. The N content of the Paramutai plants increased four-fold when inoculated. The addition of *Azospirillum* was favorable to root yields in both cultivars grown in San Ramon, producing double the yields of those of the control pots.

Sweet potato germplasm collection at VISCA, Leyte, Philippines.

National program and CIP researchers discuss sweet potato consumption with a farm family in Peru

Thrust X

Food Systems Research

Thrust Profile: 1990

The client's or user's perspective is a fundamental concept built into Thrust X food-system work to help guide both national and international research. This perspective helps 1) assess the concrete needs and demands of the final "users" of technology: small farmers, low-income consumers, processors, and other participants in the food systems of developing countries and 2) provide field-based information for decision-makers and researchers in national potato and sweet potato programs and in other public and/or private institutions. It is a demand-driven, bottom-up alternative to the top-down, supply-driven model of conventional "technology transfer."

In the words of the formal goal statement, the approach is designed to "expand the knowledge of agricultural programs and policies and the production, marketing, and use of potatoes and sweet potatoes." The objectives are to aid in the identification of clients' needs and priorities, the generation and diffusion of appropriate technologies, and the assessment of program results and policies.

The "expansion of knowledge" referred to in this formal goal statement is achieved through hands-on needs and impact assessment and through strengthening the research capacity of National Agricultural Research Systems (NARS).

Research on needs and impact assessment is being conducted within three important fields of research: food-system characterizations; marketing, demand, and utilization studies; and impact assessment.

Work on food-system characterization progressed well during 1989, as national scientists completed surveys and analyses of constraints to potato and sweet potato production and use for five major agroecological zones. Potato-seed problems appear to cut across the different zones, but are particularly serious in tropical rainy and dry areas. The importance of the weevil as a constraint in sweet potato production is limited to tropical rainy zones. In other zones, planting material, lack of moisture, and soil fertility figure as production problems. In all zones, postharvest constraints are severe, especially in marketing.

Case studies of potato and sweet potato in food systems were completed in Asia, Africa, and Latin America. Continuing studies in China helped to deepen knowledge of the diverse utilization patterns in different provinces. This knowledge will be used to broaden the use of the crops in other countries. In India, a survey of sweet potato researchers identified the sweet potato weevil as the major production problem, but postharvest issues were of most concern. Informal interviewing in Kenya, Uganda, and Rwanda laid the groundwork for priority-setting by national programs, and for the organization of a formal survey in Kenya. Early results of structured informal surveys in four countries of Latin America point to distribution patterns as the key variable differentiating sweet potato systems.

The principal research on marketing was developed through a sabbatical leave project that synthesized six potato-marketing case studies completed over the past six years. Preliminary conclusions note the geographic concentration of potato production in Asia and the importance of rural marketing and rural consumption in south Asia and sub-Saharan Africa, versus urban marketing in Latin America. Two studies of sweet potato marketing were conducted in Latin American cities; the findings highlight the importance of root and flesh color, and other aspects of presentation for urban markets.

In preparation for CIP's Third External Review, the 1984 impact study *Potatoes for the Developing World* was updated using responses to new questionnaires from national program leaders and CIP senior headquarter staff and regional leaders. Results showed the growth in national program research in areas related to CIP research. Training was felt to have had the greatest impact on NARS, followed by a number of production technologies, especially related to seed. There was a much lower level of perceived benefit from non-technical and non-production activities, perhaps due, in part, to the solid production orientation of most program leaders.

As part of interdisciplinary technology development, social scientists were involved in the study of TPS in farmers' fields in India and Indonesia. Results from India show that seedling tubers have lower net costs than seed tubers. In research involving farmer evaluation of TPS in Indonesia, farmers identified a few appropriate methods for using TPS and are now assessing them.

Thrust activities are closely associated with two food-system networks. The PRACIPA marketing network completed two years of activities in March 1989, and backstopping continues via workshops and annual meetings. In Southeast Asia, the Users' Perspective with Agricultural Research and Development (UPWARD) began activities with 12 projects focused on production, postharvest, or consumption issues, within a food-system context.

In addition to participation in formal courses and workshops, strengthening of NARS' capacity also has been achieved through collaborative research activities with a strong "training with research" component; these include the diagnostic studies of sweet potato in food systems completed or being planned in Latin America and Africa.

Food Systems Characterization

Assessment of Production and Use Constraints, by Climatic Region

Knowledge of the constraints to potato and sweet potato production and use in major production zones and food systems is essential in helping set appropriate research priorities, target regional efforts, and extrapolate location-specific research results.

National researchers answered questionnaires on the relative importance of several potential constraints to potato and sweet potato production and use at different sites in their own countries. The potential constraints ranged from pre-planting and field-production problems, to marketing costs and limited demand.

Because constraints are generally related to ecological conditions that cut across political or administrative units, averaged findings for countries or CIP regions can be misleading. Thus, the data have been analyzed for major world climates using Koppen's classification of five major climatic zones on the basis of temperature and moisture combinations. Constraints are also influenced by other variables apart from climate, but in the absence of detailed global information on these variables, Koppen's classification of climates provides a useful preliminary scheme. Results are presented for five major climate zones:

- Tropical rainy climates with no cool season (A climates in the Koppen system)
- Dry climates (B climates)
- Mid-latitude rainy climates with mild winters (C climates)
- Mid-latitude rainy climates with severe winters (D climates)
- Cold climates with no warm season (E climates)

A more refined analysis of constraints is in progress to define 12 climatic types, including altitude as one of the criteria.

Potato and sweet potato production areas. For both potato and sweet potato about one-half of the sites for which national researchers provided information have mid-latitude, rainy climates with mild winters (C climates). Consequently,

Boxes of potatoes ready for export. Guangdong Province, China.

given the large number and expertise of the survey respondents, it seems likely that C climates are the most typical for both potato and sweet potato production in developing countries. The tropical rainy (A) climate was the second-ranked for both crops; accounting for about two-fifths of the sweet potato sites and one-third of the potato sites covered by the survey. Between 10% and 15% of the sites for both crops have dry (B) climates, and less than 10% have climates with severe winters or no warm season (D or E climates) (Table 10-1).

According to national researchers, potatoes usually are produced for sale to urban areas, and are usually eaten by people with relatively high incomes. In contrast, sweet potatoes generally are grown for household use in rural areas, and in urban areas, are usually eaten by lower-income families (Table 10-2). There are important exceptions for both crops, however. In most dry areas (B climates) and in the cooler northern areas (D climates) of China, sweet potatoes are grown primarily for sale. And in many cool, rainy areas (C climates), particularly in the mountains, potatoes are grown primarily for home consumption (Table 10-3).

Potato constraints by zones. In tropical rainy zones (A climates), the principal constraints are considered to be the high cost and poor quality of seed, high production costs, transport problems, handling losses, unstable prices, late blight, and drought.

In dry zones, scarcities and poor quality of seed are considered to be serious constraints, particularly as related to storage. Insects and late blight cause important losses in the field, and consumer potato storage also is a major problem in the dry zones.

Many mid-latitude rainy zones (C climates) are traditional potato-growing areas. Perhaps because potatoes have been grown for such a long time, many pests and diseases attack the crop. Researchers consider fungal and virus diseases and several seed-related problems to be especially critical.

Sweet potato constraints by zones. The sweet potato weevil (*Cylas formicarius*) is

Table 10-1. Number of production sites[a] by climate and altitude.

Climates[b]	Potato: Below 1,000 m	Potato: Above 1,000 m	Sweet potato: Below 1,000 m	Sweet potato: Above 1,000 m
Tropical rainy (A)	19	22	53	14
Dry (B)	7	11	14	3
Moderate rainy, cool winters (C)	25	35	69	18
Moderate rainy, cold winters (D)	2	1	5	0
Cold (E)	1	4	0	0
All sites	54	73	141	35

[a] Numbers of sites with information vary among tables.
[b] Based on Koppen's classification of climates, presented in Trewartgam G.L. and L.H. Horn. *An Introduction to Climate.* McGraw-Hill: New York, 1980.

Table 10-2. Income level of potato and sweet potato consumers.

Climates	Potato consumers		Sweet potato consumers	
	Low income	Middle & high income	Low income	Middle & high income
A	7	30	47	17
B	1	17	9	6
C	16	51	60	29
D	0	0	4	1
All sites	24	98	120	53

considered to be the most important constraint to sweet potato production and use in tropical rainy areas, where lack of processed products, price instability, transport problems, drought, and low-fertility soil are also major constraints.

In dry areas, the major problems are unstable supplies and prices, handling losses, weeds, and the poor quality of planting material.

In mid-latitude rainy zones, researchers have found the principal constraints to be low-fertility soil, lack of moisture, storage diseases, unstable prices, and lack of processed products.

In the cool, rainy zones of northern China, the principal problems cited are lack of moisture, low-fertility soil, salinity, marketing problems, and the lack of a variety with good qualities for fresh consumption.

Agroecological Studies of Potato

During 1989, country profiles were completed for all developing countries and maps of zones are being refined. To more precisely identify the climate characteristics of each production zone, the Koppen classification is being overlayed on these maps. The potato zones are being refined by a geographer at Clark University (USA) and details of the spatial distribution are being reviewed carefully. The European Potato Research Association has agreed to provide summaries on potato production and utilization in Europe in the form of a book, entitled *World Geography of the Potato*, which is now being prepared and will be submitted for publication in 1990.

Table 10-3. Principal final destinations of potatoes and sweet potatoes (number of sites).

Climates	Potatoes		Sweet potatoes	
	Urban areas	Rural areas[a]	Urban areas	Rural areas[a]
A	30	11	9	50
B	16	2	7	10
C	25	42	16	66
D	0	0	2	3
All sites	71	55	34	129

[a] Includes both rural and urban areas.

China. Of total developing-country production, China grows over 50% of the potatoes and over 80% of the sweet potatoes. Because of the importance of this production, an agreement was made with the International Food Policy Research Institute (IFPRI) to study both crops in Chinese food systems, to identify Chinese research needs, and to explore the opportunities for horizontal transfer of technologies to other developing countries. Provincial and local investigations of potato and sweet potato utilization patterns begun in late 1988 were completed in Hebei, Shanxi, Shaanxi, Heilongjiang, and Inner Mongolia. Data are now being collected in Henan, Anhui, Hubei, Hunan, Guizhou, and Sichuan and these findings should complete the description of all major potato- and sweet potato-cultivating provinces in China.

A key initial observation is that production practices and uses of both potatoes and sweet potatoes are widely diverse, and potentials vary substantially among the regions and sub-regions of China. Further studies are needed to understand the different roles these crops can play, especially the industrial use of sweet potato, so as to determine the potential for use in other developing countries. Similarly, China might benefit from international experience with food processing of potatoes.

Both potatoes and sweet potatoes are important staple foods for millions of Chinese and are likely to remain so for decades. In some localities, production accounts for more than 80% of direct staple-crop consumption. But use of the 2 crops as staples varies considerably, from less than 1% in some localities to almost 100% in others. Potato and sweet potato use as animal feed (especially sweet potatoes), and as processed food, industrial material, and export product is expanding in several areas in China, with growth potential for both crops.

A special study was made in Yunnan Province, where roughly 80% of the potatoes are of the East German variety Mira, which was introduced into Yunnan in the early 1960s. This variety originally had some late-blight resistance, but was very susceptible to virus. White potatoes in northwest Yunnan, which is one of the poorest areas of China, are generally of low quality and of small size. A high-altitude potato improvement base in the region might be an attractive project to increase the nutritional and income levels of the population.

Observations in northwest Yunnan also provide strong evidence, matching that gained from local investigations in north China, that the traditional statistical reporting system may be substantially underestimating white-potato cultivation in China's mountainous areas.

India. Official statistics provide little information on sweet potato; thus there is a strong need to collect primary data.

A survey conducted by scientists and technicians working at experimental stations in sweet potato areas indicated that sweet potato is grown as a minor crop throughout India, usually on plots of less than one quarter ha. In general, the crop is rainfed, with only rare supplemental irrigation. The main planting season coincides with the onset of the monsoons, and rice-sweet potato seems to be the most common rotation. Most roots are consumed boiled or fried as snack foods or vegetables, and in some areas the leaves are also eaten as greens. Most of the vines and some culled roots are fed to livestock.

Local markets are the main commercial outlets and farmers generally bring their produce directly from the fields. In major producing areas, agents also are involved in crop marketing.

According to the scientists, the principal constraints to production and use of sweet potato are related to marketing problems and limited demand. They cited the instability of supplies and prices, unacceptability of varieties, poor presentation of the merchandise, lack of adequate transportation, and use of late-maturing varieties as the major marketing limitations. Lack of diversification of the product and the lack of a tradition of sweet potato in the diet were the major demand factors identified. The sweet potato weevil (*Cylas*) was considered to be a serious production problem. Of the abiotic stresses, drought was considered the most serious problem. In some areas, scarcity of planting material is a major constraint. Nematodes, viruses, fungi, and bacteria were not considered to be important problems.

Indonesia. Potato and sweet potato are important crops for Indonesia, where the potato is generally grown as a cash crop and has high export potential; sweet potato is one of the most important Indonesian subsistence crops, and is sold as a low-cost carbohydrate food throughout the country. Until recently, national research focused on potato cultivation in cooler, upland areas, while the role of the sweet potato was generally overlooked.

A special project was begun in 1987 to characterize the food system and develop technology, working primarily with the Agency for Agricultural Research and Development (AARD).

Indonesian and CIP scientists collaborated on two interdisciplinary, rapid-appraisal rural research projects in Java and in West Sumatra, in the areas of highest commercial production. Three shorter surveys were conducted throughout Java to examine the existing market for sweet potato and to collect sweet potato germplasm and identify farmer-based characterization of sweet potato cultivars. Provincial time-series data were collected on sweet potato yields and production areas in Indonesia.

The rapid-appraisal surveys in rural Java show that farmers seek new sweet potato cultivars that mature quickly, can be intercropped, grow well in the wet season, are high-yielding, and whose color and taste qualities make them easily marketable. Deterioration during transport is a problem. Insects, diseases, period of home storage, weeds, flavor, quality, and marketability of local cultivars were not considered to be major constraints. Yields in fields ranged from 10 t/ha (with no fertilizers, weeding or care) to 22 t/ha (with fertilizers and weed control).

In West Sumatra, the farmers' primary problem is growing sweet potato in the wet season, when yields are said to be lower and sweet potato skins darken, making them unattractive, and prices for lower quality roots are reduced by as much as 50%. The sample yields in March were very high, and 3 villages had yields of over 30 t/ha. Farmers have developed methods to use animal labor for harvesting, and they now grow cultivars that mature in 4 months at 700 masl, which may be adaptable to conditions in Java. The Central Research Institute for

Food Crops (CRIFC) is preparing to publish these results, as well as the findings of the marketing, cultivar, and collection surveys.

These surveys help to identify new directions for CRIFC Bagor Research Institute for Food Crops (BORIF) research as Indonesian sweet potato breeding in the past has tended to emphasize high yields with little consideration given to other factors, and previous introductions of improved varieties have met with little success.

The database on sweet potato cultivar selection, production, marketing, consumption/sale, and processing in Java is quite extensive, providing an example and a framework for further studies in Indonesia.

Food Systems of East and Central Africa

Initial work has focused on defining the scope and priorities for research, through collaborative links with national researchers and with The International Institute of Tropical Agriculture (IITA) personnel.

Workshops and training activities conducted as part of the development of a research program in Kenya have helped tighten the dispersed sweet potato research of the Kenyan Agricultural Research Institute (KARI) into a more user-oriented program.

Farmers in the major production zones were surveyed informally and available statistics and the results of previous research were reviewed.

Several production regions are now being formally surveyed and these findings will provide a cross-section of the roles of sweet potato in different rural food systems.

A fundamental reorganization of research is under way in Uganda, the most important sweet potato-producing country in Africa. Based on preliminary interviews with users and pooling of local technical knowledge, priorities were set and a potential work plan developed, including interdisciplinary socioeconomic surveys. The team has surveyed one district, and results are being analyzed.

Food Systems of Latin America and the Caribbean

Work on sweet potato in food systems of Latin America began in 1988 with a diagnostic survey of sweet potato production and use in the Cañete Valley in Peru. The full report has now been extensively revised and the final publication is in press.

During 1989, diagnostic surveys were conducted in Argentina, Uruguay, and in northern Peru. All were prepared via small interdisciplinary, collaborative workshops involving national research and extension personnel and CIP scientists. The early stages of field work in Argentina and Uruguay involved social science support from CIP, but national program staff did the bulk of the interviewing. In Peru, personnel from CIP and INIAA took part in all field work and a joint workshop was held shortly after completion of fieldwork to analyze results and to define the framework for the reports. These reports are now being processed.

Peru. Two initial studies have reported different roles for sweet potato in different food systems. Production on the dry irrigated coast is highly commercialized and largely determined by the metropolitan market of Lima. In contrast, production in the northern hills is largely subsistence-oriented, with systems including kitchen gardens, intercropping, border and short-cycle rotation; marketing in the hill area is local, sporadic, and small-scale. Sweet potato is eaten as a regular co-staple.

The differences in the two areas are reflected in variety use. On the coast, only a few varieties are acceptable in Lima, so there is great uniformity in the varieties grown at any given time in the Cañete Valley, which supplies the Lima market. Many varieties are tested as farmers look for the most commercial types, but few are selected. On the other hand, in the northern hills, many varieties are grown at any given time, because no single market imposes characteristics. There is also less change in varieties over time, because there is less pressure to select or reject.

Argentina and Uruguay. In Argentina, most production is highly commercial and extensive, especially in Buenos Aires and Cordoba, where average area planted to sweet potato is 21 ha and 32 ha, respectively. Innovative locally designed machinery and a well-developed marketing system are used in the washing and special sacking of the roots.

One of the major problems identified for future work is the narrow genetic base available to commercial regions, despite a wealth of genetic material in the north of the country. This situation is similar to that of Peru, and raises the issue of how to exploit national germplasm resources. Other problems identified include the special technical requirements and associated problems of the temperate zone, especially the need for seedbeds, with their high costs and phytopathological

Sweet potato market in Kampala, Uganda.

problems, as well as the need to store the crop.

Smaller-scale, subsistence production is found in the northern region of Tucuman, however, with some selling to local fairs and markets. The situation is similar to that in northern Uruguay, where the foliage also is used for animals. Although less sophisticated than the Buenos Aires system, the Southern Uruguay system is also a metropolitan system in which many small farmers supply fresh roots to intermediaries of the Montevideo wholesale market.

Paraguay. A survey was conducted to characterize the production stages, commercialization, and industrialization of the sweet potato in Paraguay. The socioeconomic importance of the sweet potato in relation to other crops was analyzed both for commercial farmers and an indigenous group in the southern region. Interviews conducted with farmers, commercial agents, agronomists, and processors of sweet potato and the findings of a bibliographic review indicated a limited expansion of sweet potato cultivation in comparison with other crops, as well as diminishing yield trends. Problems encountered include low levels of production technology, lack of quality varieties, limited commercial access to the market, the displacement of sweet potato by foreign products in the diet, and limited processing of the roots into alternative food products. The study indicated the need to activate programs to improve the technical and financial assistance currently available to sweet potato producers and processors. Educational programs also are needed to promote the consumption of this underexploited source of nutrition.

These preliminary results from Latin America depict a crop that, on the one hand, is commercially produced to satisfy a clear demand niche in major population centers and, on the other hand, is a co-staple or special-use subsistence crop, with small-scale marketing potential.

Marketing, Demand, and Utilization

Potato Marketing

A substantive synthesis and analysis was developed based on case studies of potato marketing already conducted and published in Bangladesh, Bhutan, Burundi, Rwanda, Zaire, Madagascar, Peru, and Thailand. Preliminary results of this synthesis emphasize:

- the geographic concentration of potato production in Asia, and the disparate evolution of output and yields in Latin America, Africa, and Asia.
- the shifting importance of potato production by agroecological zones, e.g. rising output in the lowlands of southern Asia due to changes in production and postharvest technology, demographic trends, and shifts in relative prices.
- the importance of rural marketing and consumption in sub-Saharan Africa and southern Asia versus urban markets in Latin America.

A study of demand for processed potato products in New Delhi showed that 15 different processed potato products are sold at a wide range of outlets, from confectionery shops to street vendors. Products are differentiated on the basis of form (chip, crisp, strip), packaging (fancy, plain, none), weight (25 gr to 250 gr) and price. The most expensive products were potato crisps in "fancy" packages, but most sales consist of dried chips (nearly 50%) and potato chips (16%).

Most processed products were sold at confectionery, general, and provision stores. Venders as well as juice and tea shops also sell processed potatoes.

The major buyers of all types of processed products come from middle-income groups (57%), with high-income groups purchasing exclusive, "fancy" products (23%). Just 4% of retailers sold only to low-income groups. Females and children are more frequent customers than are men.

From the retailer's point of view, the principal constraints to expanded sale of processed products are price, packaging and the need for greater advertising.

Sweet Potato Marketing

At Lima, Peru, a Master's thesis on the wholesale demand for sweet potatoes showed that, although national sweet potato production fell from 167 thousand tons in 1971 to about 123 thousand tons in 1987, sweet potato shipments to Lima almost doubled, from 47 thousand tons in 1971 to nearly 74 thousand tons in the first 10 months of 1988. About 70% of this total consists of yellow-flesh varieties, while 30% have purple flesh; however, shipments of purple-flesh varieties have increased much more rapidly since 1972. The largest concentration of output has shifted from the northern coast and highlands (which had 45% of annual output in 1944 versus 18% today) to the central coast, in particular the Cañete Valley. The demand has been met through increasing area, doubling yields (through a small but successful breeding program), and the break-up of the cooperatives that favored small-scale, intensive agricultural production. The bulk of production in Cañete is sold through local assemblers, who are in charge of grading, bagging, loading, and transport to the wholesale market in Lima.

Estimates of sweet potato consumption, based on household surveys, indicated a range between 6.5 kg/yr in 1971-72 and 13.6 kg/yr (for low-income families) in 1979. Consumption (and availability) of sweet potatoes, as reflected in marketing data, is much higher: about 20% of the sweet potatoes shipped to Lima are re-shipped to northern locations, and an apparently substantial, but unknown, percentage of the total quantity is used in Lima to feed household pets. Sweet potatoes represent about 4% of the total calories consumed in Lima on an average daily basis (1977-1980).

Sweet potatoes are now also used for processing. One researcher's thesis suggests that if 5% of the wheat flour used to make bread were to be replaced by a sweet potato product, the total demand would require doubling of current national sweet potato production.

A study of sweet potato marketing in the central market of Buenos Aires, Argentina indicated that 86% of sweet potato supplies to the market now come from the provinces of Buenos Aires and Cordoba. Santiago del Estero, which was previously an important supplier to the capital, now accounts for only 11%.

The first phase of this two-stage study describes a highly sophisticated marketing system involving the machine washing and special sacking of sweet potatoes.

These findings highlight the importance of color and presentation of the product in the market, and show wide fluctuations in prices depending on the time of marketing. These factors underline the need for breeding efforts to take careful note of marketing requirements and consumer preference.

Sweet Potato Utilization

A book on sweet potato consumption and nutrition is nearing completion, which will serve as a comprehensive review of secondary sources on the nutritive components of both the fleshy storage roots and the green tops. This review examines current worldwide uses of the crop, including uses as a tropical spinach or salad green, staple food, animal feed, starch source, industrial raw material, dessert, processed convenience product, fast food, snack, multipurpose flour, and alcoholic or non-alcoholic drink.

The Impact of CIP Technology

The 1984 impact study *Potatoes for the developing world* was updated in preparation for CIP's Third External Review. Sources of information for the update included results of an "impact questionnaire" filled out by CIP regional leaders in 1984, with an updated version filled out in 1989; a similar questionnaire completed by national program leaders between 1987 and 1989, and written responses of thrust managers, department heads and regional leaders to five open-ended questions about the major achievements, impacts, and constraints of their programs.

Figure 10-1 shows the growth in national-program research related to CIP

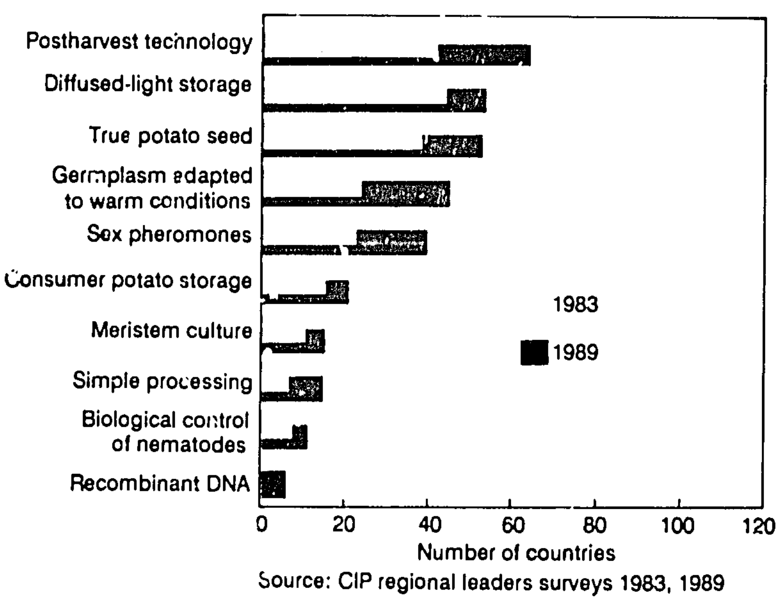


Figure 10-1. NARS research in progress.

research, which can be used to analyze effectiveness of the way research priorities are identified through collaboration between CIP and national programs. The rapid growth in the number of countries screening materials for adaptation to warm conditions probably reflects both CIP's increasing adapted populations and the growing interest of national programs in cultivating potatoes in warm and hot areas. A similar analysis can be made of the increase in use of sex pheromones and TPS. The lower levels of activities for the other research areas might indicate either a problem of regional rather than global importance (nematodes), or a relatively new area of research activity for CIP (consumer potato storage).

National program leaders were asked how their institutional or research activities have benefited as a result of collaboration with CIP (Figs. 10-2 and 10-3). Institutional benefits that were considered especially valuable included training, links with other programs, improved capacity for planning, and management of research. These improved capacities stem from regional courses in which scientists from various countries are brought together and asked to prepare research plans as a routine part of course activities.

The responses of program leaders to questions relating to increased capacity to conduct certain activities (Fig. 10-3) indicated that CIP's train-the-trainer philosophy, using experienced former students as instructors for CIP courses, has paid great dividends. Seed technologies, ranging from seed storage to rapid-multiplication techniques, also were rated as highly beneficial. Several important factors may be reflected in the low level of perceived benefits in a range of non-technical and non-production ac-

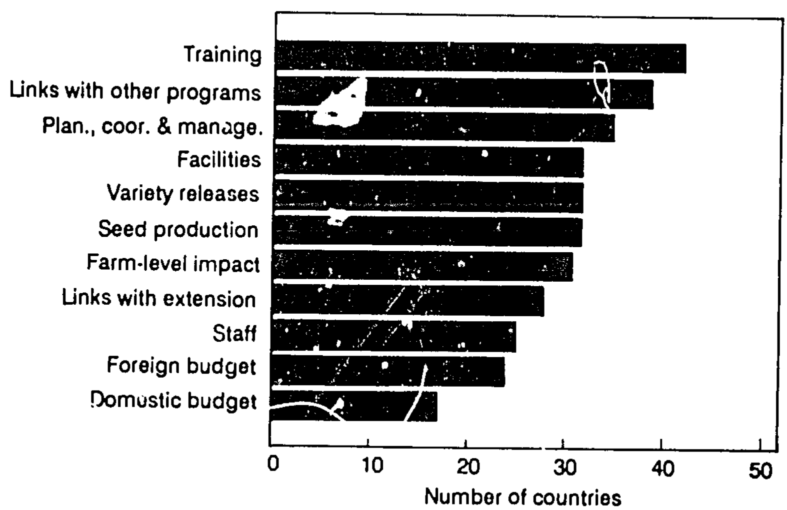


Figure 10-2. Number of countries reporting specific institutional benefits due to collaboration with CIP.

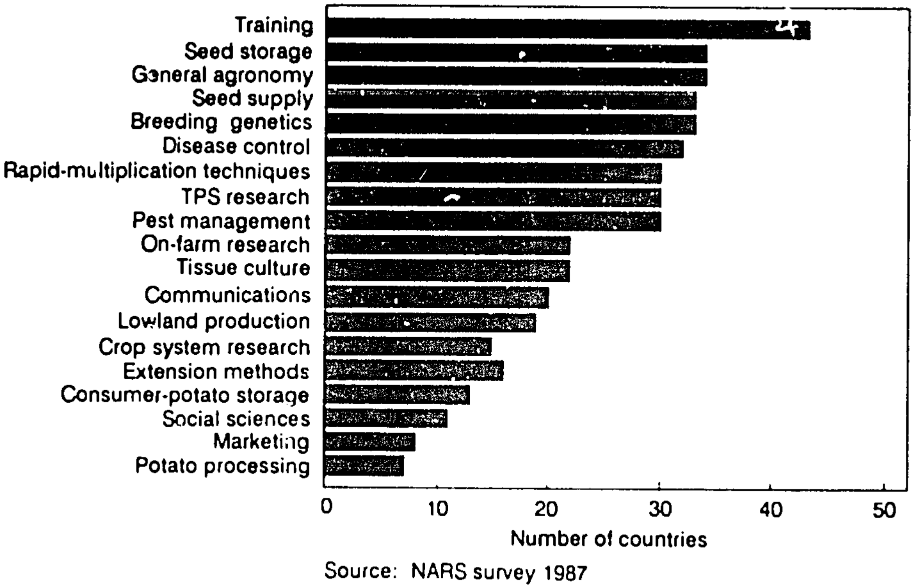


Figure 10-3. Number of countries reporting increased capacity in specific areas due to collaboration with CIP.

tivities. For example, program leaders are drawn from the ranks of biological scientists and are trained primarily to identify and resolve problems in these disciplines. The social sciences usually are not represented in national agricultural programs, but often are located in other sectors of the ministry or in universities; therefore, the questionnaire respondents may be less aware of achievements in these areas.

Figure 10-4 depicts the greater national program capacity to improve the welfare of farmers. Given the mixed view of outsiders' opinions on whether national programs have improved links with extension services (Fig. 10-2), and the improvement in extension methods as perceived within the national programs, (Fig. 10-3), it is not surprising that national program leaders feel that most of the benefits to farmers have been in the form of technologies (e.g. improved seed) that are delivered directly to the farmers by the research program.

These are tentative results, as CIP is now placing a top priority on the review of impact assessment methodologies to establish a fully institutionalized impact-assessment process.

Socioeconomic Aspects of Technology Development: Cost of Potato Production Using TPS

India. An evaluation was made of agro-ecological characteristics and socioeconomic conditions of the three areas in India where TPS work is under way, and an assessment was made of the participation of farmers in TPS trials.

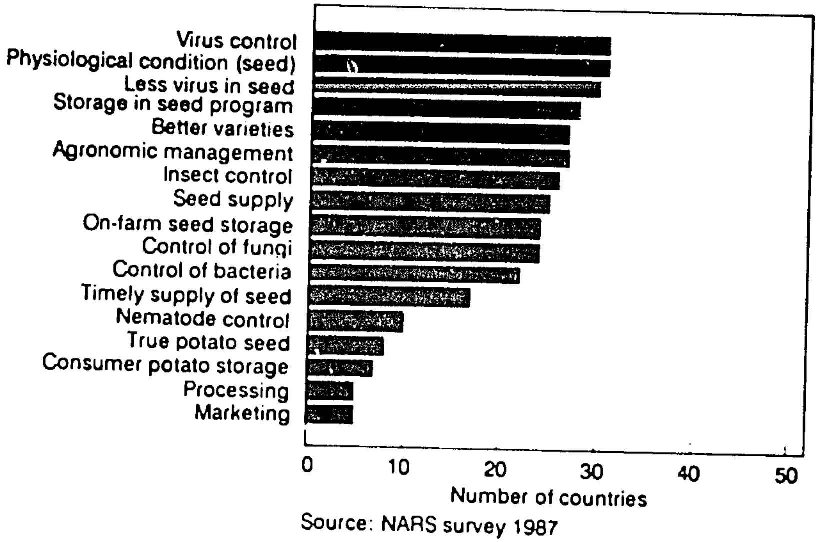


Figure 10-4. Number of countries reporting benefits to farmers in specific areas due to collaboration with CIP.

Producers, with medium to large farms, who cultivate wheat, sugar cane, and potato in Modipuram in the northern plains, successfully tested TPS for seedling tuber production.

In Deesa, in the arid western plains, where the cooperators are large-scale farmers and almost exclusively potato producers, the trials generally were not successful, as the cooperators were unhappy managing the small trial plots. These findings suggest that the experiments should continue with small farmers in this area.

Farmers in Tripura, in the humid northeast, have major problems obtaining seed tubers. Thus, TPS should have great potential. Farmers are mostly small-scale, and many have only rudimentary irrigation facilities. Potatoes are their major crop, and they are not familiar with transplanting techniques. These factors combined with heavy rains after one or two days of sowing created problems in some of the experiments. In both on-station and on-farm trials, costs were calculated for use of F1C1 seedling tubers of HPS-1/13 as compared to costs of using seed tubers of a local cultivar (Kufri Bahar or Kufri Jyoti). In all trials, net costs were less for the seedling tubers. However, in further trials at Modipuram, F1C2 and F1C3 seedling tubers showed higher costs per ton than did seed tubers, due to reduced yields. However, these comparisons were of large-size seed; thus further research should be made of the cost of small-sized F1C2 and F1C3 seedling tubers.

Indonesia. An interdisciplinary team of national (LEHRI) and CIP scientists has been working in collaboration with farmers to develop and refine techniques for the production of ware potatoes and seed tubers from true potato seed (TPS). Farmers formulate their own research, assess results, refine techniques, and proceed with new experiments. LEHRI-CIP researchers primarily document and discuss farmer-formulated trials and their results with the farmers, using an unstructured group format.

Whether farmers carry out research as individuals or as a family "team" within a larger group, they constantly compare, assess, and experiment with their own techniques for TPS cultivation, tuber production, and sale. They reformulate their trials based on their own findings, as well as those of their fellow farmers. With a new technology such as TPS, farmers experiment with techniques used successfully for other crops, modifying them to fit TPS and their agronomic requirements. In early trials, farmers narrowed their choice of techniques to a few promising methods, and experiments in following seasons served to refine these techniques. Farmers' TPS yields have equaled or surpassed yields from seed tubers. This project has been expanded to a second area in Majalengka, West Java, where the Indonesian agricultural research and extension service (Dinas Pertanian) is actively participating in CIP-LEHRI visits to farmers and their fields. The extension service also is in the process of introducing TPS to one large farmer and an additional cooperative group of small farmers. LEHRI plans to host a training session for extensionists, farmers, and scientists on flexible TPS technology transfer.

Strengthening Capacity of NARS

UPWARD Project

UPWARD (Users' Perspective with Agricultural Research and Development) was established in 1989 and is the first research network to stress the role of food systems in the development of appropriate potato and sweet potato production in Southeast Asia. The network will focus on the "users" of agricultural technology and knowledge, with a specific emphasis on the role of the household as a unit for production, consumption, distribution, and use. One of the key objectives is to train young developing-country researchers from the social sciences and non-traditional agricultural sciences (nutrition, marketing, home economics) as members of national program teams, which in the past have usually emphasized only technical aspects of production.

Twelve projects were started or launched during the year in three countries: Thailand, Indonesia, and the Philippines.

Thailand. Projects concentrated on sweet potato production and household utilization. Sweet potato, like potato, is a supplemental vegetable and little research information is available on its production and use. Since concentrations of production vary greatly, a decision was made to study 13 areas representative of high and low production zones. Examples are Ratchaburi, near Bangkok, with over 800 ha of production, and Chiang Mai, with less than 100 ha. In initial research, Thai food habits were shown to vary widely in consumption of sweet potato. Popular sweet potato preparations include steamed sweet potato, sweet potato in coconut syrup, sliced sweet potato sweets (Mun Rang Nok), fried sweet potato balls (Kai Nok Krata), sweet potato with ginger in syrup, and fried sweet potato. Sweet potato also is used in many curries. Preparation and simple processing of sweet potatoes are household activities. Thailand's projects are conducted by the Field Crop Section, Crop Promotion Division, Department of Agricultural Extension, Bangkok, and the Department of Agricultural Extension, Farm Home Improvement Subdivision.

Indonesia. The projects in this country are more diverse. One project led by LEHRI conducted a follow-up of the technologies that had been developed by the experiment station. The study was highly interdisciplinary and focused on the main technical areas: varieties, postharvest, seed, and agronomy. The team spent a week to 10 days in different areas looking at how the "end-user" had utilized the results of the experiment station. Findings indicated major constraints in the flow of information from experiment station to farmers, because of the large number of agencies that handle the information. This slower flow was in contrast to the more direct flow of information from private companies.

Visits were made to commercial and household processing units in another Indonesian study that investigated the processing of sweet potato in Java, which has received little research attention. A project to assess farmers' knowledge and to collect germplasm of sweet potato in Irian Java was formulated, but no research has been initiated.

The Philippines. UPWARD co-sponsored the first national socioeconomic seminar and workshop on rootcrops ("Enhancing Social Relevance in Root-Crop R&D"). Research on sweet potato progressed well in the mountain provinces, as well as in the lowlands. Sweet

Sweet potato, rice, banana, and other crops being grown on rice terraces in Indonesia.

potato is known to be the most widely cultivated root crop in the Philippines, with over 7,000 hectares planted. In the highlands, it is a staple food crop, particularly among the tribal groups. Cultivation practices and varieties differ among ethnic tribes. Detailed reports on this research are now being prepared. Other studies will concentrate on marketing in Baguio and household gardens.

PRACIPA Project

The marketing project of PRACIPA (Programa Andino Cooperativo de Investigación en Papa) completed its second year of activities in 1989; some of the research results are listed below.

Bolivia. The survey of the "formal" distribution of seed by 12 institutions continued in the Cochabamba region, where two institutions now handle 70% of such seed. Assessment of farmers' opinions of the existing seed is also continuing. A preliminary report has been prepared, which described the "informal" distribution system through local fairs. The IBTA/CIP special project added another scientist who has continued his seed research from within the project. The results of this work are being used by the special IBTA/CIP project and a sister project to design an adequate seed distribution system.

Colombia. In the second year of this project, work on simple potato processing has focused on the feasibility of using dehydrated potatoes or potato flour as feed for guinea pigs. Continued good prices for fresh potatoes in the Pasto-Ipiales region have suggested further study of the viability of this alternative, to supplement the limited amount of information available on the technical aspects of this type of processing and its economic returns. Estimates of the cost of production for simple processing in Pamplona have been made, but must be adjusted to account for the actual time and resources spent.

Ecuador. In a stratified sample multipliers, users, and non-users of improved seed, were interviewed in the northern and southern regions of the country. The results indicate that 1) seed multipliers in the north produce seed for their own use and for sale; there are no seed multipliers located in the southern region; and 2) in the northern region, 53% of the non-users reported that they did not know where to buy improved seed, whereas in the south, over half of those interviewed had no knowledge that such seed existed. These results confirm the previous year's findings that suggested the need to reassess the distribution system used for improved seed. The problem of the lack of information available to growers regarding types, local price, and timing of availability of seed, deserves special attention. A collaborative project is planning an extension of the information system for seed.

Peru. The preparation and dissemination of bulletins about potato production and marketing have continued in the central region, and a total of 27 bulletins have been printed and distributed over the last two years. The format of the bulletin has been expanded to include information about production and marketing, as well as credit, costs of production, and fertilizer prices. The database set up as part of this project also has been utilized to generate projections for potato prices in Lima. Work on marketing of seed potatoes and processed potato products

Family sorting seedling tubers, Indonesia.

in the central highlands is nearing completion.

Venezuela. Marketing research in the Merida region of the country consisted primarily of a formal survey administered to potato producers. Key survey findings reflect the highly commercial production orientation (76% of the harvest is sold), the use of "white" varieties for the market and "black" varieties for on-farm consumption, and the tendency to sell to local rural assemblers and at the farm gate. Farmers generally reported that they had to accept the prices that they were offered because they lacked the information, financial resources (or credit), storage facilities, and access to the services of a producer organization to market them directly.

Training

An increasing number of general production courses for both potato and sweet potato include a socioeconomic or food-system component. This type of formal training was given in courses in Chile, Argentina, Kenya, the Philippines, and Indonesia.

In addition, specialized training in on-farm diagnostic skills, which is part of a larger UNDP-funded project, has been integrated into the collaborative survey work in countries of Latin America.

Training associated with the joint development and execution of the individual country projects is a major component of both the UPWARD and the PRACIPA marketing networks.

Participants in a recent workshop learned about sweet potato germplasm utilization in Los Baños, Philippines.

Highlights of Information Sciences and Training Activities

Information Sciences Department

The Department of Information Sciences was created in 1989 to integrate information functions and resources at CIP, and to respond to the emerging communication challenges of the Center's progressive decentralization. CIP's information generation, processing, and relay functions are being reorganized within an organizational structure designed to meet Center-wide research and administrative needs. It includes the Information and Communication Units from the former Training and Communication Department, and incorporates the Computer, Statistics, and Public Awareness Units. The conceptualization of the information function has received a positive review from the External Review panels.

The goals of the new Department are to assess information and communication needs; design information and communication strategies; provide the structure and mechanisms for information exchange and management within CIP and with NARS, donors, and the general public; and facilitate the exchange of information among national programs.

Communication Unit

CIP's Communication Unit supports CIP in the development and implementation of communication strategies through the generation, design, production, and delivery of communication services and products. These include simplified publications, photographs, audiovisual aids, and editing/writing, translation, and communication training. Working with CIP scientists to diagnose user needs, the Communication Unit helps program and deliver optimum quality products and services for the Thrust activities. CIP research, administration, and training are assisted in the exchange of research-based information among CIP's regional operations and main headquarters, as well as among national scientists. Networks, professional associations, and mass media all play a role in this process.

Over the past year, the Unit's achievements included the following:

- The Communication Unit has provided the facilities and technical expertise for in-house processing and publishing of a wide range of publications including the CIP Annual Report, CIP Circular, training materials, research reports, books, and other print media. In total, 32 publications were produced including the translation of several titles into a second language. Nearly 90,000 copies of CIP publications are distributed each year to clients and subscribers worldwide.
- The Unit produced new slide collections (slide sets to accompany the Technical Information Bulletins, TIBs). Of these, five were produced in

English, Spanish, and French, and four in English and Spanish. In addition, the Unit has processed more than 30,000 slides and color prints for reports and presentations, as well as graphics for papers that CIP scientists regularly submit to journals. The slide collection (4,000) and black and white negatives and contacts are managed by the Unit, and a new inventory of the collection was initiated.

- Training materials were developed or translated for courses at headquarters and regional courses, as well as for in-country courses. Thirty-one translations were coordinated and 7 training guides were published in Spanish, in addition to a large number of unpublished documents produced for use in training.
- A global mailing list of nearly 6,000 entries, in operation since 1985, has been restructured and integrated with training data into the Potato Network Database.
- New electronic technologies were introduced in text processing and layout for the CIP Annual Report, CIP Circular, and other publications. Text processing has largely been transferred from the minicomputers to microcomputers. Center publications are produced almost completely within CIP. Equipment has been ordered for further development of graphic and layout capabilities.
- Copublishing ventures in English have been reassessed and new working arrangements established for commercial publishing and other translation/editing functions. Revamping of CIP-wide publications and media procedures also was begun within the Publications Committee. Copublishing agreements exist between CIP and the "Editorial Hemisferio Sur" for 20 Technical Information Bulletins in Spanish. These copublication agreements also included the translation and publication of the book *Potatoes* by D. Horton, as well as of the book *Principios de Almacenamiento de la Papa* by R. Booth and R. Shaw. New contractual arrangements were made with Cambridge University Press, Cambridge, England.

Computer Unit

Building on the computer system existing at headquarters and in the regions, the newly formed Unit evaluates CIP's computer needs and resources, helping update and develop technology in the computer and telecommunications fields. The unit assesses alternatives for the development of information systems, using appropriate technologies.

The unit provides the scientific and administrative staff with the orientation, training, and computer facilities necessary for performing their activities. It also assists in the diffusion of computer technologies for use in national programs. The Computer Unit acts as an interface between computer users and CIP's management, providing technical resources for the Computer Committee to propose guidelines and define standards for computer systems at CIP.

Several staff members were transferred from the Information Unit to the Computer Unit, and functions were redefined.

An assessment of computer and communication needs was conducted in coordination with the Communication Unit, as well as an assessment of present and projected information systems at CIP. Databases have been developed with this information.

In May, three consultants assisted CIP in determining priority changes required for better support of ongoing and projected operations. The Computer Committee and the management have analyzed their recommendations and priority recommendations are being implemented. Use of PCs has increased substantially, and CIP has received over 50 additional compatibles to support basic research and administrative information processing and management. Telecommunications through electronic mail has increased significantly during this year, both for headquarters and regional offices. Telexes and FAXs are now sent regularly through electronic mail, thereby increasing efficiency, and achieving a reduction of cost. Successful trials have been conducted to communicate through BITNET with selected universities.

Information Unit

The special project funding provided by IDRC to establish an information service for potato researchers at CIP has concluded this year. These services have been successfully incorporated into CIP's regular operations. Among the achievements of the Information Unit are the following:

- *Implementation and maintenance of CIP's Bibliographic Database*, in which has been included the input of the complete library collection of 34,000 references on potato and sweet potato.
- *Retrospective searches CIP Staff and national programs* are provided regularly. This year, special emphasis was placed on providing regular services to new users from Asia and Africa. From June 1989 to June 1990, 822 retrospective computer searches were made.

  The SDI service includes tailor-made searches offered three times a year with the objective of keeping national scientists updated in their specific areas of research. Over 300 SDI subscriptions are provided to users from CIP and NARS. The individual nature of the SDI service has been highly valued by researchers receiving this type of service, as can be found in the evaluations conducted periodically.
- *Bibliographies*. This year, CIP has produced two comprehensive bibliographies: *True Potato Seed* and *Integrated Pest Management of Potatoes* that have been distributed to all national potato programs and key libraries.
- *Accession Lists*. These publications list on a monthly basis all new documents received by the CIP library, and are distributed to all potato programs.
- *Photocopies and Publications Supplied*. Based on specific items identified in the searches or SDIs, users of these information services can request from CIP, for each search or SDI, up to 30 free photocopies or two articles. This service is utilized widely by researchers from all over the world, who can find information not easily available in local libraries.

One of the objectives of CIP's information and communication services is to support and strengthen the exchange of information among potato and sweet potato researchers from developing countries. Several activities have been undertaken leading towards the achievement of this objective, among which is the database on Publishing Procedures of Agricultural Journals.

The Potato Network Database has been designed to integrate all information on individuals and institutions working with potato or sweet potato around the world. This information system includes the Center's mailing list, as well as all training data.

Statistics Unit

With the reorganization of the Department, a Statistics Unit was created this year to provide statistical advice and training for the appropriate design, analysis, organization, and presentation of research projects. The Unit assists scientists, both at headquarters and regional offices, in the application of the most advanced statistical methods for research processes, using modern computing and communication software and hardware. It collaborates in the statistical design and analysis of data managed by CIP's Administration and Management. Furthermore, it assesses the specific statistical needs of CIP's scientific work in general. The Unit promotes the utilization of statistical methodologies and software by national programs and networks.

Public Awareness Unit

This newly formed Unit has been created within the Department, although no staff were contracted during 1989, and the public awareness function is being assessed by the Public Awareness Committee, which was formed at mid-year. The Committee has developed a short-term operational plan to respond to the communication needs of CIP's publics, including CIP employees, and specific external audiences including NARS, donors, and the international scientific community.

Training Department

CIP training is developed jointly with national and regional programs to help improve research and technology, and respond to farmers' problems in potato and sweet potato production and use. The annual work plan consists of group and individual participation in both short-term and specialized training (see Table 1). CIP also supports graduate training for students from NARS that have potato and sweet potato improvement projects. Regional and headquarters staff assist as resource scientists in courses organized by national and international organizations, presenting lectures and seminars when required.

Jointly with CIAT and IITA (the other international centers whose research and development mandates include root and tuber crops), CIP began the second year of a three-year project on Human Resources Development. This project focuses on the generation and transfer of root- and tuber-crop technology in national agricultural research systems of Africa, Asia, Latin America, and the Caribbean. The three centers have developed and integrated concepts and methodologies to cover six areas of special need: organization and management of vegetative seed production programs; integrated pest management (IPM); training in farm-level diagnostic skills; product development; training and communications; and formative and summative evaluation. This project began in 1988 as a follow-up to earlier projects.

Table 1. CIP training activities for 1989.

Training activity	No. of participants	No. of countries represented	No. of courses
Specialized group	399	47	21
Group	188	24	16
Training at CIP headquarters	47	22	119
Thesis	94	14	---

Training on Collection, Maintenance and Use of Unexploited Genetic Resources

CIP's central goal of improving potato and sweet potato production builds upon the wide genetic base represented by the world collection of these two crops now maintained at CIP headquarters. Effective use of this genetic wealth depends largely on the capabilities of national scientists who do their research on breeding, selection, and adaptation in diverse environments. The required expertise for breeding work is not always available or sufficient at the NARS, thus CIP training is selectively directed toward improving national scientists' capabilities in this area.

Several courses on Germplasm Management were offered during 1989. A course on Potato Germplasm Management was held in Colombia and Ecuador, with participants from all 5 Andean countries: Bolivia (1), Colombia (1), Ecuador (2), Peru (8), and Venezuela (2). The course was initiated in Bogota where the students received lectures and "practicals" on principles of potato breeding, selection of progenitors, and breeding methods. Emphasis was given to breeding for resistance to late blight and bacterial wilt. The trainees participated in the harvest and selection process of an International Late-Blight Project Trial in Rionegro, Colombia. In

Quito, Ecuador, the students learned about breeding for resistance to the potato cyst nematode.

A two-week regional training course on potato germplasm management in Nairobi, Kenya was attended by 17 trainees representing 11 National Potato Programs from countries in east, central, and southern Africa. This course emphasized screening techniques for biotic and abiotic factors. Summary analysis and discussion by the participants covered four major areas: (1) mechanisms of communication in potato germplasm utilization; (2) methods and efficiency of acquisition of potato germplasm; (3) potato germplasm screening methods, procedures and strategies, and (4) TPS research and the use of seedling tubers as an alternative propagation method. Recommendations were made to improve the germplasm utilization program in the regions.

A Workshop on Sweet Potato Germplasm in Kenya was co-sponsored by the Kenyan Agriculture Research Institute (KARI) and CIP at Nairobi and Katumani. A total of 22 participants attended: 12 from the sweet potato programs at six of KARI's stations, 3 from other Kenyan institutions, 2 from IBPGR, and 5 from CIP. Topics included collaborative research and sweet potato germplasm collection and utilization. In addition, Kenyan researchers were trained on the use of the morphological descriptions developed by Dr. Zósimo Huaman, of CIP.

A regional course for Asia – Potato Germplasm Management, Breeding, and Evaluation – was held at PCARRD, Los Baños, Philippines, sponsored by CIP, SAPPRAD and PCARRD. Participants came from China (4), Fiji (1), Indonesia (1), Malaya (1), Pakistan (1), the Philippines (8), Thailand (2), Vanuatu (1) and Vietnam (3). The participants were potato scientists now involved in germplasm management and evaluation. Course topics included; basic genetics; crop taxonomy; tissue culture as a means of maintaining germplasm; virology involving the identification and detection of viruses; and breeding strategies and evaluation methods.

Training on Integrated Management of Pests and Diseases

Developing countries generally have few scientists with experience in integrated methods for disease and pest management. Thus, CIP works in collaboration with other international institutions in putting together comprehensive training programs. Over the past year, IPM workshops and conferences were held in regions II, VI, and VIII.

In Guatemala, in September, trainees prepared a master plan to initiate and conduct IPM work in their respective countries. The course was attended by 14 participants from Guatemala (9), Panama (1), Honduras (1), Costa Rica (1) and Nicaragua (1), all in the PRECODEPA network. Entomologists from CIP and from the countries of PRECODEPA are backstopping and monitoring IPM activities in the region.

An International Conference on Sweet Potato Pest Management was sponsored by the University of Florida and CIP in Miami, Florida. Researchers studying insect pests of sweet potatoes worldwide exchanged information about insect problems and management approaches. Special emphasis was placed on topics concerned with the sweet potato weevil, including the use of sex pheromones, biological controls, and weevil/host plant interactions.

The sweet potato weevil is the most serious pest affecting production and utilization of the sweet potato in Asia. To support Asian researchers, the International Training Course on Integrated Control of Sweet Potato Weevil was held at the Central Tuber Crops Research Institute (CTCRI), Trivandrum, India, in August. Attending the course were participants from Bangladesh (2), the Philippines (2), Thailand (1), Indonesia (1), and India (5). Key topics included taxonomy, biology, and evaluation of genetic resistance and other control methods for the sweet potato weevil. Toward the end of the course, work plans on integrated control of sweet potato were prepared by the trainees with the assistance of CIP and CTCRI scientists.

A related seminar on diseases and pests of sweet potato was also held in August at CTCRI, and was attended by participants from India (6), Bangladesh (2), the Philippines (2), Thailand (1), and Indonesia (1).

A training course on potato bacterial wilt was sponsored by the Institute of Plant Protection of CAAS and CIP at Beijing, China, in May. The course was designed for scientists from China and included discussion of: 1) the principles and applications required for breeding for resistance to bacterial wilt, (2) germplasm evaluation for bacterial-wilt resistance, and (3) bacterial-wilt management and serological techniques. Twelve trainees from different provinces of China attended the course.

Training on Communication and Training Methods

Training on communication and training methods is an integral part of the relay and exchange of technology developed within CIP's research Thrusts through departmental and collaborative research projects. In May, a workshop on Training and Communication skills was held in Lima, Peru, with participants from Colombia (6), Ecuador (6), and Peru (5). Course instructors were from CIAT (1) and CIP (3). During the course, each national team developed a plan to support future training and communication activities in their countries.

In a related activity, CIP and CIAT have screened and compiled nearly 100 documents on communication, training, and evaluation in an Inventory of Training Materials. The materials, in both the Spanish and English languages, were shared with participants in the workshop. Documents in English are being further screened and classified, and several documents in Spanish are being translated into English for use in the Asian and African workshops to be held in 1990 and 1991.

Seed-Technology Training

Although excellent potential varieties have been produced by CIP breeding programs and by breeders in the national programs through collaborative research projects, recent CIP studies of global use of improved potato varieties have shown that new genetically improved materials have not been reaching farmers' fields. Thus, upward trends in potato production in developing countries apparently stem from higher yields obtained from traditional varieties and/or expansion of the areas growing such varieties.

The analysis of the factors that are hampering use of improved breeding products readily indicates that the availability of healthy planting material is a first-order constraint. Thus, CIP's Regional Programs and training efforts are directed towards assisting national programs in developing efficient seed multiplication programs and in strengthening existing programs. This initiative requires specialized training in seed technology, with emphasis on rapid multiplication of healthy vegetative materials, as well as the logistics and administration of appropriate seed programs that respond to country needs.

Group training activities in seed technology in 1989 included the Third International Storage and Seed Production Course held in January /February in Osorno, Chile. Developed jointly by INIA and CIP, the course brought together trainees from Chile (7), Brazil (1), Bolivia (1), Ecuador (1), El Salvador (1), Dominican Republic (1), Mexico (1), Honduras (1), Peru (1), and Panama (1).

Instructors from INIA, the Universidad Austral, CIP, and the private sector emphasized seed production and storage, as well as technology of TPS production. The course is part of a UNDP-funded project oriented toward development of human resources and technical and scientific training. The course consisted of lectures, "practicals," discussions, field visits, and group work.

A potato production course was held in Canoinhas, Santa Catarina, Brazil and was organized by the potato program of EMBRAPA-CNPH, in collaboration with the Basic Seed Production Service, and was funded by CIP. Held in October and November, the course was attended by participants from Brazil (23), Hungary (2), Paraguay (1), and Mozambique (1). Emphasis was given to seed production in collaboration with government and private institutions.

In Quito, Ecuador, INIAP and CIP offered a course on Production of Basic Potato Seed in October/November. Major topics included tissue culture, rapid propagation by stem cuttings, and prevention of dissemination of systemic diseases associated with vegetative propagation. Eleven participants attended the course, with 2 each from Colombia and Ecuador, and 1 each from Chile, Argentina, Uruguay, Peru, Guatemala, Brazil, and Venezuela. Discussion topics included prebasic seed production, in vitro maintenance and multiplication, serological techniques for virus detection, and NASH for viroid detection.

As part of CIP headquarters' assistance to national programs, a practical course in virology had been programmed as an annual activity for individual trainees interested in the basic techniques of virology. This course was held at CIP headquarters in Lima, Peru in February, bringing together participants from Colombia (1), Venezuela (2), the Dominican Republic (1), Costa Rica (2), Ecuador (1), Peru (7), and Bolivia (1).

Likewise, a first course in advanced virology was held at CIP-Lima in June. Six trainees participated: one each from Colombia, Brazil, Peru and Austria, and 2 from Mexico. This six-week course is designed for scientists with advanced degrees who are actively engaged in virus research and in identification or preparation of antisera for virus detection. Each week of training is built around learning modules that cover a particular technique in detail, with intensive practical experience under the guidance of an expert virologist.

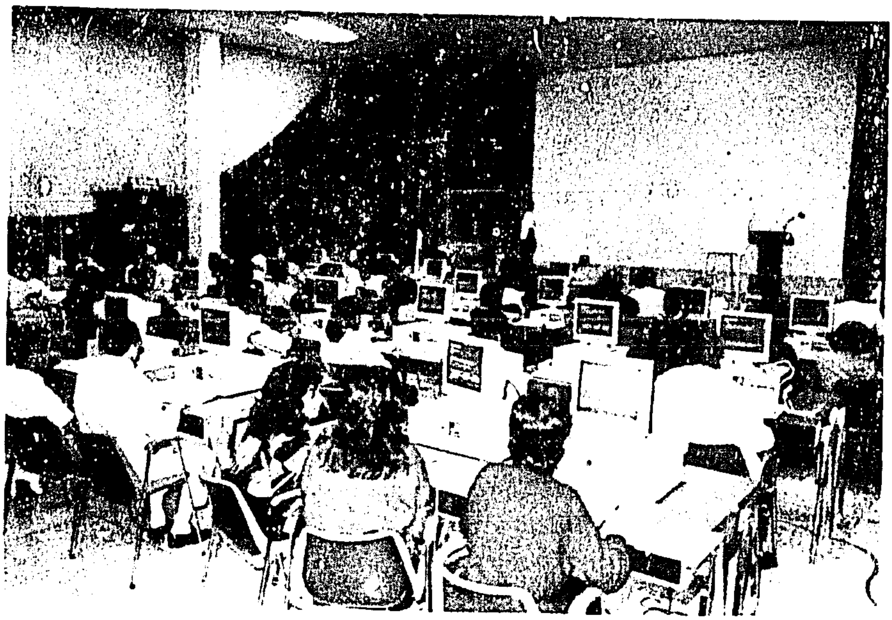
In San Jose, Costa Rica, CIP collaborated with the Ministry of Agriculture in holding a training course for the PRECODEPA network. The course, Pathology in Seed Potato Production, was attended by eight participants from Costa Rica and one each from Mexico, El Salvador, Haiti, Panama, Honduras, Guatemala, and the Dominican Republic. Country reports were presented by participants from each country on completion of the course, providing a two-way exchange of information and enabling assessment of participants' comprehension of the subject matter.

An in-country course on Storage of Potatoes was held in February at Gisozi, Burundi, organized by the Institut des Sciences Agronomiques du Burundi (ISABU). The course was attended by 10 trainees from government and private organizations.

CIP and IITA collaborated to offer a course on Organization and Management of Vegetative Seed Production Programs, which was funded by the UNDP in Nairobi and Kakamega, Kenya, in October. A total of 17 participants attended from Uganda, Zambia, Seychelles, Ethiopia, Mauritius, Sudan, Swaziland, Lesotho, and Rwanda.

A training course in virus detection for six regional staff also was held in Nairobi in July, with participants from Kenya, Rwanda, and Ethiopia.

Regions III and VI had specialized training courses on TPS as an alternative method of propagating potatoes. During May, in Nairobi, Kenya, a total of six



CIP staff receive training in the software programs needed for their work.

trainees representing the national programs of Kenya, Rwanda, Uganda, Mozambique and Ethiopia attended a one-week course on practical aspects of TPS technology.

An in-country seed production and storage course was held at CPRA-Saida in Tunisia. Eighteen trainees from several development agencies attended the course, which was organized by Tunisian scientists of CPRA-Saida, INRAT, and CIP.

An in-country potato production course was held in Menemem, Turkey, and Bagdad, Iraq and was attended by 12 trainees from private or semi-private seed companies.

At Agadir, Morocco, 15 trainees from state extension, research, and seed production agencies attended an in-country course held at the Institut Agronomique et Veterinaire.

The first Specialized Regional Course on Germplasm Management and Seed Production for West and Central Africa was held in Bamenda, Cameroon in June. A total of 18 scientists attended from Senegal, Gambia, Nigeria, Ghana, Mali, Cape Verde, Côte d'Ivoire, and Cameroon.

The Ninth International Training Course on Potato Seed Production and Certification was sponsored by CIP at CPRS Modipuram, in November/December, and was attended by trainees from Nepal (8), Sri Lanka (3), Buthan (4), and India (3).

A Regional Workshop on Low-Cost Storage of Ware and Seed Potatoes held in India in May, was attended by participants from Kenya (1), Nepal (2), Buthan (3) and India (10). The workshop focused on technologies available for transfer to farmers and analysis of their needs. Participants made recommendations for plans and strategies for future research and development activities on storage in cool and warm climates.

A total of 28 scientists attended a Regional Workshop for Researchers on True Potato Seed (TPS) held at New Delhi in January. Participants were from Bangladesh (1), Buthan (2), Nepal (2), the Philippines (2), and Vietnam (1).

A regional course on Sweet Potato Tissue Culture and Virology was held in the Philippines, under the sponsorship of SAPPRAD, CIP, and PCARRD at VISCA. The course was designed for scientists from the Philippines, Indonesia, Malaysia, Sri Lanka, and Papua New Guinea. Course work covered the basic concepts and techniques of tissue culture and virus erradication, identification, and indexing. Such knowledge is required to develop the procedures for sending germplasm for clean-up and for receiving clean materials from the Plant Research Institute in Victoria, Australia.

A training course on utilization of ELISA and dot-ELISA kits was held at Inner Mongolia University in Tukei Province, China in January, with seven trainees from six of the country's potato research or production institutions.

A course on Seed Potato Production of improved varieties was held in China in May, and was attended by 20 participants from provinces of southern China.

CIP, in collaboration with the Institute for Agronomic Research (IRA-Bambui), sponsored an In-Country Potato Production Course in Bamenda, Cameroon. The course was held in two-day sessions, starting in April with planting, and finishing in July with harvest. The course was attended by 20 agronomists from government and private organizations of Cameroon.

The First In-country Course on Potato Production sponsored by CIP in collaboration with the National Root Crops Research Institute (NRCRI) was held in Jos, Nigeria in July. Twenty researchers, extensionists, and production specialists from government organizations attended the course, which dealt primarily with ware and seed-potato production.

CIP also sponsored the 18th International Training Course on Modern Methods of Potato Production held at the Central Potato Research Institute (CPRI) in Shimla, India. A total of 22 researchers, extension specialists, and university teachers from India, Nepal, and Bangladesh participated. The course was coordinated by CPRI's Division of Social Sciences and most of the 40 instructors were from CPRI.

Sweet Potato Training

Production technology is the central focus of most of CIP's training related to sweet potatoes (*Ipomoea batatas* L.). As research projects develop and NARS' interest continues to increase, CIP plans to adjust the balance between production and specialized training, according to users' needs. In 1989, CIP sponsored sweet potato production courses, seminars, and workshops in CIP regions I, IV, VI and VII, as indicated in the following summary.

The First International Course on Sweet Potato Crop was held in San Pedro, Argentina in March, coordinated by the Instituto Nacional de Tecnología Agropecuaria of Argentina and sponsored by CIP. Course participants came from Paraguay and Brazil (3 each); Argentina, Colombia, Ecuador, Peru, Uruguay (2 each); and Mexico, the Dominican Republic, Cuba, and Venezuela (1 each). Course objectives were to enable participants to: (1) identify and describe problems and potentials in sweet potato production; (2) explain the scientific basis for sweet potato production, including botany, physiology, agronomy, pathology, economics, etc. and (3) develop research projects oriented to solving problems of sweet potato production and marketing.

At the Kafr El Zayat station in Egypt, a one-week Sweet Potato Production course was held for potato growers, researchers, horticulturists, and extensionists.

A Seminar on Sweet Potato in Asia was held in July at CTCRI, Trivandrum, India.

The National Sweet Potato Seminar-Workshop was held in Baybay, Leyte, Philippines in collaboration with PRCRTC and VISCA. A total of 47 participants attended this in-country course.

A Regional Sweet Potato Production training course was held at PCARRD, Los Baños, Philippines in January/February, attended by trainees from the Philippines and Indonesia (6 each); Vietnam (4); the Solomon Islands, Thailand and Taiwan (2); and Korea, Tonga,and Australia (1). The objectives were to communicate the present state of scientific knowledge on major disciplines of sweet potato research; to equip national scientists for teaching general production courses in their home countries; and to develop research work plans for each participating country. The focus was on farm-level problems, with analysis of the farmers' production constraints. Presentations dealt primarily with production, breeding, and postharvest problems.

An In-Country Workshop on Sweet Potato Production Utilization and Marketing was held in Vietnam, in September, with 3 groups of 35, 11, and 22 participants.

Postharvest Technology

CIP sponsored a course on Village-Level Processing of Root and Tuber Crops at the Society for the Development of Appropriate Technology (SOTEC) in Bareilly, India in March. Participants came from India (5), Bangladesh (2), and Nepal and Sri Lanka (1).

Potato and Sweet Potato Agronomy

In Peru, in close collaboration with the Soil Department of the Universidad Agraria at Lima, training courses were held, emphasizing fertilizers and fertilization techniques used in potato and sweet potato production. More than 200 Peruvian researchers and extensionists from government and private institutions from throughout Peru attended these courses. The courses included presentations on plant nutritional requirements; types, dosage, and methods of fertilizer application; and economic analysis of inputs and returns.

Support for Collaborative Research Networks

CIP-sponsored research networks are progressively increasing their abilities to conduct training within their regions. The senior network, PRECODEPA, is fully meeting the needs of its country members for training in potato production technology, along with some specialized training. The other networks are making similar progress and the increased capabilities of the NARS and collaborative networks have released CIP's staff for more specialized training, technical assistance, and development of training materials.

The national leaders of the potato programs of the PRECODEPA countries attended a seminar in Lima, Peru in February/March, which provided a scientific update for the participants, while helping strengthen and develop collaborative bridges within the individual countries and PRECODEPA.

List of Abbreviations and Acronyms

AGRIS	International Information System for Agricultural Sciences and Technology (Italy)
AID	Agency for International Development
ALAP	Asociación 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)
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
CLD	chlorotic leaf distortion
CMS	cytoplasmic male sterility
CNPH	Centro Nacional de Pesquisa de Hortaliças (Brazil)
COTESU	Cooperación Técnica Suiza
CPRI	Central Potato Research Institute (India)
cm	centimeter
cv	coefficient of variation
cv.	cultivar
d	day
DAP	days after planting
DLS	diffused-light store
DMRT	Duncan's multiple range test
DNA	deoxyribonucleic acid
EB	early blight
EBN	endosperm balance number
EDTA	ethylenediaminetetraacetic acid
ELISA	enzyme-linked immunosorbent assay
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria (Brazil)

ERSO	Consorzio "Mario Neri" (Italy)
FAO	Food and Agriculture Organization of the United Nations
FDR	first division restitution
FONAIAP	Fondo Nacional de Investigaciones Agropecuarias (Venezuela)
g	gram
GA	gibberellic acid
GAAS	Guandong Academy of Agricultural Sciences
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)
ILBRT	International Late Blight Resistance Trial
INIA	Instituto Nacional de Investigaciones Agropecuarias (Chile)
INIAA	Instituto Nacional de Investigación Agraria y Agroindustrial (Peru)
INIAP	Instituto Nacional de Investigaciones Agropecuarias (Ecuador)
INIFAP	Instituto Nacional de Investigaciones Forestales y Agropecuarias (Mexico)
INIPA	Instituto Nacional de Investigación y Promoción 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	milliequivalent
min	minute
ml	milliliter
mm	millimeter
mo	month
NAR	net assimilation rate
NARS	National Agricultural Research Systems
NASH	nucleic acid spot hybridization test
NCM	nitrocellulose membranes
NCSU	North Carolina State University
ND	not determined
NS	not studied
NSAC	Nova Scotia Agricultural College
nm	nanometer
ns	not significant
OP	open-pollinated
PBI	Plant Breeding Institute (UK)
PCARRD	Philippine Council for Agriculture and Resources Research and Development
PCN	potato cyst nematode
PIPA	Programa de Investigación en Papa (Peru)
PLRV	potato leafroll virus
PNAP	Programme National de l'Amelioration de la Pomme de Terre (Rwanda)
PRACIPA	Programa Andino Cooperativo de Investigación 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 Investigación Agrícola 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
RFLP	Restriction Fragment Length Polymorphism
RGTC	relative growth rate
RH	relative humidity
RICA	Red Interamericana de Comunicadores Agricolas
RKN	root-knot nematode
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)
SEM	Scanning Electron Microscopy
SLA	special leaf area
SNC	single node
SOTEC	Society for the Development of Appropriate Technology
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)
UNCP	Universidad Nacional del Centro del Peru
UNDP	United Nations Development Programme
UPLB	University of the Philippines - Los Baños
UPWARD	User's Perspective with Agricultural Research and Development
USAID	United States Agency for International Development
var.	variety
vol	volume
vs.	versus
WUE	water use efficiency
wk	week
wt	weight
yr	year

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182

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Research and Consultancy Contracts in 1990

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

Departmental Projects

1. Biosystematic Studies of Selected Wild Species and their Utilization in Breeding (in preparation - two previous projects merged). **Genetic Resources.** *P. Schmiediche/ C. Ochoa*
2. The Maintenance, Documentation, Distribution, and Evaluation of Potato and Sweet Potato Germplasm. (In preparation - two previous projects merged). **Genetics Resources.** *Z. Huamán*
3. Germplasm Enhancement through the Use of Haploids and 2n Gametes. **Genetic Resources.** *K. Watanabe*
4. Development of Cytological and In Vitro Techniques to Facilitate Exploitation of Sweet Potato Germplasm. **Genetic Resources.** *P. Schmiediche/G. Orjeda*
5. In Vitro Potato and Sweet Potato Germplasm Collection. Introduction, Maintenance, and Analysis. **Physiology.** *R. Lizarraga/J. Dodds*
6. Use of Innovative Tissue Culture Techniques to Improve Potato Germplasm. **Physiology.** *J. Dodds*
7. Collection of the Sweet Potato Genetic Resources and Sweet Potato Germplasm Enhancement. **Genetic Resources.** *F. de la Puente/ Z. Huamán*

Contract Projects

8. Instituto Nacional de Investigaciones Agropecuarias (INIAP) *Ecuador.* "Maintenance of the Potato Germplasm In Vitro Collection". **Region I.** *G. García*
9. Ente Nazionale di Energie Alternative (ENEA), *Italy.* "Development of Potato Project Varieties Resistant to Insect Pests by Means of Conventional Innovative Breeding Technologies." **Special Project.** *A. Sonnino, L. Bacchetta*
10. Zuzhou Institute of Sweet Potato (XISP), *China.* "Evaluation of Sweet Potato Germplasm." **Genetic Resources.** *Sheng Jialian*
11. Guangdong Academy of Agricultural Sciences (GAAS), *China.* "Sweet Potato Germplasm for the

Tropics." **Genetic Resources.** *Feng Zu-Xia*

12. Università degli Studi della Tuscia Viterbo, *Italy.* "Use of Genetic Engineering Methods to Confer Fungal Disease Resistance to Potatoes." **Special Project.** *C. Di Pace*

13. Università di Napoli, *Italy.* "In Vitro Selection of Potato Mutant Tolerant to Abiotic Stress." **Special Project.** *L. Monti*

14. Maintenance of In Vitro Sweet Potato Germplasm in Venezuela. *L. Villegas* (IDAE, Venezuela) **Genetic Resources.** *J. Dodds*

15. 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." **Physiology.** *J. M. Jaynes*

Thesis Projects

16. The Utilization of Wild Potato Species of the Series *acaule* and *etuberosa* as Sources of Resistance to Potato Leaf Roll Virus (PLRV) and Potato Spindle Tuber Viroid (PSTVd). UNA, *Peru.* **Genetic Resources.** *C. Arbizu, (P. Schmiediche)*

17. Crossability between *Ipomoea* species of Section Batatas. UNA, *Peru.* **Genetic Resources.** *J. Diaz, (F. De la Puente)*

18. Production of Synthetic 6x Clones of *Ipomoea trifida.* UNA, Peru. **Genetic Resources.** *R. Freyre, (M. Iwanaga)*

19. Techniques for the Management and Conservation of Sweet Potato (*Ipomoea batatas*) Cuttings. UNA, *Peru.* **Genetic Resources.** *A. Robles, (F. De la Puente)*

Thrust II
Production and Distribution of Advanced Breeding Material

Departmental Projects

20. Adaptation and Utilization of Potato and Sweet Potato Populations in Breeding. **Breeding & Genetics.** *H. Mendoza*

21. Breeding of True Potato Seed Populations. **Breeding & Genetics.** *H. Mendoza*

22. Breeding and Selection of Potato Clones with Disease Resistances and Other Appropriate Horticultural Characteristics. **Breeding & Genetics.** *H. M. Kidane-Mariam*

23. Breeding, Selection, and Distribution of Appropriate TPS Progenies and/or Parental Lines in East and Southern Africa. **Breeding & Genetics.** *H. M. Kidane-Mariam*

24. Breeding Sweet Potato for Low Sugar and Resistance to Weevil. **Breeding & Genetics.** *T. Dayal*

25. Evaluation of Potato Clonal and TPS Germplasm for Adaptation to Warm Climates. **Breeding & Genetics.** *E. Chujoy*

26. Development of Improved Sweet Potato Germplasm for Warm and Cool Tropics of Southeast Asia. **Breeding & Genetics.** *E. Chujoy*

27. Development of True Potato Seed (TPS) Parental Lines and Progenies for Agronomic and Reproductive Characters. **Breeding & Genetics.** *A. Golmirzaie*

Collaborative Projects

28. Production, Evaluation, and Utilization of Potato Germplasm in

Colombia. **Region I.** *I. Valbuena* (ICA, *Colombia*)/*O. Hidalgo*

29. Evaluation of Germplasm and Selection for Cyst Nematode Resistance. **Region I.** *R. Eguiguren* (INIAP, *Ecuador*)/*O. Hidalgo*

30. Evaluation of Advanced Potato Breeding Material in Ecuador. **Region I.** *H. Andrade* (INIAP, *Ecuador*)/*O. Hidalgo*

31. Evaluation of Advanced Potato Breeding Material in Venezuela. **Region I.** *R. L. Palencia* (FONAIAP, *Venezuela*)/*O. Hidalgo*

32. Evaluation of Advanced Potato Breeding Material in Peru. **Region I.** *A. Hidalgo* (INIAA, *Peru*)/ *O. Hidalgo*

33. Evaluation of Advanced Potato Breeding Material in Chile. **Region I.** J. Kalazich (INIA, *Chile*)/*CIP Breeders*

34. Evaluation of Advanced Potato Breeding Material in Argentina. **Region I.** A. Mendiburu (INTA, *Chile*)/*CIP Breeders*

35. Evaluation of Advanced Potato Breeding Material in Uruguay. **Region I.** *F. Vilaro* (CIAAB, *Uruguay*)/*CIP Breeders*

36. Evaluation of Advanced Potato Breeding Material in Paraguay. **Region I.** *A. Lopez* (Min. of Agriculture, *Paraguay*)/*CIP Breeders*

37. Evaluation of Advanced Potato Breeding Material in Brazil. **Region I.** *J. Buso* (CNPH/EMBRAPA, *Brazil*)/ *CIP Breeders*

38. Collaboration with National Programs in the Evaluation and Selection of Superior Clones and TPS Progenies. **Region III.** National Breeders of East & Southern African Countries/ *H. M. Kidane-Mariam*

39. Introduction, Maintenance, and Distribution of Advanced Genetic Materials of Potato. **Region III.** *C. Carli*/*H.M.Kidane-Maria*/*Sylvester Nganga*

40. Evaluation of Advanced Genetic Materials with Resistance to Late Blight, Bacterial Wilt, Storability, and Adaptation. **Special Project.** *A. Rubirigi* (ISABU, *Burundi*)/ *J. Rueda*

41. Selection of Potato Cultivars with Late Blight Resistance, Adaptation, and Quality. **Special Project.** *B. Tuku* (IAR, *Ethiopia*)/*P. Callejas*

42. Evaluation of Advanced Genetic Materials of Potato with Emphasis on Virus Resistance. **Region IV.** *M. Fahem* (CPRA, *Tunisia*)/ *R. Cortbaoui*

43. Evaluation of Advanced Genetic Materials of Potato in Egypt. **Region IV.** *L. Anrity* (Min. of Agriculture)/*R. El-Bedewy*

44. Evaluation of Advanced Genetic Materials of Potato for Cameroon and Countries with Similar Agroecological Conditions. **Region V.** National Breeders of West and Central Africa/*C. Martin*

45. Introduction, Evaluation, and Multiplication of Sweet Potato Germplasm. **Region V.** IRA Scientists/ *C. Martin*

46. Breeding for TPS Parental Lines. **Region VI.** CPRI Scientists/*M. Upadhya*

47. Evaluation, Multiplication, and Distribution of Advanced Genetic Materials of Potato. **Region VII.** Na-

tional Breeders from Southeast Asian Countries/*P. Vander Zaag*/*E. Chujoy*

48. Evaluation of TPS Progenies and Production of Hybrid Seed. **Region VII.** National Scientists (LEHRI, *Indonesia*)/*M. Potts*

49. Introduction and Utilization of Potato Germplasm. **Region VIII.** National Scientists of China (CAAS, *China*)/*S. Bofu*

50. Evaluation of Cultivated Sweet Potato Germplasm in Paraguay. **Region I.** *M. Cardoso* (Ministry of Agriculture, *Paraguay*)/*A. Strohmenger*

51. Development of Improved TPS Progenies for Various Environments of China. **Region III.** National Scientists of China (CAAS, *China*)/*S. Bofu*

Contract Projects

52. Cornell University, Ithaca, *USA*. "The Utilization of *Solanum tuberosum* spp. *andigena*. Germplasm in Potato Improvement and Adaptation." **Breeding & Genetics.** *R. L. Plaisted*/*H. D. Thurston*/*W. M. Tingey*/*B. B. Brodie*/*E. Ewing*

53. North Carolina State University, *USA*. "Breeding and Adaptation of Cultivated Diploid Potato Species." **Breeding & Genetics.** *W. W. Collins*

54. University of Wisconsin, Madison, *USA*. "Potato Breeding Methods with Species, Haploids, and 2n Gametes." **Genetic Resources.** *S. J. Peloquin*

55. Instituto Nacional de Tecnología Agropecuaria, (INTA), Balcarce, *Argentina*. "The Utilization of Increased Genetic Variability in the Potato Breeding Program." **Breeding & Genetics.** *A. Mendiburu*

56. Agriculture *Canada*. "The Nutritional and Chipping Evaluation of Selected Parental Clones in Peru, the Philippines, and Canada." **Breeding & Genetics.** *T. R. Tam*

57. University of Tacna, *Peru*. "Evaluation of Sweet Potato Germplasm for Tolerance to Certain Abiotic Stresses under Arid Conditions." **Breeding & Genetics.** *N. Arevalo*

58. Instituto Nacional de Investigación Agraria, (INIAA), *Peru*. "Evaluation of CIP Advanced Clones for the National Potato Program of Peru." **Breeding & Genetics.** *D. Untiveros*

59. Centro Nacional de Pesquisas de Hortaliças (CNPH/EMBRAPA), *Brazil*. "Evaluation of Potato Germplasm Evaluation (*Solanum tuberosum* L.) related to Resistance to *Alternaria solani*." **Region I.** *F. J. B. Reifschneider*

60. Consorzio "Mario Neri", ERSO, Imola, *Italy* "Selection of Potato Clones with High Starch Content." **Special Project.** *F. Concilio*/*F. Cioni*

61. Centro Nacional de Pesquisas de Hortaliças (CNPH/EMBRAPA), *Brazil*. "Selection of TPS Progenies Adapted to Northeast and West Central Brazil." **Region I.** *J. A. Buso*

62. North Carolina State University, *USA*. "Breeding Early-Yielding, and Disease-Resistant Sweet Potatoes with Enhanced Food Quality and Nutritional Value." **Breeding & Genetics.** *W. W. Collins*

63. Aegean Regional Agricultural Research Institute (ARARI), *Turkey*. "Potato Germplasm Evaluation and

Multiplication." **Region IV.** *N. Kuzman*

64. Centro de Investigaciones Agrícolas, "A. Boerger" (CIAAB), *Uruguay.* Consultancy on Sweet Potato Breeding. **Region I.** *F. Vilaro*

Thesis Projects

65. Inheritance of Earliness in Autotetraploid Potatoes. UNA, Peru. **Breeding & Genetics.** *L. Calua (H. Mendoza)*

66. Inheritance of Earliness, Yield, and Dry-Matter Content in Sweet Potatoes. UNA, Peru. **Breeding & Genetics.** *L. Díaz (H. Mendoza)*

67. Inheritance of Quality Factors in Autotetraploid Potatoes. UNA, Peru. **Breeding & Genetics.** *E. Hernández (H. Mendoza)*

68. Comparison of Methods for Selection of General Combining Ability for Yield. UNA, Peru. **Breeding & Genetics.** *J. L. Marca (H. Mendoza)*

69. Quantitative Variation in Potato Breeding. UNA, Peru. **Breeding & Genetics.** *J. Tenorio, (A. Golmirzaie)*

70. Components of Genetic Variance for Various Traits in Advanced Populations of Autotetraploid Potatoes. UNA, Peru. **Breeding & Genetics.** *N. Zuñiga (H. Mendoza)*

Thrust III
Control of Bacterial and Fungal Diseases

Departmental Projects

71. Integrated Control of Bacterial Wilt. **Pathology.** *J. Elphinstone*

72. Procedures which Determine Resistances to Bacterial Diseases in Potato. **Pathology.** *J. Elphinstone*

73. Soilborne Diseases. **Pathology.** *H. Torres*

74. Breeding for Early-Blight Resistance. **Breeding & Genetics.** *H. Mendoza*

75. International Testing of Late Blight-Resistant Clones. **Breeding & Genetics.** *J. Landeo*

76. Breeding for Late-Blight Resistance with Populations A and B. **Breeding & Genetics.** *J. Landeo*

77. Breeding for Resistance to Bacterial Wilt. **Genetic Resources.** *P. Schmiediche*

78. Ecology and Taxonomy of *Pseudomonas solanacearum*. **Pathology.** H. El-Nashaar

Collaborative Projects

79. Integrated Control of Bacterial Wilt. **Special Project.** *A. Autrique* (ISABU-*Burundi*)/*J. Rueda*

80. Management of Late Blight Through Resistant Germplasm. **Region VII.** *E. Badol* (NPRCRTC, *The Philippines*)/*E. Chujoy*

81. Managing Bacterial Wilt Through Resistant Germplasm and Appropriate Farming Systems. **Region VII.** *N. Balanay* (Ministry of Agriculture, *The Philippines*)/*P. Vander Zaag*

82. Control of Bacterial Wilt on Potatoes. **Region VIII.** *H. Liyuan* (CAAS, *China*)/*S. Bofu*

83. *Erwinia* Disease in Different Phases of the Tunisian Potato Seed Program. **Region IV.** *M. Makjoub* (ESH, *Tunisia*)/*R. Cortbaoui*

Contract Projects

84. Centro Nacional de Pesquisas de Hortaliças (CNPH/EMBRAPA), *Brazil.* "Potato Germplasm Evalua-

tion for Resistance to Bacterial Wilt." **Region I.** *C. A. Lopez*

85. Instituto Colombiano Agropecuario, (ICA), Rionegro, *Colombia*. "Evaluation of Genetic Resistance to *Pseudomonas solanacearum* and *Phytophthora infestans*." **Pathology.** *P. L. Gomez*

86. Instituto Nacional de Investigaciones Agropecuarias (INIAP), *Ecuador*. "Study and Control of the Potato Diseases, Rosellinia Black Rot (Lanosa) and Common Rust (Roya) in Ecuador." **Region I.** *H. Orellana*

87. University of Wisconsin, *U.S.A.* "Fundamental Research to Develop Control Measures for Bacterial Pathogens of the Potato." **Pathology.** *A. Kelman, L. Sequeira*

88. Universidad Nacional de Huánuco, *Peru*. "Development of Potato Varieties with Resistance to Diseases and Adaptation to Ecological Zones of the Department of Huánuco." **Pathology.** *E. Torres Vera*

89. National Agricultural Laboratories, Nairobi, *Kenya*. "The Reaction of Selected Potato Clones to Two Races of *Pseudomonas solanacearum* in Kenya." **Region III.** *A. O. Michieka*

90. Cornell University, Ithaca, *U.S.A.* "Population Genetics of *Phytophthora infestans* in its Natural Ecosystem at Toluca." **Pathology.** *W. E. Fry*

91. Centro de Investigaciones Agrícolas "A. Boerger" (CIAAB), *Uruguay*. "Selection of Clones with Resistance to *A. solani* and Precocity in Materials with Antecedents to Virus Resistance." **Region I.** *F. Vilaro/ C. Crisci*

92. Consultative Contract, Universidad Agraria, La Molina, *Peru*. "Early Blight of Potatoes: Specialization of *Alternaria* spp." **Pathology.** *T. Ames de Icochea*

93. Gilat Regional Experimental Station, *Israel*. "*Verticillium* Wilt and Early-Blight Tolerance of Potato in Hot Climates." **Pathology.** A. *Nachmias*

94. Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), *Mexico*. "Selection of Potato Genetic Material Resistant to Late Blight." **Region II.** *M. Villarreal*

Thesis Projects

95. Serological Detection of *Erwinia carotovora*. UNA, *Peru*. **Pathology.** *C. Corredor*, (*J. Elphinstone*)

96. Selection of in-Laboratory, Greenhouse, and Field Clones Resistant to *Spongospora subterranea* and Pathogenicity to Different Isolates. UNA, *Peru*. **Pathology.** *W. Galindez*, (*E. French*)

97. Biological Control of *Rhizoctonia solani* with Antagonistic Organisms. UNA, *Peru*. **Pathology.** *P. Gutierrez*, (*H. Torres*)

98. Sources of Resistance to Early Blight in CIP's Germplasm Collection. UNA, *Peru*. **Pathology.** *A. Palomino*, (*V. Otazu*)

99. Identification of Native and Introduced Hosts of *Pseudomonas solanacearum* in Peru. UNA, Peru. **Pathology.** *B. Paz*, (*E. French*)

100. Incidence of Wilt and Fungous Rots of Potato in Central Highlands of Peru. UNA, *Peru*. **Pathology.** *W. Perez*, (*L. de Lindo*)

101. Inventory of Pests and Diseases Affecting Sweet Potato Production. UNA, *Peru*. **Pathology**. O. *Quincho*, (*J. Elphinstone*)

102. Interaction between *Erwinia carotovora* var. *caratovora* and *Fusarium* spp. Affecting Potatoes in Peru. UNA, *Peru*. **Pathology**. *H. Silva*, (*E. French*)

103. Biological Control of Bacterial Wilt. UPLB, *The Philippines* **Region VII**. Hongqi Zeng (P. Vander Zaag)

104. Genetics of Bacterial Wilt Resistance. UPLB, *The Philippines*. **Region VII**. Pham Xuan Tung (E. Chujoy)

Thrust IV
Control of Virus and Virus-Like Diseases

Departmental Projects

105. Antiserum Production and Improvement of Serological Techniques for Virus Detection. **Pathology**. *L. Salazar*

106. Identification and Characterization of Sweet Potato Viruses. **Pathology**. *L. Salazar*

107. Mechanism of Resistance and Variability of Potato Leaf Roll Virus (PLRV). **Pathology**. *U. Jayasinghe*

108. Studies on Potato Viruses X and Y. **Pathology**. *E. N. Fernandez-Northcote*

109. In Vitro Eradication of Sweet Potato Viruses and Viroids. **Physiology**. *J. Dodds*

110. Genetic Studies and Breeding of Viruses and Viroid Resistance. **Breeding & Genetics**. H. Mendoza

111. Molecular Analysis of Genetic Resistance to Viruses. **Pathology**. *M. Querci*

112. Development of Molecular Probes for the Identification of Pathogens. **Pathology**. *M. Querci*

113. Epidemiology of Potato Viruses in Peru. **Special Project**. *L. Bertschinger*

Collaborative Projects

114. Effect of Potato Virus S on Growth, Yield, and Late Blight. **Special Project**. *M. Goethals* (ISABU, *Burundi*)/*J. Rueda*

115. Epidemiology of PVY and PLRV in Potato Seed Fields in Tunisia. **Region IV**. *C. Cherif* (INRAT, *Tunisia*)/*R. Cortbaoui*

116. Development and Utilization of Virus Detection Techniques. **Region VIII**. *Z. Heling* (University of Inner Mongolia, *China*)/*S. Bofu*

117. Studies on Yellow Vein Virus. **Region I**. *A. Saldarriaga* (UNM, *Colombia*)/*O. Hidalgo*

Contract Projects

118. Istituto Agronomico per l'Oltremare (I.A.O.), *Italy*. "Production of Antisera Against Major Potato Viruses." **Special Project**. *M. Broggio*/*M. Galanti*

119. Scottish Crops Research Institute, *Scotland*. "Resistance to Potato Leafroll Virus." **Pathology**. *B. D. Harrison*

120. North Carolina State University, *USA*. "The Accumulation of Sweet Potato Feathery Mottle Virus, ds-RNA and Selected Viral Proteins in Sweet Potatoes. **Pathology**. *J. Moyer*

121. Universidad Nacional Agraria, La Molina. *Peru*. Consultative Contract

on "Monoclonal Antibodies for Potato Viruses." **Pathology.** *J. Castillo*

122. Universidad Nacional Agraria, La Molina, *Peru*. "Maintenance of Monoclonal Antibodies for Potato Viruses." **Pathology.** *J. Castillo*

123. Centro de Investigaciones Agricolas "A. Boerger" (CIAAB) *Uruguay*. "Evaluation of Genetic Material for Resistance to PVX and PLRV Under Field Conditions." **Region I.** *C. Crisci/F. Vilaro*

124. Instytut Ziemniaka, Institute for Potato Research, *Poland*. "Breeding Potatoes Resistant to the Potato Leafroll Virus, PLRV." **Pathology.** *K. M. Swiezynski*

125. Louisiana State University, *USA*. "Attempts to Elucidate the Etiology of Sweet Potato Chlorotic Leaf Distortion." **Pathology.** *C. A. Clark*

126. North Carolina State University, *U.S.A.* "Development of Virus Testing Procedures for Sweet Potatoes." **Pathology.** *J. Moyer*

Thesis Projects

127. Studies on the Mechanisms of Resistance of Potatoes to Viruses: Determining the Factor that Confers Extreme Resistance to Potato Virus X in Potato. UNA, *Peru*. **Pathology.** *S. Vega, (M. Querci/L Salazar)*

128. Combination of PVX and PVY Immunity with High Resistance to *Phytophthora infestans* in Potato Clones. UNA, *Peru*. **Pathology.** *J. L. Zapata, (E. N. Fernández-Northcote)*

129. Efficiency of PLRV Transmission by Different Species of Aphids. UNA, Peru. **Pathology.** *G. Brignetti, (U. Jayasinghe)*

130. Identification and Some Characteristics of Sweet Potato Feathery Mottle Virus Isolates from Peru. UNA, *Peru*. **Pathology.** *C. Cedano, (L. Salazar)*

131. Virus Infections in Potato Clones with Different Levels of Resistance to PVX, PVY, and PLRV under Field Conditions and Associated Aphid Species. UNA, *Peru*. **Pathology.** *Edgar García, (E.N. Fernández-Northcote)*

132. Studies on Virus and Viroid Sequences in Chromosomal DNA from Potatoes. UNA, *Peru*. **Pathology.** *P. Chimoy, (L. Salazar)*

133. Identification of Viroids in Sweet Potatoes. UNA, *Peru*. **Pathology.** *A. Hurtado, (L. Salazar)*

134. Inheritance of Extreme Resistance to PVY in *S. tuberosum*. UNA, *Peru*. **Pathology.** *R. Galvez, (H. Mendoza)*

135. Breeding for PVY Immunity. UPLB, *The Philippines*. **Region VII/UNDP** *Vu Dinh Hoa (E. Chujoy)*

Thrust V
Integrated Pest Management

Departmental Projects

136. Screening for and Utilization of Resistance to Root-Knot Nematode Species. **Nematology & Entomology.** *P. Jatala*

137. Components of Integrated Root-Knot Management and Interrelationships of this Nematode with Other Organisms. **Nematology & Entomology.** *P. Jatala*

138. Screening for and Utilization of Resistance to Potato Cyst Nematode. Nematology & Entomology. *M. Scurrah/ J. Franco*

139. Components of Integrated Potato Cyst Nematode Management. **Nematology & Entomology.** *J. Franco*

140. Management of Potato and Sweet Potato Insect Pests of Global Importance. **Nematology & Entomology.** *K. V. Raman/M. Scurrah*

141. Management of Potato and Sweet Potato Insect Pests of Importance in Specific Regions. **Nematology & Entomology.** *K. V. Raman*

142. Management of Potato Insect Pests of Importance in The South American Andean Region. **Nematology & Entomology.** *L. Valencia*

143. Resistance to Potato Tuber Moth. **Nematology & Entomology.** *L. Valencia*

144. Integrated Control of Potato Tuber Moth and Other Insect Pests of Potato and Sweet Potato. **Nematology & Entomology.** K. V. Raman.

Collaborative Projects

145. Ecology and Control of the Andean Weevil. **Region I.** *H. Calvache* (ICA, *Colombia*)/*L. Valencia*

146. Biological Control of Potato Tuber Moth. **Region I.** *R. Lopez* (ICA, *Colombia*)/*L. Valencia*

147. Integrated Control of Potato Tuber Moth in Venezuela. **Region I.** *J. Rincon* (FONAIAP, *Venezuela*)/*L. Valencia*

148. Integrated Control of Andean Weevil in Venezuela. *F. Torres* **Region I.** (FONAIAP, *Venezuela*)/*L. Valencia*

149. Integrated Control of Potato Tuber Moth and Aphids in Eastern and Southern African Countries. **Special Project.** National Entomologists/*B. Parker*

150. Integrated Control of Root-Knot Nematode. **Special Project.** M. Goethals (ISABU, *Burundi*)/*J. Rueda*

151. Integrated Management of Tuber Moth in Burundi. **Special Project.** *Z. Nzoyihera* (ISABU, *Burundi*)/*C. Turner*

152. Integrated Management of Potato Tuber Moth and Aphids in Ethiopia. **Special Project.** *B. Tuku* (IAR, *Ethiopia*)/*P. Callejas*

153. Integrated Control of Potato Tuber Moth in Egypt. **Region IV.** *S. Doss* (Ministry of Agriculture)/*R. El-Bedewy*

154. Integrated Management of Sweet Potato Weevil (*Cylas formicarius*) **Region VII.** *D. Amalin* (VISCA, The Philippines)/*P. Vander Zaag*

155. Evaluation of Trap Types with Sexual Pheromones of *Cylas* spp. **Region II.** National Scientists of Cuba, Venezuela/*O. Malamud*

156. Evaluation of Sweet Potato Germplasm for Resistance to Sweet Potato Weevil in Central America and the Caribbean. **Region II.** National Scientists of the Region/*O. Malamud*

157. Agronomic Practices to Control Sweet Potato Weevil. **Region II.** National Scientists of the Dominican Republic and Haiti/*O. Malamud*

158. Biological Control of Sweet Potato Weevil in Central America and the Caribbean. **Region II.** National Scientists of the Region/*O. Malamud*

Contract Projects

159. University of the Philippines, Los Baños (UPLB), *The Philippines*.

"Integrated Control of Weeds and Nematodes by the Use of Biological Control Agents and Solarization." **Nematology & Entomology.** *R. Davide*

160. North Carolina State University, *USA*. "Evaluation of Potato Lines for Resistance to the Major Species and Races of Root-Knot Nematodes (*Meloidogyne* spp.)." **Nematology & Entomology.** *J. N. Sasser*

161. Instituto Nacional de Investigaciones Agropecuarias (INIAP), *Ecuador*. "Evaluation of Clones Resistant to the Root-knot Nematode (*Globodera* spp.) in Ecuador." **Region I.** *R. Eguiguren and J. Revelo*

162. Universidad Nacional Agraria, La Molina, *Peru*. Consultancy on "*Pratylenchus* spp. as an Important Nematode Pest of Potatoes." **Nematology & Entomology.** *M. Canto*

163. Universidad Nacional Agraria, La Molina, *Peru*. Consultancy on "Biological and Selective Chemical Control of Potato and Sweet Potato Insect Pests." **Nematology & Entomology.** *J. Sarmiento and Colleagues*

164. The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), *The Philippines*. "Management of Thrips and Mites Attacking Potato in the Lowlands." **Region VII.** *E. N. Bernardo.*

Thesis Projects

165. Extraction and Inoculation Methods of *Nacobbus aberrans* and its interaction with *Globodera pallida*. UNA, *Peru*. **Nematology & Entomology.** *J. Arcos, (P. Jatala/ M. Canto)*

166. Development of IPM Approach to Control the Potato Tuber Moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) in Storage. **Nematology & Entomology.** *G. P Das.(K. V. Raman/ E. Magallona)*

167. Effect of Glandular Trichomes on Leafminer Fly (*Liriomyza huidobrensis*) Damage in Potatoes. UNA, *Peru*. **Nematology & Entomology.** *G. Hospina, (K. V. Raman)*

168. Detection and Evaluation of Granulosis Virus (GV) for Potato Tuber Moth (PTM) *Phthorimaea operculella* Control. UNA, *Peru*. **Nematology & Entomology.** *H. Leal, (K. V. Raman)*

169. Variability of *Nacobbus aberrans*. UNA, *Peru*. **Nematology & Entomology.** *R. Montecinos, (P. Jatala/ M. Canto)*

170. Reaction of Potato Clones to *Pratylenchus* spp. from Umari Huanuco. UNA, *Peru*. **Nematology & Entomology.** *Z. Nicolas, (P. Jatala/ M. Canto)*

171. Determination of Some Components for an Integrated Control of *Pratylenchus flakkensis*. UNA, *Peru*. **Nematology & Entomology.** *J. Saldívar, (M. Canto)*

172. Life Cycle of the Central American Potato Moth, *Scrobipalpopsis solanivora* Povolny and Studies on Monitoring Field Populations. **Nematology & Entomology.** *F. Torres, (L. Valencia)*

Thrust VI
Warm-Climate Potato and Sweet Potato Production

Departmental Projects

173. Improving Efficiency of Fertilizer, Water, and Light Use in Non-Tradi-

tional Warm Potato-Growing Areas. **Physiology.** *D. Midmore*

174. Agronomic Management for Control of Bacterial Wilt. **Physiology.** *D. Midmore*

175. Adaptation and Utilization of Potato Populations for the Hot Tropics. **Breeding & Genetics.** *H. Mendoza*

176. Evaluation of the Physiological Response of Potatoes and Sweet Potatoes to High Temperature and Water Use Using In Vitro Techniques. **Physiology.** *I. Ekanayake*

177. Evaluation of Genotypic Responses to Water Stress and Improvements in Water Use Efficiency by Potatoes and Sweet Potatoes for Warm Climates. **Physiology.** *I. Ekanayake*

178. In Vitro Screening of Sweet Potatoes to Saline and Osmotic Stress Conditions. **Physiology.** *I. Ekanayake*

179. In Vitro Tuberization Response of Potatoes at High Temperatures. **Physiology.** *I. Ekanayake*

180. Soil Fertility and Mineral Nutrition of Potato in Adverse Climate and Soil Conditions. **Physiology.** *S. Villagarcia*

181. Potato Production in the Cropping Systems of the Warm Climate Zone of Asia. **Physiology.** *M. Potts.*

Collaborative Projects

182. Potato Production from True Potato Seed in Paraguay. **Region I.** *T. Mayeregger* (I A M , *Paraguay*). *A. Strohmengher*

183. Improvement of Sweet Potato in Egypt. **Region IV.** *S. Doss* (Ministry of Agriculture, *Egypt*)/*R. El-Bedewy*

184. Potato Production from True Potato Seed. **Region IV.** *N. Farag* (Ministry of Agriculture, *Egypt*)/ *R. El-Bedewy*

185. Potato Production from True Seed in Cameroon and Other Countries of the Region. **Region V.** *S. Nzietchueng* (Ministry of Dachang, *Cameroon*)/ *C. Martin*

186. True Potato Seed Hybrid Families in Different Agroecological Zones of India. **Region VI.** (National Scientists of CPRI, *India*)/*M. Upadhya*

187. True Potato Seed on Farm Trials in India. **Region VI.** (National Scientists of CPRI, *India*)/*M. Upadhya*

188. Use of Plant Growth Substances in Improving Quality and Quantity of Potato Yield. **Region VI.** (National Scientists of CPRI, *India*)/*M. Upadhya*

189. Tuber Seed Production and Storage for Warm Climates in Asia. **Region VII.** (National Scientists, LEHRI, *Indonesia*)/*M. Potts*

190. Agronomic and Physiological Studies on Sweet Potato in Warm Climates: The Philippines and Vietnam. **Region VII.** *H. Taja* (Institute of Biology, *The Philippines*)/*N. Van Uyan* (HCMC, *Vietnam*)/*P. Vander Zaag*

191. Intercropping Studies on Potato with Maize. and other Annual Crops. **Region VIII.** *L. Jiemin* (S. China Potato Research Center)/ *S. Bofu*

Contract Projects

192. Universidad Nacional Agraria, La Molina, *Peru*. "Soil Management, Fertilizers and Mineral Nutrition of the Potato Under Adverse Conditions of Soil and Climate." **Physiology.** *S. Villagarcia*

193. Scottish Crops Research Institute, *Scotland*. "Drought Tolerance in Potatoes." **Physiology.** *P. Waister*

194. Maritius Sugar Industry Research Institute (MSIRI), Nairobi, *Kenya*. "Development of Potato Varieties for Lowland Tropical Conditions." **Region III.** *K. Wong yen Cheong*

195. Instituto Nacional de Tecnología Agropecuaria, (INTA), *Argentina*. Consultancy on Sweet Potato Production and Utilization. **Region I.** *A. Boy*

Thesis Projects

196. Effect of Nitrogen Fertilizer and Inoculation with *Azospirillum* on Yield and Nitrogen Content of Two Sweet Potato Varieties. **Physiology.** (UNA, *Peru*.) *M. Julca*, (*P. Malagamba*)

197. Management of Sweet Potato Planting Material. UNA, *Peru*. **Physiology.** *F. Wizman*, (*P. Malagamba*)

198. Irrigation Requirements for Sweet Potato. **Physiology.** *E. Rios*, (*D. Midmore*)

Thrust VII
Cool-Climate Potato and Sweet Potato Production

Departmental Projects

199. Breeding for Resistance to Frost, Early Maturity, Wide Adaptability and other Major Constraints of the Highlands. **Breeding & Genetics.** *J. Landeo*

200. Improving Efficiency of Fertilizer, Water, and Light Use in Traditional Potato Growing Areas. **Physiology.** *D. Midmore*

201. Evaluation and Selection of Sweet Potatoes in Cool Environments. (In revision). **Genetic Resources.** *F. de la Puente*

202. Breeding for Highland Adaptation Including Cyst Nematode, Late Blight, and Frost, PVX, and PVY Resistance. **Breeding & Genetics.** *J. Landeo* (In revision).

Collaborative Projects

203. Ecophysiology of Potato Production in the Southern Region of Chile. *J. S. Rojas* (INIA, *Chile*). **Region I.** *D. Midmore/P. Malagamba*

204. The Production of Sweet Potato Basic Planting Materials in Burundi. **Special Project.** *A. Sinduhije* (ISABU, *Burundi*)/*J. Rueda*

205. On-Farm Trials to Introduce Cultivars to Improve Potato Production in Burundi. **Special Project.** *Z. Nzoyihera* (ISABU, *Burundi*)/ *C. Turner*

206. Yield Improvements through Agronomic Practices. **Special Project.** *Z. Nzoyihera* (ISABU, *Burundi*)/ *C. Turner*

207. Potato Production from True Seed: Progenies and Agronomy. **Special Project.** *B. Tuku* (IRA, *Ethiopia*)/ *P. Callejas*

208. Development of Cultural Practices for Potato Production from Seed Tubers and Seedling Tubers. **Region IV.** *A. Sharara* (Ministry of Agriculture, Egypt)/*R. El-Bedewy*

209. Potato Production from True Potato Seed. **Region IV.** *N. Farag* (Ministry of Agriculture, *Egypt*)/ *R. El-Bedewy*

210. Potato Production from True Seed in Morocco. **Region IV.** *A. Hilali* (I.A.V., *Morocco*)/*R. Cortbaoui*

211. Potato Production from True Potato Seed in Tunisia. **Region IV** *M. Fahem* (C D R A, *Tunisia*)/ *R. Cortbaoui*

212. Agronomy of Potato Production in Cameroon and Other Countries with Similar Agroecological Conditions. **Region V.** *P. Foncho* (IRA, *Cameroon*)/*C. Martin*

Contract Projects

213. Instituto de Investigaciones Agropecuarias (INIA), *Chile*. "Selection of Potato Genetic Materials Adapted to Sub-optimal Temperatures." **Region I.** *J. Rojas*

Thesis Projects

214. Determination of Type of Gene Action in the Control of Frost Resistance. UNA, *Peru*. **Breeding & Genetic.** *V. Huanco*, (*J. Landeo*)

215. Techniques for Selecting Potato Genotypes for their Efficient Use of Nutrients and Evaluating Leaf Longevity with Respect to Efficient Use of Nitrogen. UNA, *Peru*. **Physiology.** *S. Sarapura*, (*D. Midmore*)

Thrust VIII
Postharvest Technology

Departmental Projects

216. Low-cost Storage of Consumer Potatoes. **Physiology.** *S. Wiersema*

217. Simple Processing for Low-income Groups. **Physiology.** *S. Wiersema*

218. Physiological Aspects of Seed and Ware Potato Storage. **Physiology.** *S. Wiersema*

219. Integrated Control of Postharvest Losses During Tropical Potato Storage. **Pathology.** *J. Elphinstone*

220. Breeding Potatoes for Processing in Tropical Countries. **Breeding & Genetics.** *H. Mendoza*

Collaborative Projects

221. Improvement of Potato Storage Techniques in Burundi. **Special Project.** *Z. Nzoyihera* (ISABU, *Burundi*)/*C. Turner*

222. Research and Transfer of Postharvest Technologies to African Countries. **Region III.** (National Scientists of African Countries)/*G. Hunt*

223. Sweet Potato Storage (Post-Maturity Technology). **Region III.** *A. Abubaker* (Min. of Agriculture, *Kenya*)/*G. Hunt*

224. Low-cost Potato Processing. **Region III.** *J. Kabira* (Min. of Agriculture, *Kenya*)/*G. Hunt*

225. Assessment of Promising Potato Clones Under Seed Storage Conditions. **Region III.** *J. Kabira* (Min. of Agriculture, *Kenya*)/*G. Hunt*

226. Storage of Ware and Seed Potatoes. **Region IV.** *S. Doss* (Min. of Agriculture, *Egypt*)/*R. El-Bedewy*

227. Studies on Potato and Sweet Potato Storage. **Region V.** *J. Lekunze* (IRA, *Cameroon*)/*C. Martin*

228. Rustic Stores for War and Seed Potato and Sweet Potato. **Region VI.** *R. Nave* (SOTEC, *India*)/ *S. Mehra*

229. Table and Seed Potato Storage for Lowlands of Southeast Asia. **Region VII.** (National Scientists of Southeast Asian Countries)/*P. Vander Zaag*

Contract Projects

230. 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." **Region VII.** *T. Van Den*

231. Society for Development of Appropriate Technology (SOTEC), *India*. "Village-Level Processing of Potato and Sweet Potato." **Region VI.** *R. Nave*

Thesis Projects

232. Pre- and Postharvest Factors Influencing Consumer Potato Tuber Storability in the Tropics. UNA, *Peru*. **Physiology.** *A. Tupac*, (*S. Wiersema/J. Elphinstone/E. French*)

233. Production and Utilization of Solar-Dried Potatoes in Kenya. **Region III.** University of Nairobi, *Kenya*. J. Kabira (*G. Hunt*)

Thrust IX
Seed Technology

Departmental Projects

234. Agronomic Technology for Growing Potatoes from TPS. **Physiology.** *P. Malagamba*

235. Physiological Studies on the Production from True Potato Seed (TPS). **Physiology.** *N. Pallais*

236. Pollen Selection. **Physiology.** *N. Pallais*

237. Investigation of Environmental Conditions During the Development of Sexual Reproductive Organs of *Ipomoea batatas* and Other *Ipomoea* Species. **Physiology.** *H. Beaufort-Murphy*

238. Study on the Feasibility of TPS Production in Warm Tropics. **Physiology.** *C. Almerkinders*

239. Soil Fertility and Mineral Nutrition on Flowering and Fruit Production of Potato Clones. **Physiology.** *S. Villagarcia*

240. Potato Seed Programs in Developing Countries. **Social Science.** *C. Crissman*

Collaborative Projects

241. Production of Basic Potato Seed in Colombia. **Region I.** *P. Corzo* (ICA, *Colombia*)/*O. Hidalgo*

242. Production of Seed Tubers from True Potato Seed. **Region I.** *E. Ortega* (FONAIAP, *Venezuela*)/ *O. Hidalgo*

243. Production of Basic Seed in Venezuela. **Region I.** *E. Ortega* (FONAIAP, *Venezuela*)/*O. Hidalgo*

244. Adaptive Research on TPS Production. **Region I.** *J. S. Rojas* (INIA, *Chile*)/*J. Bryan*

245. Basic Seed Production in Peru. **Special Project.** *A. Hidalgo* (INIAA, *Peru*)/*R. Wissar*.

246. Client-oriented Seed Program. **Special Project.** *A. Hidalgo* (INIA, *Peru*)/*E. Franco*

247. In Vitro and Rapid Multiplication for Basic Potato Seed Production. **Region I.** *J. Rojas* (INIA, *Chile*)/ *J. Bryan*

248. Seed Potato Production in Paraguay. **Region I.** *M. Mayerreger* (Ministry of Agriculture, *Paraguay*)/*A. Strohmenger*

249. Basic Seed Production in Kenya. **Region III.** *I. Nyoroge* (KARI, *Kenya*) /*C. Carli*

250. Agronomic Techniques for Potato Seed Production. **Region III.** Na-

tional Scientists of African Countries/ *C. Carli*

251. Evaluation of Rapid Multiplication Techniques for Potato Basic Seed. **Region III**. National Scientists of African Countries/*C. Carli*

252. Multiplication Methods for Sweet Potato Propagation. **Region III**. National Scientists of Kenya/*C. Carli*

253. Potato Basic Seed Production in Burundi. **Special Project**. *A. Sinduhija* (ISABU, *Burundi*)/*J. Rueda*

254. On-farm Potato Seed Production. **Special Project**. *Z. Nzoyihera* (ISABU, *Burundi*)/*C. Turner*

255. Production of Hybrid True Potato Seed. **Region VI**. National Scientists (CPRI, *India*)/*K. Takur*

256. Screening of True Potato Seed Families as Transplants, and Seedling Tubers as Seedling Materials. **Region VI**. National Scientists (CPRI, *India*)/*M. Upadhya*

257. Physiological Studies on True Potato Seed. **Region VI**. National Scientists (CPRI, *India*)/*M. Upadhya*

258. Technology of Using Cuttings for Seed and Table Potato Production in Southeast Asian Countries. **Region VII**. National Scientists of Southeast Asian Countries/ *P. Vander Zaag*

259. Hybrid True Potato Seed Production in Vietnam. **Region VII**. *V. Hoang* (Min. of Agriculture, Vietnam)/ *P. Vander Zaag*

260. Seed Production Systems Using True Potato Seed in The Philippines and Vietnam. **Region VII**. National Scientists of Vietnam/*P. Vander Zaag*

261. Development of a Propagation System for Potato and Sweet Potato in Cameroon and Other Countries in the Region. **Region V**. *J. Lekunze* (IRA, *Cameroon*), Country Scientists/*C. Martin*

Contract Projects

262. Victoria Department of Agriculture, *Australia*. "Production of Pathogen-tested Potato Germplasm for Southeast Asian and Pacific Countries." **Region VII**. *P. T. Jenkins*

263. Istituto di Agronomia, Università di Napoli, *Italy*. "Selection of TPS Parental Lines in the High Seed Production." **Special Project**. *L. Monti*, *L. Politano*

264. Instituto de Investigaciones Agropecuarias, (INIA), Osorno, *Chile*. "True Potato Seed Production in Chile." **Region I**. *J. Santos Rojas*, *A. Cubillos*

265. 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." **Physiology**. *S. Villagarcia*

Thesis Projects

266. Embryo Culture and Sweet Potato. UNA, *Peru*. **Physiology**. *R. Salinas*, (*J. Dodds*)

267. An Investigation of the Flowering Responses of *Ipomoea purpurea* in Lima, from Accessions Collected in Peru, Ecuador, Venezuela, Colombia, and Bolivia. UNA, *Peru*. **Physiology**. *A. Reyes*, (*H. Beaufort-Murphy*)

268. Promotion of Flower and TPS Production Via Growth Regulations.

UNA, *Peru*. **Physiology.** *R. García*, (*P. Malagamba*)

269. Cutting Production and Utilization Under Warm Conditions. UPLB, *The Philippines*. **Region VII/UNDP.** *He Wei* (*P. Vander Zaag*)

Thrust X
Potato and Sweet Potato In Food Systems

Departmental Projects

270. Impact Assessment. **Social Science.** *D. Horton*

271. Root Crop Statistics. Formerly "Patterns and Trends in Root Crop Production and Use". **Social Science.** *D. Horton*

272. Constraints to Potato and Sweet Potato Production and Use. **Social Science.** *D. Horton*

273. User's Perspective on Generation of Appropriate Sweet Potato and Potato Techniques. **Social Science.** *R. Rhoades*

274. Marketing and Demand for Potatoes in Developing Countries. **Social Science.** *G. Scott*

275. Survey of National Seed Programs. **Social Science.** *J. Bryan/C. Crissman*

276. Cooperative Program of Potato Marketing Research in the Andean Region (PRACIPA-Comercialización). **Special Project.** *G. Scott*

277. Assessing the Feasibility of Potato Agriculture in Mid-Elevations. **Social Science.** *G. Watson*

278. The Sweet Potato in Food Systems. **Social Science.** G. Watson

279. Potato Production in Warm Climates of Indonesia. **Social Science.** *G. Watson*

Collaborative Projects

280. Farmer's Cultural Practices and Farmer and Consumer Selection of Sweet Potato Varieties. **Region VII.** *G. Watson/M. Potts*

281. Farmer Participation in Research to Develop Low-cost Technology. **Special Project.** *V. Lama* (INIA, *Peru*)/*E. Franco/G. Prain*

282. Collection and Analysis of Data on Potato and Sweet Potato Production in Indonesia. **Region VII.** *A. Supriadi* (LEHRI, *Indonesia*)/ *G. Watson*

283. The On-farm Production of Seed and Ware Potatoes from TPS. **Region VII.** *M. Potts/G. Watson*

Contract Projects

284. England. Sweet Potato: An Untapped Food Resource. **Social Science.** *J. A. Woolfe*

285. International Food Policy Research Institute (IFPRI), *U.S.A.* "White Potato/Sweet Potato Development in China." **Social Science.** *B. Stone*

286. H. P. University, *India*. "Demand Study for Processed Potatoes." **Social Science.** *B. K. Sikka*

287. *Peru*. "Demand for Sweet Potato." **Social Science.** *M. Collins*

Staff

SENIOR MANAGEMENT

Richard L. Sawyer, Ph.D., Director General

José Valle-Riestra, Ph.D., Deputy Director General

William A. Hamann, B. S., Assistant to the Director General

Peter Gregory, Ph.D., Director of Research

Kenneth J. Brown, Ph.D., Director of Regional Research

Primo Accatino, Ph.D., Associate Dir., Transfer of Technology

Adrián Fajardo, M. S., Executive Officer

Leonardo Hussey, Controller

RESEARCH THRUSTS

(Managers and Associate Managers)

I. Collection, Maintenance and Utilization of Unexploited Genetic Resources (P. Schmiediche – Z. Huamán)

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)

IX. Seed Technology (P. Malagamba – A. Golmirzaie)

X. Food Systems (D. Horton – R. Rhoades)

RESEARCH DEPARTMENTS

Breeding and Genetics

Humberto Mendoza, Ph.D., Geneticist, Head of Department. (sabbatical leave from Sept. 3, 1989)

Andrea Brandolini, Dot. Agr., Visiting Associate Scientist†

Edward Carey, Ph.D., Sweet Potato Breeder

Carlo Carli, Dot. Agr., Sweet Potato Breeder (Kenya)

Enrique Chujoy, Ph.D., Geneticist (The Philippines)

T. R. Dayal, Ph.D., Sweet Potato Breeder (India)

Ali Golmirzaie, Ph.D., Geneticist, Acting Head of Department (from Sept. 3, 1989)

Haile M. Kidane-Mariam, Ph.D., Breeder (Kenya)

Juan Landeo, Ph.D., Breeder

Il Gin Mok, Ph.D., Sweet Potato Breeder (Nigeria)

María Scurrah, Ph.D., Breeder

Genetic Resources

Peter Schmiediche, Ph.D., Breeder, Head of Department

Fermín De la Puente, Ph.D., Breeder

Zósimo Huamán, Ph.D., Geneticist

Masaru Iwanaga, Ph.D., Cytogeneticist*

Kazuo Watanabe, Ph.D., Cytogeneticist

Nematology and Entomology

Parviz Jatala, Ph.D., Nematologist, Head of Department

Rolf Aalbu, Ph.D., Entomologist (Tunisia)

Javier Franco, Ph.D., Nematologist (until Sept. 9, 1989-transferred to PROINPA-Bolivia)

Hirotaka Kokubu, Ph.D., Entomologist, (Dominican Republic)

K. V. Raman, Ph.D., Entomologist

Luis Valencia, Ph.D., Entomologist (Colombia)

Pathology

Edward R. French, Ph.D., Pathologist, Head of Department

Hossien El-Nashaar, Ph.D., Bacteriologist

John Elphinstone, Ph.D., Bacteriologist

Enrique Fernández-Northcote, Ph.D., Virologist

Gregory A. Forbes, Ph.D., Mycologist

Upali Jayasinghe, Ph.D., Virologist

Masaaki Nakano, B. S., Virologist†

Maddalena Querci, Dot. Agr., Visiting Associate Scientist†

Luis Salazar, Ph.D., Virologist

Linnea G. Skoglund, Ph.D., Mycologist (Kenya)

L. J. Turkensteen, Ph.D., Adjunct Scientist (The Netherlands)†

Physiology

Patricio Malagamba, Ph.D., Physiologist, Head of Department (sabbatical leave, part of 1989)

Cornelia Almekinders, Ir., Scientific Associate†

Helen Beaufort-Murphy, Ph.D., Physiologist

John Dodds, Ph.D., Tissue Culture Specialist

Indira Ekanayake, Ph.D., Physiologist

David Midmore, Ph.D., Physiologist, Acting Head of Department (part of 1989)

Nöel Pallais, Ph.D., Physiologist

Frederick Payton, Ph.D., Agronomist (Dominican Republic)

Michael Potts, Ph.D., Agronomist (Indonesia)

Siert Wiersema, Ph.D., Physiologist (Thailand)

Social Science

Douglas E. Horton, Ph.D., Economist, Head of Department

Charles Crissman, Ph.D., Economist (Ecuador)

Peter Ewell, Ph.D., Economist (Kenya)

Keith Fuglie, Ph.D., Economist (Tunisia)

Gordon Prain, Ph.D., Anthropologist

Robert E. Rhoades, Ph.D., Coordinator, UPWARD (The Philippines)

Gregory J. Scott, Ph.D., Economist (sabbatical leave, part of 1989)

Greta Watson, Ph.D., Visiting Associate Scientist (Indonesia, until May 31, 1989)†

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INFORMATION SCIENCE DEPARTMENT

(Previously Training & Communications)

Manuel Piña, Ph.D., Head of Department (left June 1989)*

Carmen Siri, Ph.D., Head of Department (from July 1989)

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Christine Graves, M.A., Writer/Editor

Linda W. Peterson, B. F.A., English, Editor*

Carmen Podestá, M.A., Librarian/Information Officer

Hernán Rincón, Ph.D., Communications Unit

Alfredo García, M.S., Statistics Unit

Marciano Morales-Bermúdez, M.S., Supervisor, Communication Unit

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Margarita Villagarcía, M.S., Training Coordinator Assistant

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Francisco Muñoz, Ph.D., Superintendent, Quito, Ecuador

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ADMINISTRATION

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Haydeé Zelaya, International Personnel Officer

Mary Ellen Mulholland, Consultant

Internal Auditor

Carlos Niño Neira, C.P.C., Internal Auditor

Office of the Executive Officer

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Arturo Alvarez, Local Purchasing Officer

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Marcela Checa, Liaison Officer

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Carlos Bohl, Supervisor

Jacques Vandernotte, Chief Pilot

Djordje Velickovich, Pilot

Percy Zuzunaga, Co-Pilot

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Budget Unit

Guillermo Romero, Chief Accountant

ACCOUNTING UNIT

Miguel Saavedra, Chief Accountant

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SCIENTIFIC ASSOCIATES

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Anselmo Morales, Artist, Communication Unit
Félix Muñoz, M.S., Communication Assistant, Communication Unit
Godofredo Lagos, Print Shop, Communication Unit
María del Carmen Prieto, Text Processing, Communication Unit
Rufino Failoo, Photomechanics, Communication Unit
César Sepúlveda, Photocopy, Communication Unit
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Jorge Palacios, Dep., Training

Lauro Gómez, Tech., Research Support

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Jorge Queiroz, Ing. Agr. (Reg. II)

Stan Kasule, B.S. (Reg. III)

John Kimani, B.S. (Reg. III)

M. Shahata, B.S. (Reg. IV) (Egypt)

M. Sharkani, B.S. (Reg. IV) (Egypt)

S. K. Menra, M.S., Postharvest Assistant (Reg. VI)

A. Demagante, M.S. (Reg. VII)

V. Escobar, M.S. (Reg. VII)

B. Fernández, M.S. (Reg. VII)

C. Montierro, M.S. (Reg. VII)

B. Susana, B.S. (Reg. VII)

Jorge Bautista, B.S., Controller's Office

José Belli, C.P.A., Controller's Office

Luz Correa, C.P.A., Controller's Office

Vilma Escudero, B.S., Controller's Office

Alfredo González, C.P.A., Controller's Office

Alberto Monteblanco, C.P.A., Controller's Office

*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
Japan, Tropical Agriculture Research Center
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

February 26, 1990

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, 1989 and 1988, 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), up to December 31, 1988, 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 were recorded in the year of their commitment rather than at the time when the actual liability arises. As from 1989, the afore-mentioned firm orders are being accounted for when the actual liability arises.

As described in Note 3, because of the manner in which the Inter-American Development Bank transfers its contributions to the Center, the core donation receivable from such bank at December 31, 1989 is in effect overstated by approximately US$1 million at that date.

In our opinion, except for the effect in 1988 of the matter described in the second paragraph, and for the effect in 1989 of the situation mentioned in the preceding paragraph, the financial statements examined by us present fairly the financial position of International Potato Center - CIP as of December 31, 1989 and 1988 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

F. J. Moreno
------------------------------(partner)
Francisco J. Moreno
Peruvian Public Accountant
Registration No. 155

INTERNATIONAL POTATO CENTER — CIP

BALANCE SHEET (Notes* 1 and 2)
as of December 31, 1989 and 1988
(Expressed in U.S. dollars)

	1989	1988
ASSETS		
CURRENT ASSETS		
Cash and short-term deposits	2,396,335	3,352,991
·Accounts receivable		
Donors (Note 3)	3,930,728	1,558,152
Advances to personnel	124,097	59,544
Loans to executives and employees – current portion (Note 4)	153,450	118,304
Other (Note 5)	850,830	496,096
Inventories of laboratory and other supplies	820,347	720,349
Prepaid expenses and other current assets	140,714	97,222
Total current assets	8,416,501	6,402,658
RESTRICTED FUNDS (Note 4)	325,131	203,578
LOANS TO EXECUTIVES AND EMPLOYEES – NON-CURRENT PORTION (Note 4)	24,252	74,212
FIXED ASSETS (Note 6)	16,541,773	15,235,347
	25,307,657	21,915,795

* *The accompanying notes are an integral part of the financial statements.*

	1989	1988
LIABILITIES AND FUND BALANCES		
CURRENT LIABILITIES		
Bank overdrafts and current portion of long-term debt (Notes 4 and 7)	241,939	140,200
Accounts payable and other liabilities	691,231	1,424,455
Grants received in advance	57,600	-
Other payables and accrued expenses	555,956	383,494
Total current liabilities	1,546,726	1,948,149
LONG-TERM DEBT (Note 4)	-	55,237
PROVISION FOR SEVERANCE INDEMNITIES, net of advances of 53,745 (23,012 in 1988)	739,052	212,919
FUND BALANCES		
Funds invested in fixed assets (Note 6)	16,541,773	15,235,347
Unexpended funds -		
Operating funds - Unrestricted	574,940	3,591
- Restricted	942,358	564,680
Capital fund	892,750	-
Working funds	1,575,000	1,575,000
Special projects	2,287,427	2,219,116
Cooperative activities	207,631	101,756
	6,480,106	4,464,143
GRANTS PLEDGED (Note 8)		
	25,307,657	21,915,795

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, 1989 and 1988

(Expressed in U.S. dollars)

	1989	1988
REVENUE		
Operating grants:		
Unrestricted	13,170,541	12,418,294
Restricted	3,004,400	3,081,939
Other restricted core grants	1,232,165	851,549
	17,407,106	16,351,782
Special project grants	2,386,087	2,215,755
Grants for fixed asset additions	1,835,000	1,188,000
Grants for cooperative activities	247,713	140,562
Working fund grants	–	258,000
Other income, net	534,311	560,927
	22,410,217	20,715,026
EXPENDITURES		
Operating costs:		
Potato and sweet potato research program	5,102,430	3,983,190
Research services	1,765,771	1,614,033
Regional research program and training	4,083,905	3,477,441
Conferences and seminars	24,876	152,401
Information services and library	854,152	646,616
Administration cost	1,619,473	1,281,626
Other operating costs, including replacement of an aircraft for 3,019,180 in 1988	2,098,057	4,641,182
External program and management review	215,854	–
	15,764,518	15,796,489
Other restricted core expenditures	932,172	604,589
Special projects	2,317,776	1,503,137
Cooperative activities	141,838	91,911
Grants returned	–	4,471
	19,156,304	18,000,597
Additions to fixed assets	1,237,950	1,414,443
	20,394,254	19,415,040
Excess of revenue over expenditures	2,015,963	1,299,986
Unexpended fund balance, beginning of year	4,464,143	3,164,157
UNEXPENDED FUND BALANCE, END OF YEAR	6,480,106	4,464,143

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, 1989 and 1988
(Expressed in U.S. dollars)

	1989	1988
SOURCE OF FUNDS		
Excess of revenue over expenditures	2,015,963	1,299,986
Decrease in accounts receivable	-	1,353,190
Decrease in prepaid expenses and other assets	-	16,280
Decrease in restricted funds	-	71,422
Decrease in loans to executives and employees – non-current portion	49,960	102,333
Increase in funds invested in fixed assets	1,306,426	3,879,405
Increase in accounts payable and other liabilities	-	395,436
Increase in grants received in advance	57,600	-
Provision for severance indemnities	747,976	216,236
	4,177,925	7,334,288
APPLICATION OF FUNDS		
Purchase and replacement of fixed assets		
- Core acquisitions	1,237,950	1,414,443
- Special projects	45,295	70,501
- Net cost of replacement	23,181	2,394,461
Increase in accounts receivable	2,827,009	-
Increase in inventories	99,998	95,876
Increase in prepaid expenses and other current assets	43,492	-
Increase in restricted funds	121,553	-
Decrease in accounts payable and other liabilities	459,023	
Decrease in grants received in advance	-	2,182,245
Decrease in long-term debt	55,237	112,272
Payment and advances of severance indemnities	221,843	428,346
	5,134,581	6,698,144
Increase (decrease) in cash and short-term deposits	(956,656)	636,144
Cash and short-term deposits, beginning of year	3,352,991	2,716,847
CASH AND SHORT-TERM DEPOSITS, END OF YEAR	2,396,335	3,352,991

The accompanying notes are an integral part of the financial statements.

INTERNATIONAL POTATO CENTER — CIP

NOTES TO FINANCIAL STATEMENTS
as of December 31, 1989 and 1988
(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. The 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.

The 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.

In accordance with existing legislation and provisions of the Agreement described above, the 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 as 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, and of administrative costs of special projects.

c. Expenditures —
Prior to 1989, firm orders for purchases of fixed assets and services were recorded in the year of their commitment. At December 31, 1988, the amount recorded

under this practice totalled 892,740. As from 1989, the afore-mentioned firm orders are being accounted for when the actual liability arises.

Expenditures made by international programs are recorded on the basis of reports 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 costs of replacement 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. Accounts receivable from donors

At December 31, 1989 this account includes a core contribution receivable from the Inter-American Development Bank (IDB) for 1,650,000. IDB's dollar contributions to the Center are transferred via the Central Bank of Peru and converted to intis at the official government rate, rather then at the free market rate. At the year end, the official rate is about 40% of the published free market rate, which is the rate with which the Center operates. If this situation were to prevail, when the donation is finally received, the Center would receive some 1,000,000 less than the Bank's actual dollar contribution.

4. Loans to executives and employees and long-term debt

The 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, 1989, outstanding loans obtained from Citibank N.A. amount to 40,130 (157,409 in 1988), which 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:

	1989	1988
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	40,130	157,409
Loans funded by CIP, repayable over a one to three year-period, bearing interest (as from 1988) at the New York prime rate plus 1.5% of 11.5% per annum and secured by employees' homes	137,572	35,107
	177,702	192,516
Less current portion	(153,450)	(118,304)
	24,252	74,212

In addition, at December 31, amounts outstanding under the term loan from Citibank N.A. are as follows:

	1989	1988
Current portion (Note 7)	40,130	102,172
Non-current portion (maturing 1989-1990)	-	55,237
	40,130	157,409

These amounts are guaranteed by a portion of a deposit of 325,131 (203,578 in 1988) in the aforementioned financial institution, which earns interest at 7.5% per annum (8% in 1988).

5. **Accounts receivable — Other**

This balance is comprised of the following at December 31:

	1989	1988
Advances to organizations for research work	359,609	264,150
Travel advances	33,895	72,399
Advances to contractors and other	246,806	113,267
Claim to insurance company	198,370	-
Other	12,150	46,280
	850,830	496,096

6. **Fixed assets**

Fixed assets at December 31, comprise the following:

	1989	1988
Buildings and constructions	3,853,956	3,709,009
Research equipment	1,852,690	1,779,833
Vehicles and aircraft	5,056,850	4,828,323
Furniture, fixtures, and office equipment	1,662,300	1,330,152
Operating farm equipment	592,625	546,887
Installations	1,856,300	1,654,794
Site development	822,182	783,671
Communications equipment and other	576,562	581,217
Construction in progress	268,308	21,461
	16,541,773	15,235,347

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, 1989 is 644,933 (817,010 in 1988).

7. **Bank overdrafts and current portion of long-term debt**

At December 31, this balance is comprised of the following:

	1989	1988
Bank overdrafts	201,809	38,028
Current portion of long-term debt (Note 4)	40,130	102,172
	241,939	140,200

The CIP has various credit lines and loan arrangements with Citibank N.A. totalling 525,000 in 1989 and 1988, which bear interest at the New York prime rate plus 1.5%.

8. **Grants pledged**

During 1989, the following donations were pledged to the CIP for special projects in 1990 through 1993:

	1990	1991	1992	1993
International Development Research Centre - Canada	101,000	-	-	-
Swiss Development Cooperation and Humanitarian Aid	1,965,955	1,304,746	528,730	-
United States Agency for International Development	404,875	22,500	-	-
Netherlands Government	239,808	78,540	-	-
Rockefeller Foundation	209,000	-	-	-
Belgian Government	446,400	446,400	446,400	-
Federal German Government Agency for Technical Cooperation - GTZ	148,186	106,375	95,565	81,075
	3,515,224	1,958,561	1,070,695	81,075

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