
CIP 19

Cover:
These children, in the Kalam Valley of Pakistan's northern hills (2000 m), are helping to sort seed potatoes that have been stored for six months in pits. CIP and its collaborators, like the Pakistan-Swiss Development Project, are working to improve nutrition and farmers' income through improved production and storage systems.

International Potato Center

Annual Report 1988

INTERNATIONAL POTATO CENTER
Apartado 5969, Lima, Peru

1988

The **International Potato Center (CIP)** is a nonprofit, autonomous scientific institution established in 1972 by agreement with the Government of Peru for developing and disseminating knowledge for greater use of the potato as a basic food 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.

CIP received funding in 1987, through the CGIAR, from the following donors: the governments of Australia, Austria, Belgium, France, Germany, India, Italy, Japan, Mexico, Netherlands, Norway, People's Republic of China, Philippines, Spain, and Switzerland; the Canadian International Development Agency (CIDA); the Danish International Development Agency (DANIDA); the European Economic Community (EEC); the Inter-American Development Bank (IDB); the 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.

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Foreword

The strength of the International Potato Center can be measured by the quality and quantity of collaborative bridges established with scientists and institutions in both developed and developing countries within the public and private sectors who work on priority problems of potato and sweet potato improvement in the developing world. The collaborative bridges are a major source of help for solving priority problems and channeling information and material to clients. They also provide feedback, evaluation, and constructive criticism of CIP's program and help us to improve our service to developing countries. The bridges may be through a collaborative project or research contract, a country research network, a regional program, or a research planning conference.

Until recently, CIP's collaborative bridges were mainly with public-sector institutions responsible for agricultural research, training, and extension. However, CIP has now established a number of collaborative bridges with private institutions. Collaboration by institutions such as ours with the private sector has been frequently questioned in the past, due at times to the exploitation of developing countries by multinational companies. Thus, we have to ensure that collaboration with the private sector is for the genuine good of developing countries.

During recent years, an increasing proportion of agricultural research in many countries has been conducted by the private sector. This is particularly true in developed countries where funds are even more scarce for agricultural research in national and regional institutions. Furthermore, in the development and use of the new tools of biotechnology, collaboration between the public and private sectors is essential because of the high costs involved and the complexity of the problems being addressed. In fact, due to the necessity of collaboration in biotechnology, a global approach to agricultural research is evolving, which will use the comparative advantages of both the public and private sectors across the developed and developing worlds. This should allow for a more cost-effective approach to agricultural research than in the past.

Through collaborative bridges into the private sector of the developed world, the international agricultural research centers can make sure that the new tools of biotechnology do not bypass the needs of the developing world. We must maintain a window on the developed world's advances in biotechnology in order to best serve our clients across the developing world wherever a practical application can be identified.

As we establish collaborative bridges with private sector institutions, our objectives have not changed; neither have our clients. We still work for farmers of the developing world to help them improve potato and sweet potato production. Through collaborative bridges we are also getting the private sector to serve our clients. The public sector alone can no longer face the costs of the many problems in food, population, and environment. We must learn how to collaborate with the private sector in a way that is beneficial for both them and our clients, without exploitation.

Richard L. Sawyer

Richard L. Sawyer
Director General

Board of Trustees

Executive Committee

Program Committee

CIP's Move into Sweet Potatoes

A Chinese farmer prepares sweet potato cuttings for planting

In the future, sweet potato, more than any other major world food crop, should have the greatest potential for much of the world's land and people. Presently, it ranks third in value of production and fifth in its contribution of calories to the people of developing countries. As populations increase and more marginally productive land comes into use by farmers with scarce investment resources, this low-input crop could become an increasingly important world food resource.

More than a decade ago, in 1972, CIP was incorporated into the newly established CGIAR system of agricultural research centers to concentrate specifically on the potato, *Solanum tuberosum*. At that time, CIP did not attempt to add other tuber and root crops to its program, even though they were included as part of its mandate.

Recently, the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) produced a study on priorities for the CGIAR system. In the balance of investments among food commodities, the study indicated that sweet potato was considerably underfunded by a ratio of eight times in relation to its global importance. At the same time, an impact study of the centers by the CGIAR Secretariat inferred that the most successful centers were the commodity centers, in particular those working with only a few commodities.

CIP's Research Program and Sweet Potato

Shortly after the early drafts of the two studies emerged, several members of the TAC and several major donors to the CGIAR system asked CIP if sweet potato had ever been considered as being included in the Center's research activities. Serious consideration was given by CIP staff and the Board of Trustees to adding sweet potato to CIP's research program; and, informal meetings were held with the directors of the centers already working on this crop. In 1985, CIP's Board of Trustees formally approved the move into sweet potato and gave permission to use up to five percent of CIP's current funding for research.

In 1986, CIP was given official endorsement by TAC to include research on sweet potato in addition to the Center's long-standing research activities on the potato. CIP, being located in the center of origin of both potato and sweet potato, would be in an excellent position to collect and maintain a major sweet potato germplasm collection and could use its already well-established tissue culture and virology units to clean up the material before it is distributed worldwide through CIP's regional network system.

A Joint Approach to Sweet Potato Research

Already working on sweet potato within the CGIAR system were the International Institute of Tropical Agriculture (IITA), and the International Board for Plant Genetic Resources (IBPGR), with its germplasm mandate. Also, associated with the CGIAR system was the Asian Vegetable Research and Development Center (AVRDC), with sweet potato as one of its six commodities. A meeting, sponsored by the German Agency for Technical Cooperation (GTZ), was held in Germany in 1986 with participation by CIP, IITA, AVRDC, and the CGIAR Secretariat to look at a joint approach to sweet potato research and what role CIP would play. The goal was for CIP to complement the substantial progress already made by IITA, AVRDC, and other institutions around the world. During this same period, IITA was already reevaluating its program, which had a broad mandate covering a large number of commodities. Eventually, IITA's Board of Trustees decided, based on the results of an external program review, to drop sweet potato research from its mandate, even though the Center would continue some sweet potato work in the context of African root and tuber crop country networks and national programs.

In early 1988, an agreement was developed between IITA and CIP and has now been signed, which passes IITA's sweet potato germplasm collection and breeding lines to CIP. IITA has sent a letter to the African countries, informing them of the change in its mandate and that CIP will provide sweet potato germplasm and technical information to IITA's networks and its farming systems research involving sweet potatoes.

National Research Priorities

There have been intensive discussions with national program scientists and other experts from developed and developing countries to address national research priorities for sweet potato improvement. A formal planning conference has been held at Lima and a series of workshops have taken place in Latin

America, Asia, and Africa to help determine priority research areas for which CIP has a comparative advantage and how inter-institutional collaboration could be developed.

CIP's Sweet Potato Collection

Already, CIP has accumulated, through collaborative projects, donations, and collecting expeditions in Latin America, the largest collection of sweet potato germplasm in the world. Early support for these activities was provided by the International Board for Plant Genetic Resources. Rapid progress has been made in characterizing the CIP collection and valuable breeding materials have been identified. The Japanese Government is providing funds to build a new sweet potato germplasm unit at CIP, which should be completed by the end of 1988. CIP's virology team, which is highly competent in the detection and elimination of potato viruses, is now putting the same expertise to work with sweet potato to facilitate distribution of pathogen-tested germplasm around the world. This is being strengthened by collaborative research with North Carolina State University.

Collaborative Research on Production Constraints

Socioeconomic studies have already revealed some important global constraints to sweet potato production and utilization, and ongoing studies will be carried out in collaboration with the International Food Policy Research Institute (IFPRI). Two research contracts have been made with institutions in China—which produces and utilizes about 80 percent of the world's sweet potatoes—one at Xuzhou Institute for Sweet Potatoes and the other at Guangdong Academy of Agricultural Science, to catalyze the evaluation of Chinese sweet potato collections for characters important in removing major constraints to production and use in China and elsewhere.

CIP Program for Sweet Potato Improvement

Over the next five years, CIP's research program will gradually evolve so that by 1992, 60 percent of the program will be for potato and 40 percent for sweet potato improvement. CIP will continue to use the same developmental strategies that have been so effective in its work with worldwide potato improvement. CIP's plans include the following: continuing morphoagronomic characterization and disease and pest evaluation of the germplasm collection; continuing the identification of duplicate accessions in the collection (soon to be augmented by results of collaboration with the Institute for Biochemistry in Braunschweig, West Germany, where methods of duplicate identification have been developed); obtaining seeds for long-term conservation of the collection; ongoing development of cytological and in vitro techniques to facilitate germplasm exportation; refining in-vitro introduction procedures for sweet potato and developing conditions for long-term storage in vitro; continuing collecting expeditions in Central and South America; and identifying sites for storing duplicate accessions.

Methods for routine in vitro propagation and germplasm distribution will be optimized. Breeding will be carried out for high yielding, early, and disease-resistant material with enhanced food quality and nutritional value. This work will be strongly reinforced through contract work with North Carolina State University.

Strong emphasis will continue on screening for resistance to pests and diseases, such as root-knot nematode; and a strong program will be developed for integrated pest management, especially of sweet potato weevil. Studies will continue on the response of sweet potato to water stress under high temperatures, as well as on effective propagation methods for sweet potato as affected by various crop habits and environmental conditions.

Through collaborative bridges, CIP and institutions working with sweet potatoes around the world are rapidly organizing and working on the major problems that exist with sweet potato production and utilization. This commodity will undoubtedly play an increasingly important role as the problems of food production, population growth, and environmental development are addressed.

Summary of Research and Regional Programs

Potato Germplasm Collection

Biosystematic research on potato concentrated on four little-known species of the taxonomic series Conicibaccata from Colombia and Ecuador: *Solanum colombianum*, *S. chomatophilum*, *S. flahaultii*, and *S. tundalomense*. These species were intercrossed, but only the combination *S. colombianum* x *S. tundalomense* and its reciprocal was successful in giving abundant fertile hybrid seeds. Studies are underway to determine whether failures in the other crosses were due to different endosperm balance numbers. Extensive utilization studies on the species *S. acaule* resulted in confirmation of its resistance to potato leafroll virus (PLRV) and potato spindle tuber viroid (PSTV). This further highlights the enormous potential of *S. acaule* for use in breeding programs. Resistance had already been found against potato viruses X and Y, *Pseudomonas solanacearum*, *Phythophthora infestans*, and other pathogens. Also, most genotypes of *S. acaule* are highly frost resistant. There appear to be no serious obstacles to the genetic utilization of this species.

Elimination of duplicates from the world potato collection continued. Electrophoretic analyses of accessions from previous donations of native potatoes from Peru and Bolivia confirmed the duplicate status of 497 of them. Thus the number of accessions that still have to be compared with those from the world potato collection has been reduced considerably. More than 2900 potato accessions are now under long-term storage in the in-vitro gene bank. Of these, 1670 clones are being kept as duplicates in the laboratory of the National Institute of Agricultural Research in Ecuador, with whom CIP has a contract for maintaining the collection. A computerized labeling system for the potato collection has been set up, which saves time and minimizes the risk of human error in labeling during the subculture steps.

Good progress was made in developing diploid populations with combined resistances, genetic diversity, acceptable tuber traits, and a relatively high frequency of 2n pollen production in order to facilitate 4x-2x crosses. Such germplasm enhancement at the diploid level is designed to facilitate the use of wild species with specific resistances and the hybridization of these species with tuberosum haploids. There was a significant increase over last year's population with respect to the number of genotypes that produce 2n pollen. This increase was almost certainly due to a higher frequency of the *ps* gene in the new 2x population. The *ps* gene determines the formation of parallel spindles during meiosis which, in turn, stimulates the formation of 2n gametes. Of the 2554 genotypes that produced 2n pollen, 402 had tubers with acceptable characteristics. Thus it was possible to carry out selection for good tuber traits exclusively within the group of 2n pollen producers. This material will now be screened for the resistances that had been identified in its parents, and the resistant genotypes will then be used in 4x-2x crosses.

A large number of diploid clones were evaluated for potential resistance to important diseases and pests. Sixty clones, the majority of which produce 2n pollen, were found to have resistance to root-knot nematode, 69 to bacterial wilt, 28 to early blight, and 19 to potato virus Y.

Research collaboration with the Weizmann Institute in Israel on potato has confirmed successful asymmetric protoplast fusions. One of the aims is to transfer nuclei of specific *S. tuberosum* clones into cytoplasm that confers the tetrad-type male sterility through cytoplasmic-nuclear interaction. Such male-sterile potato clones are needed to produce hybrid true potato seed (TPS). Many cybrids have been regenerated from fusions between *S. tuberosum* clones and various *Solanum* species. Fourteen out of 21 fusion products of the combination Y245.7 (the male-sterile cytoplasm donor with cytoplasm from the wild species *S. stoloniferum*) x Atzimba (the male-fertile recipient) produced male-sterile cybrids in Israel. Similar results were not obtained in Peru, suggesting that the expression of male sterility of at least some clones is influenced by environmental conditions.

In contract research with Louisiana State University to produce gene constructs for pest and disease resistance, a number of cDNA constructs have been inserted into *Agrobacterium*. These include constructs for production of the toxin protein of *Bacillus thuringiensis*, the production of chitenase for insect resistance, and the production of the family of Cecropins for bacterial resistance.

Sweet Potato Collection

During 16 collecting expeditions to seven Latin American countries, 579 cultivated sweet potato accessions were collected. This material included samples of weedy material, native cultivars, improved varieties, and advanced breeding lines. Wild sweet potato germplasm was also collected, representing eight wild *Ipomoea* species. Donations were also received from national programs, and duplicates of all collections were left with the respective national institutions in the countries visited. CIP's sweet potato collection now has 2900 cultivated and 488 *Ipomoea* accessions. More than

790 are now stored in vitro. All Peruvian cultivated sweet potato accessions that can be grown in the field at Lima have been characterized according to key morphological characters, using a revised list of descriptors developed at CIP. According to the data obtained, about 60% of the Peruvian cultivated sweet potato collection represents duplicates. Preliminary electrophoretic analyses verified the high degree of accuracy of the morphological analyses. Electrophoretic procedures are being further defined in German-funded collaboration with the Institute for Biochemistry in Braunschweig, West Germany.

More than 28,000 hand pollinations were carried out to obtain 4x interspecific hybrids between 6x cultivars and 2x *I. trifida*. The production of 2n pollen in the 2x *I. trifida* population was studied to investigate the possibility of sexual polyploidization in *Ipomoea*. Some plants that produced 2n pollen were crossed with 4x *I. trifida* material, and the hybrids that resulted from these crosses are being checked for their ploidy level. Since *I. trifida* is regarded as the ancestor of the cultivated sweet potato, sexual polyploidization through 2n pollen would enhance the prospects of using this species for the transfer of important characteristics from wild to cultivated germplasm.

Maintenance, Breeding and Distribution of Advanced Clones

There has been a major step forward in the development of the tetraploid population, which recombines factors controlling resistances or tolerances to diseases, pests, and environmental stresses. Immunity to PVY and PVX and resistance to PLRV has been achieved. Eighteen PVY-immune progenitors that carry a PVY immunity allele at the duplex stage have been identified. When intercrossed, these produce progenies with 97.2% immunity to PVY. Intensive research is in progress to identify duplex genotypes at loci for immunity to both PVY and PVX. Their identification and intercrossing will increase the joint immunity frequency from the present 56% to 94.5%. Good progress was made in selecting for a combination of high yield, earliness, heat tolerance, and immunity to PVY and PVX.

In the heat-tolerant, early maturing population, good progress was made in selecting for resistance to PLRV, early blight, late blight, and bacterial wilt. The goal of this population development is to provide national potato programs with genetic materials from which new potato varieties can be selected that carry several resistances.

In the Peru-Colombia-Mexico system of selecting for late blight resistance, earliness, and other attributes, the Colombian national potato program field-tested in Colombia 200 clones produced under quarantine conditions in Peru. Of these, 150 were selected for late blight resistance, earliness, and good tuber appearance.

Selection of progenitors with early blight resistance continued in Peru, and the clones CIP 378676.6 and Maine-47 will be cleaned up for regional distribution and use in breeding for early blight resistance. Genetic studies have confirmed that the heritability of early blight resistance is high, thus this explains the rapid progress already achieved in selecting for resistance to this disease.

A survey of CIP's breeding populations was started to evaluate these materials for their potato processing quality. Thirteen clones were selected for their high dry matter content and low reducing-sugar content and will be used as prospective progenitors. These clones have resistance to late blight, cyst nematode, bacterial wilt, and root-knot nematode. The aim is to select high-performing clones with sufficient processing quality for the warmer environments of tropical countries. At present such clones are unavailable.

Work of the national program in Senegal has identified seven high-yielding potato clones from CIP-introduced germplasm. In Pakistan, 25 clones that outyielded three commercial varieties and also exhibited improved resistance to late blight have been selected by the Pakistan Agriculture Research Council. Four CIP clones have been code-named in Inner Mongolia, China, and are ready for release. Their major attributes are high yield and resistances to PVX, PVY, and late blight. Clone B-71-240.2 (origin INTA, Argentina), recently released as a variety, is gaining popularity among potato producers in China.

Disease Research

A large population of new tetraploid material with resistance to bacterial wilt (*Pseudomonas solanacearum*) has become available. This material was tested in Peru as well as in CIP's regions for its resistance to bacterial wilt, agronomic performance, adaptation to specific sites, and, in some instances, for tuber dry matter content. Several tetraploid true potato seed (TPS) families from Austria showed high levels of resistance to bacterial wilt. The best Austrian family, STANM SL-24 983, was highly resistant to a Brazilian and Peruvian strain of *P. solanacearum* with 77.3% and 88.9% of resistant genotypes, respectively. Contract research with the University of Wisconsin has resulted in the production of useful monoclonal antibodies against strains of *P. solanacearum*. In work at Wisconsin with callus tissue culture, it was shown that when these cultures from resistant and susceptible potato clones were grown, they exhibited the same differential responses to *Pseudomonas* as the clones themselves.

In Kenya, clone 800224, with bacterial wilt resistance, has been released to farmers as a new variety, "Kenya Dhamana." In the Philippines, several advanced clones showed good wilt resistance, and yields ranged from 27 to 45 tons per hectare. Results from a survey in China on bacterial wilt disease in several provinces indicated that clone MS-42.3 continues to show resistance to *P. solanacearum*, race 3. CIP clone 377852.2 (BR-63.74 x WRF 1923.1) was resistant to all races.

Through a contract with the University of Wisconsin, an attempt was made to produce a *P. solanacearum*, race 3 specific diagnostic method. Restriction fragment length polymorphosisms (RFLP) of the genomic DNA were prepared for 53 strains of *P. solanacearum*, representing four biovars and three races, so as to assess their relatedness by Southern blot analysis involving cloned DNA fragments in plasmids as probes. This method has facilitated the distinction between many strains of *P. solanacearum* by both race and biovar simultaneously.

Ecological studies on bacterial soft rot *Erwinias* showed that weed species growing in shallow streams support large populations of this bacteria. A rapid test was developed to screen potato for resistance to *E. chrysanthemi*, and a strong interaction between fungal infection and Erwinia rots was observed.

In continuing efforts to produce cultivars resistant to late blight (*Phytophthora infestans*), CIP is carrying out work with two breeding populations. The traditional population (Population A) has been developed primarily from *Solanum tuberosum* ssp. *tuberosum* germplasm, which includes resistance derived from *S. demissum*. The newer population (Population B) is free of major genes for late blight resistance and should eventually provide durable field resistance that could be screened effectively wherever late blight is a problem. From Population A, in collaboration with the Peruvian national potato program of INIPA, 204 clones were selected for resistance to late blight in combination with earliness and desirable agronomic characters. From Population B, based on intercrosses between *S. tuberosum* ssp. *andigena* clones, some levels of horizontal resistance have already been identified. Clones with late blight resistance were evaluated in the Philippine highlands by the Mountain State Agricultural College. Yields were good, with some clones yielding over 20 tons per hectare and some as high as 39 tons.

Good progress was made in improving resistance to early blight (*Alternaria solani*), although it is sometimes linked to lateness. Scientists at the National Center of Horticultural Research in Brazil selected 74 clones with early blight resistance for further testing, and CIP's scientists selected 12 clones for global use.

CIP has made good progress in the chemical control of soil-borne pathogens at Lima and San Ramon, where their presence is limiting CIP's research. Clones from the CIP pathogen-tested list were evaluated for resistance to *Verticillium dahliae* and differences in resistance were found. Several andigena clones with resistance to *V. dahliae* were identified in Colombia, where this pathogen is becoming increasingly important. New sources of immunity to powdery scab (*Spongospora subterranea*) have been identified as well as sources of resistance to *Fusarium oxysporum* and *F. solani* that cause dry rot. As part of the agreement with the Research Institute of Plant Protection in the Netherlands, a second survey was conducted in November 1986 on potato diseases in several regions of Colombia. Several diseases, particularly *V. dahliae*, were rated as serious. Existing methods of control used by farmers were noted and recommendations were made on how to improve some of these practices.

Training activities increased on bacteriology with courses being held in China and Central Africa, and individual studies at CIP headquarters in Peru. The course participants worldwide represented potato programs or educational institutions in Brazil, Burundi, Colombia, Ecuador, Equatorial Guinea, Peru, Netherlands, Venezuela, and Zaire.

It was confirmed that potato clones with resistance to both PVX and PVY are less acceptable to damage by PLRV. Thus, in order to develop sustainable PLRV-resistant genotypes, a background resistance to PVX plus PVY is required. New sources of resistance to PLRV, PVY, and to the HB strain of PVX have been identified and selected. Some excellent materials with resistances to PLRV, PVY, and PVX alone or in combination have been selected through trials performed in Brazil, Peru, Uruguay, and Tunisia. Good agronomic traits have been found.

Screening for resistance to PLRV has been streamlined by aphid inoculation of sprouted tubers versus inoculating plants grown from apical cuttings. This new approach is less time consuming and requires lower labor input. Also, tuber inoculation generally resulted in higher levels of infection than did plant inoculation. Variability among geographically diferent isolates of PLRV was found in their transmission by aphids but not in their serological properties. Histopathological studies on PVY-susceptible and PVY-immune clones suggested that immunity to PVY involves a virus-induced mechanism of resistance rather than a constitutive one.

Research on potato virus epidemiology in Tunisia on potato seed tubers multiplied in consecutive generations concluded that the buildup of vector pressure does not increase constantly, the spread of PVY and PLRV remains very limited, the buildup of PVS is important, and the yield of third generation seed in Tunisia is comparable to yield of imported seed.

The whitefly (*Trialeurodes vaporariorum*) was identified as a vector of the agent causing "yellow vein" syndrome in potatoes in Colombia. It was shown that virus SB-22, which can cause TPS necrosis and 25% to 93% reduction of germination, is morphologically similar, but serologically distinct, from the alfalfa mosaic virus.

A method to detect PSTV without the use of a radioactive probe was developed in collaboration with the University of Inner Mongolia, China. This will facilitate sensitive testing in the absence of radioactive supplies and suitable facilities. A new kit using nitrocellulose membranes as a supporting medium in ELISA has been developed to detect potato viruses. The technique has been used to detect PVA, PLRV, PVY, PVX, and other potato viruses, as well as some sweet potato viruses. At CIP, this technique is considered as a potential tool to monitor sustained resistance to viruses in germplasm sent to different countries.

A strain of sweet potato feathery mottle virus (SPFMV) has been identified. A polyclonal antiserum produced against this strain has been in ELISA serology for routine detection and comparison of other Peruvian isolates of SPFMV.

Integrated Pest Management

Collaborative research with the Peruvian national potato program of INIPA has resulted in the release of the first variety with resistance to potato cyst nematode, *Globodera pallida*. The new variety, "Maria Huanca," is resistant to races P_4A and P_5A of *G. pallida*, tolerant to late blight, immune to PVX, hypersensitive to PVY, and resistant to races 1 and 2 of potato wart. It has red skin, oblong shape, and is a high yielder.

New sources of resistance to the root-knot nematode (*Meloidogyne incognita*) have been identified in potatoes (4x-2x crosses and diploid clones) and in sweet potatoes. Most of the resistant sweet potato accessions were also resistant to the root lesion nematode, *Pratylenchus flakkensis*. At the University of Los Baños in the Philippines, solarization was effective in controlling sweet potato infestation by the nematodes, *M. incognita*, *Rotylenchulus reniformis*, and *Hemicycliophera* sp. It was also found that in potato the fungus, *Paecilomyces lilacinus*, was even more effective than the nematicide Furadan in controlling *G. rostochiensis*.

Various levels of resistance to potato tuber moth (*P. operculella*) were confirmed in most of the 173 clones tested in Peru. Improvement of resistance at the diploid level was effective. There is high heritability of resistance to this important pest. Good protection against tuber moth in stored tubers was given by application of granulosis virus isolates from Peru, Tunisia, Australia, and India. When tubers were infested 90 days after virus application, 78% of the larvae became infected with the virus. In stores, applications of microcapsulated tuber moth pheromone were effective in reducing the rate of moth reproduction. The level of infested tubers in the treated store was three times lower than that in the non-treated store. Also, the use of dried, crushed *L. camara* or the insecticide Decamethrin (Decis) was effective in controlling tuber moth in consumer potato stores in three Bangladesh locations.

New sources of resistance to the Andean potato weevil, *Premnotrypes suturicallus*, and the potato leafminer fly, *Liriomyza huidobrensis*, have been identified. Resistance to the sweet potato weevil, *Euscepes postfasciatus*, has been found in 15 sweet potato accessions from CIP's germplasm.

Warm and Cool Climate Production

Several early maturing and heat-tolerant potato clones have been selected as a result of using progenitors with a high general combining ability for adaptation to warm and hot climates. In Vietnam, potato clones have been selected with exceptionally good storage characteristics under high temperatures for nine months and resistances to viruses and late blight. The best virus resistance resulted from the use of CIP progenitor 7XY.1 as the male parent.

Experiments were carried out in Peru on the role of nitrogen fertilizer in the adaptation of potato to mid- and low-elevation tropics. Despite the intensive heat stress in the central jungle of Peru, at Puerto Bermudez, clone LT-7 produced 15.2 tons per hectare with an average of 19.3% tuber dry matter content while cultivar Desiree yielded only 3.5 tons per hectare with an average of 10.1% dry matter. Clone LT-7 also outyielded Desiree as well as Katahdin in San Ramon under warm but less stressful conditions. In both dry and wet seasons, the amount of dry matter partitioned to the tubers decreased with increased application of nitrogen fertilizer.

In studies on the response of potato clones to drought in warm locations, it was found that reduced canopy development contributed to yield reduction in plants exposed to longer drought periods. A gradual decline in marketable yield was noted in the drier environments, and apparent water use efficiency in heat-adapted clones ranked lower in these environments.

The effect of heat stress on two planting materials of potato leaves was examined using a membrane thermostability test and a visual score. These tests gave results that are highly correlated and that can be used to evaluate clonal ability to tolerate heat-induced membrane damage and canopy survival, but not dry matter partitioning for which yield tests are necessary.

In an attempt to reduce the high cost of seed in the warm tropics, experiments were conducted on seed cuttings in Vietnam and the Philippines. Cut seed pieces produced yields equal to those of whole seed, with consistent results in both countries. This approach could reduce seed costs significantly for farmers, providing that they are trained properly in the use of this method.

Improvements have been made in the development of frost-tolerant potatoes. A total of 520 clones were selected in the central Andes of Peru for relatively high yields despite severe frost 85 days after planting. This was the result of early tuberization, fast tuber bulking, and frost tolerance.

A survey of foliar blight distribution in the cold climates of Peru was concluded. It revealed that *Alternaria* is distributed in mid and low elevations below 3000 meters, *Phoma* is found in the Andean valleys at altitudes between 3200 and 3300 meters, and *Septoria* is distributed mainly above 3500 meters. Also in Peru, field tests with 30 varieties and cultivars in a field with natural *Phoma* infestation indicated that four varieties exhibited good resistance to this pathogen.

Postharvest Technology

Storage research on storage of consumer potatoes was carried out in the warm climates of Peru, Thailand (where Thrust VIII is now located), and Pakistan. Experiments on integrated control of postharvest losses caused by storage pests, storage diseases, water loss, and early sprouting showed several interactions between treatments. Evaporative cooling of potato stores reduced tuber weight losses during storage and also deterred natural infestation by tuber moth. Tuber rotting was reduced when tuber moth was controlled by dried, insect-repellent foliage or by evaporative cooling. The sprout inhibitor CIPC inhibited sprouting of tubers stored in cool highland areas and reduced tuber weight losses; however, in warm areas, CIPC did not inhibit sprouting and it caused tuber rotting.

A strong focus was maintained on methods to evaluate seed storability of genetic material under warm conditions during prolonged storage periods. Over 50 advanced clones, most of which are on the CIP pathogen-tested list, were assessed for storability in a cool (Huancayo) and in a warm site (San Ramon). The seed tubers of each clone stored in both sites were planted in one location (Huancayo) for comparison of field performances. A storability index for each clone was calculated, which ranged from 0.39 (poor seed storability) to 0.94 (excellent storability). The incubation period—the time between onset of sprouting and tuber formation on the sprouts—was also determined for each clone. Clones with a short incubation period usually have poor seed storability. It was found that the incubation period is particularly useful for comparing a large number of clones, whereas the storability index is more suitable for characterizing seed storability of a limited number of clones. The data obtained are of particular importance to many national potato programs, who are now considering seed storability as an important factor in evaluating genetic material.

In potato processing, emphasis continued on technology transfer to produce dehydrated potato-based foods that are acceptable to consumers. Low-cost, commercial processing units are now operational in Peru and India. In Peru, methods to produce dehydrated French fries have been developed for local low-cost processing and excellent products have been produced. Consumer tests have shown good acceptability of these products. Testing of various solar drying systems for different potato products and different quantities has continued in Peru.

In Thailand, 25 clones were evaluated for processing and cooking quality with 9 being selected for further testing. A study was carried out on marketing, consumption, and demand for potatoes and potato products in Bangkok. It showed that as household incomes increase in Bangkok, potato consumption appears to increase both in processed and fresh forms.

Seed Technology

A major focus of the TPS breeding work was on testing advanced progeny selections for tuber yields under a wide variety of locations with different climates and daylengths. Clones AVRDC-1287.19, 377964.5, and LT-8 were good combiners for wide adaptation in TPS crosses and most crosses had a high degree of adaptation to short-day conditions. Twenty-six crosses were found to have an acceptable tolerance to early blight and late blight diseases during seedling screening.

An index criteria for acceptable TPS vigor was developed, using both the coefficient of velocity of emergence calculated from daily counts 0-10 days after sowing at greater than 25 degrees, and seedling dry weight after 17 days. Data showed that seedling vigor evaluations among different TPS crosses must be conducted using nondormant (greater than 6 months after harvest) seed. Although the standard treatment with gibberellic acid (GA) was shown to promote final emergence in dormant TPS, seedling vigor was impaired by GA. Priming TPS in solutions of low water potential was found to be the most effective presowing treatment for optimizing seed vigor in nondormant TPS.

In two crosses, the optimal stage of TPS maturity at harvest was 10 to 12 weeks postpollination. Nevertheless, the maturity of berries from the cross, Atlantic x LT-7, could not be extended beyond nine weeks. Seedling vigor in this cross was superior to the other crosses tested. The importance of proper storage conditions for preserving vigor prior to testing was clearly demonstrated in all seed tests. Eight open-pollinated progenies were identified with acceptable performance in a large-scale screening test for germination at high temperatures. Pollen selection and seed size separation techniques were found promising in certain crosses for the enhancement of progeny uniformity characteristics.

Continuing international TPS trials have resulted in the identification of several new progenies for use by national programs. Three TPS progenitors—C83.199, 377964.5, and Maine-28—were introduced into the seed program for cleanup. Following several testing cycles, two new potato progenitors, 377250.7 and C83.551, are now ready for cleanup. All of these progenitors transmit yield, earliness, and tuber uniformity. Ten TPS progenies that maintain a stable yield from the F_1 generation through four generations of successive open-pollination have been identified. This will facilitate the use of TPS by farmers, since they will be able to produce needed TPS from open-pollinated berries produced in their own fields.

The superiority of raised bed systems for seedling transplanting was confirmed this year with respect to yield advantages. The application of a layer of gypsum to the soil surface during seedling tuber production in beds increased tuber yields and acted as an effective tuber moth control system.

The most important pathogens causing damping off in seedlings are in the AG-3 group or race of *R. solani*. These organisms were shown to be present only in cool areas while the more pathogenic AG-4 group was found in the warmer areas.

Potato flowering was increased with a four-hour night interruption of the night period under short-day environments. Factors involved in reducing TPS yields generally included increasing stem densities and berry loads per plant, as well as producing the berries at the end of the flowering period (in lower order inflorescences). The collaborative project between INIA in Chile and CIP on commercial scale TPS production determined that the average costs of non-emasculated TPS were US$246 per kilogram, ranging from $128 to $307 depending on the cross. Pollination tasks—especially labor and technical management costs—were the most expensive inputs in TPS production. The collaboration between CIP and INIA will continue for a fourth season, but a foreign commercial seed company is interested in contracting large-scale TPS production by farmers. This will probably start in 1988-89 with several hectares of production.

It was shown that warm climate-produced seeds (tubers, cuttings, and TPS seedlings) are likely to yield lower than those produced in cooler areas. The production efficiency of cuttings was lower than that of seed tubers, but the larger size of tubers produced from cuttings still makes this alternative suitable for direct production of consumer potatoes.

A case study conducted in the Philippines showed that institutional and nontechnical factors are closely associated with the level of success of a seed potato program. In Burundi, the basic seed production program has redesigned the strategy to eliminate latent bacterial wilt disease. This new system is based on in-vitro micropropagation methods with subsequent transplanting of plantlets to large plastic bags for production of small tubers. The use of sprout cuttings for planting material is now well advanced in Vietnam.

The developmental responses of 15 sweet potato clones (sweet potato true seed, cuttings, and in vitro materials) to six different environments in Peru were studied, and considerable variation was observed. Several techniques such as graft-scion compatibility, stock and scion conditioning under short days, and obtaining scions at the onset flowering have improved the effectiveness of grafting in flower promotion.

Potato and Sweet Potato in Food Systems

Research continued on trends in root crop production and use. It was found that since 1960 total root crop production has declined in developed countries and expanded in developing countries. More than 800 sweet potato publications have been reviewed that focus on the various chemical, technological, and nutritional aspects of this crop. A questionnaire survey on constraints to sweet potato production in selected countries indicated that insect damage and marketing problems were of major importance.

Agroecological potato maps, organized by latitude-longitude coordinates, were developed and computerized for 121 countries, and available data on climate, altitude, and population were transformed into overlays. This information shows that in developing countries the potato is produced in ten distinct climates: 44 percent of total production occurs in lowland tropics with a cool to humid winter, mainly in Asia; 11 percent derives from hot, dry lowland climates; 5 percent comes from hot, humid climates; and the highland regions and temperate zones account for about 20 percent each. This distribution by climate shows that even though the potato is already grown in more countries of the world than any other food crop except maize, the possibilities for expansion are quite great.

In case studies on nine national potato programs, it became apparent that strong national commitment and clear priorities are of major importance if production goals are to be met. The study on China contains the most complete collection of national and provincial historical and current statistical materials of potato and sweet potato available in any language.

Seed programs received continued attention through questionnaires and case studies of developed and developing countries. For programs in developed countries, a comparative study of seed sectors in the Netherlands, Canada, and the United Kingdom was undertaken. The importance of up-to-date socioeconomic data in promoting the use of improved seed and varieties was clearly illustrated by studies in Peru on true potato seed sources and on traditional seed flows.

Potato marketing surveys in Bangladesh, Bhutan, Central Africa, Madagascar, Peru, and Thailand have been completed. The highlights include the importance of understanding the complexity of potato markets, the distinct marketing patterns for large versus small growers, and the need for lower potato prices to induce even greater consumption. Attempts have been made to stimulate countries to engage in mutually beneficial marketing research by helping them to develop a network approach.

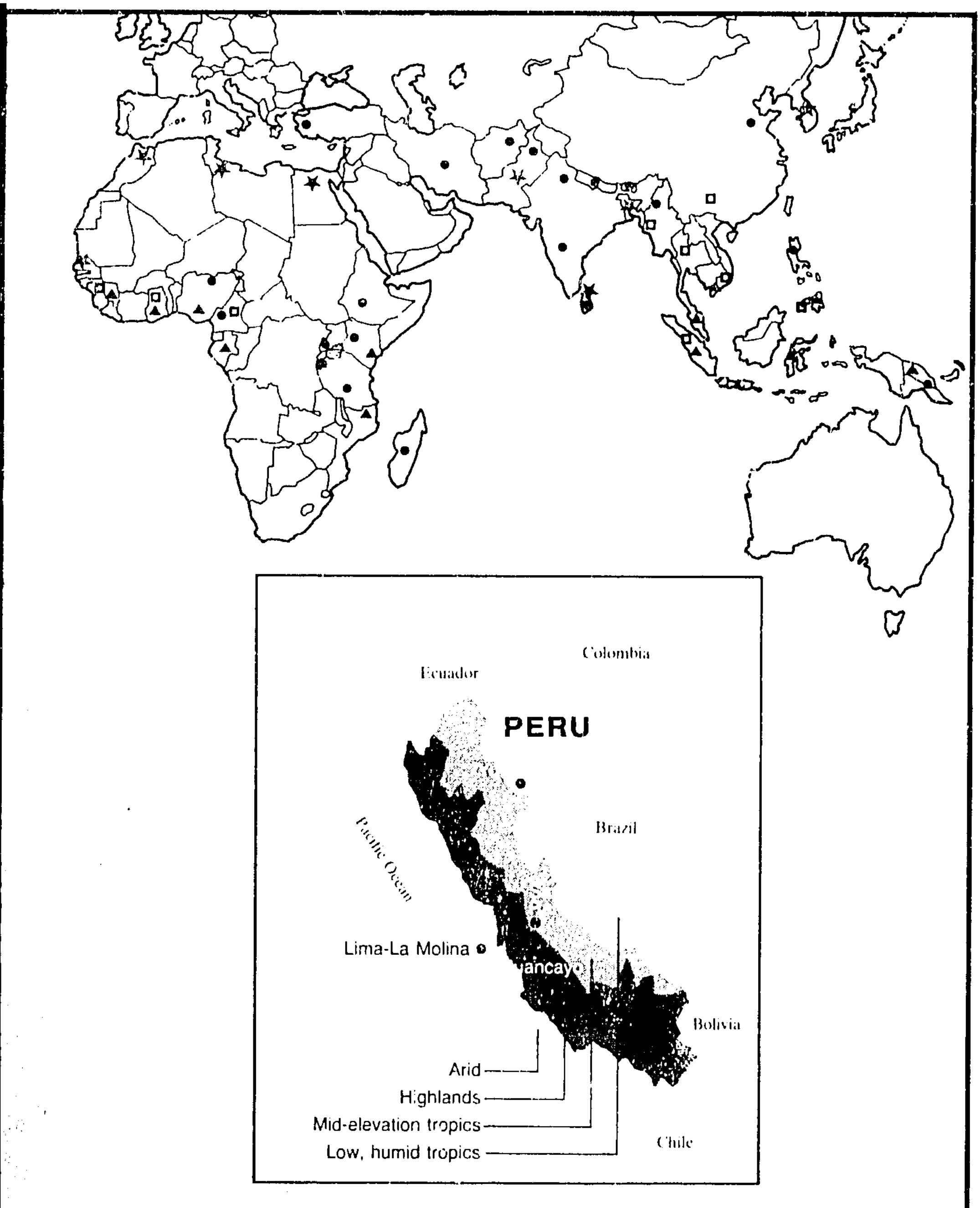
Relationship of Agroecological Zones in Peru to CIP's Regions Worldwide

The cultivated potato originated on the high plains (*altiplano*) in what are now parts of Peru and Bolivia. This center of diversity is not only for the potato but also for its major pests and diseases. The sweet potato originated in South and Central America and the Caribbean in lowland tropical conditions. CIP has already collected over 3388 cultivated and wild accessions from this region, which are maintained in its lowland stations in Peru.

CIP has four experiment stations located between latitudes 6° and 12° S that represent the four major agroecological zones of Peru: Lima-La Molina, arid; Huancayo, highlands; San Ramon, mid-elevation tropics; and Yurimaguas, low, humid tropics. The geographical location of CIP's stations ensures wide variation in altitude, temperature, rainfall regimes, soil types, and incidences of pests and diseases. All major climatic characteristics of tropical zones found in the developing world are represented within Peru's four agroecological zones.

CIP research sites in Peru and the potato-growing seasons, with meteorological data for 1987.

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	May-Nov	Nov-May	Nov-Mar	May-Aug	May-Aug
Air max (° C)	28.54	21.11	21.81	30.57	29.96	30.93
Air min (° C)	20.44	15.36	6.61	18.47	16.01	19.93
Evaporation (total mm)	519.09	624.67	1050.92	832.21	555.14	312.00
Rainfall (total mm)	0.8	1.19	490.10	1210.75	265.20	459.30
Solar radiation (daily MJ/m^2)	15.08	9.55	22.19	17.55	17.39	no data



Colombia
Ecuador
PERU
Brazil
Pacific Ocean
Lima-La Molina
Bolivia
Arid
Highlands
Mid-elevation tropics
Low, humid tropics
Chile

Collection, Maintenance, and Utilization of Unexploited Genetic Resources

Biosystematic research on potato concentrated on four little-known species of the taxonomic series Conicibaccata from Colombia and Ecuador: *Solanum colombianum*, *S. chomatophilum*, *S. flahaultii*, and *S. tundalomense*. Studies on disease resistance were carried out on the species *S. acaule*, and resistances to potato leafroll virus as well as potato spindle tuber viroid were identified and confirmed. Elimination of duplicates from the world potato collection continued with the help of electrophoretic analyses. More than 2900 accessions are now maintained under long-term, in vitro storage conditions, and duplicates of the in vitro potato collection are being maintained outside of Peru.

Progress was made in potato germplasm enhancement, using haploids, wild diploids, and 2n pollen. In collaborative research with the Weizmann Institute in Israel, protoplast culture and fusion have been successful in producing male-sterile plants through asymmetric fusion. During 1987, CIP initiated contract research with Louisiana State University in the United States to produce gene constructs for pest and disease resistance for use in genetic engineering projects at CIP.

During 1987, 16 expeditions to collect cultivated and wild sweet potato germplasm were made in seven Latin American countries. A total of 579 cultivated accessions were collected. Additionally, 251 wild species accessions were collected and have been included into CIP's sweet potato gene bank, which now has 2900 cultivated and 488 wild *Ipomoea* accessions. Significant progress was made in introducing sweet potato materials to the in vitro bank, and more than 700 accessions are now stored in vitro. A total of 28,866 hand pollinations were carried out to obtain 4x interspecific hybrids between 6x cultivars and 2x *I. trifida*. The production of 2n pollen in a 2x *I. trifida* population was studied to investigate the possibility of sexual polyploidization in *Ipomoea*. Some plants that produced 2n pollen were crossed with 4x *I. trifida* material, and the hybrids that resulted from these crosses are presently being checked for their ploidy level. Since *I. trifida* is regarded as the ancestor of the cultivated sweet potato, sexual polyploidization through 2n pollen would enhance the prospects of using this species for the transfer of important characteristics from wild to cultivated sweet potato germplasm.

Ecuadorian scientists collecting Andean potato samples at Saquisili Market along with other Andean root crops.

BIOSYSTEMATIC STUDIES ON POTATO

Biosystematic research concentrated on four little known potato species of the taxonomic series Conicibaccata from Colombia and Ecuador. *Solanum colombianum*, *S. chomatophilum*, *S. flahaultii*, and *S. tundalomense*. These four species were intercrossed to study their crossability with each other and to determine the biosystematic distance between them. Surprisingly only the combination *S. colombianum* x *S. tundalomense* and its reciprocal was successful in giving abundant fertile hybrid seeds. Other combinations were successful in only one direction and others failed completely (Fig. 1).

There is as yet no explanation for the problems or failures of crosses between species so closely related as are these from the same taxonomic series. One possible explanation could be that the different species involved in these crosses have different endosperm balance numbers (EBN), a hypothesis that needs to be confirmed through further crosses within the same taxonomic series.

UTILIZATION STUDIES

Major utilization studies on disease resistance were carried out on the species *S. acaule*. Fifty-four accessions of this species were tested for their resistance to the potato leafroll virus (PLRV), and 60 accessions were tested for their resistance to potato spindle tuber viroid (PSTV).

Resistance to PLRV was tested by inoculating the seedling material with PLRV infected aphids and then testing this material by the standard ELISA test. Genotypes found to be resistant after the aphid test were challenged again with a graft test. After the aphid test, 100 of 600 seedlings were found to be free of PLRV, and these 100 seedlings represented only 12 of the total 54 accessions. However, when these 100 seedlings were graft-

♀ \ ♂	col (4x)	chm (2x)	flh (4x)	tnd (6x)
col (4x)		◑	△	●
chm (2x)	△		△	△
flh (4x)	○	◑		△
tnd (6x)	●	◑		

col *S. colombianum*
chm *S. chomatophilum*
flh *S. flahaultii*
tnd *S. tundalomense*

● Easy cross, abundant seed.
◑ Fairly easy cross, 10-15 seeds per berry.
○ Difficult cross, 1-4 seeds per berry.
△ Cross failed, no seeds.

Figure 1. Crosses between species of the taxonomic series Conicibaccata.

tested, only 10 were still resistant. These results demonstrated that the frequency of PLRV resistance in *S. acaule* is low (1.66%) and that it is not spread over the whole of the *S. acaule* population. On the basis of these results, more seedlings were tested from the 12 accessions that had contained resistant genotypes in the first set of tests. Out of 350 seedlings, 90 were found to have resistance after the aphid test, and graft tests of this material are still to be carried out.

In an extra set of tests, 131 genotypes from the six accessions with the highest frequency of PLRV resistance were challenged with the virus. Of these 131 genotypes, 94 were found to be resistant. These results confirmed that within the species *S. acaule* there are accessions with higher frequencies of PLRV resistance than are normally found in the population as a whole. It is not clear yet whether these accessions with a high frequency of PLRV resistance come from specific geographic areas. If they do, these areas need to be clearly identified.

One important result of this work has been the finding that PLRV-infected aphids have to be reared for three to four weeks on the *S. acaule* plants in order to achieve infection of the susceptible genotypes. The customary period for such aphid tests in regular cultivated material is only three to four days. During the aphid tests, it became apparent that *S. acaule* had a background resistance to the aphid itself.

From the same *S. acaule* gene pool, 750 seedlings, which represented 60 accessions, were challenged with PSTV by mechanical inoculation and then tested with the nucleic acid spot hybridization (NASH) test. More than 200 genotypes from 12 accessions appeared to be resistant to PSTV after mechanical inoculation. From these 12 accessions, another 600 genotypes were mechanically inoculated, and again about 200 genotypes were resistant. From this latter group, 49 genotypes were further challenged with PSTV by a third round of mechanical inoculation, a graft test with PSTV-infected tomato plants, and with two strains of *Agrobacterium tumefaciens*.

One of the two strains of *A. tumefaciens* had one sequence of PSTV incorporated into its genome and the other strain had two sequences of PSTV in its genome. The infection with PSTV carrying strains of *A. tumefaciens* was a novel way of challenging the plant with this pathogen. One of the 49 genotypes tested demonstrated resistance to all forms of PSTV challenge. In nature, mechanical inoculation is the only type of inoculation the plant is exposed to. Graft testing on PSTV-infected tomato plants represents a very severe test, however, many genotypes resistant to this type of challenge were identified. The infection tests with *A. tumefaciens* were carried out to obtain possible information about the mechanism of resistance in *S. acaule*. Resistance observed at the seedling stage was regularly confirmed at later stages of plant growth.

PSTV and PLRV resistance were never found together in one genotype. Crosses are under way to confirm whether these two resistances can be combined (Fig. 2).

Solanum acaule may be considered a unique wild potato species with many different types of resistances to biotic as well as abiotic stresses in its gene pool. Resistance has been found against potato viruses X and Y, PLRV, PSTV, *Pseudomonas solanacearum*, *Phytophthora infestans*, and other pathogens, and most genotypes of *S. acaule* are highly frost resistant. This long list of useful characteristics in one species certainly merits more research into the potential use of

Figure 2. *Solanum acaule* in a graft test for resistance to potato spindle tuber viroid (PSTV).

this species in breeding. Past research has demonstrated that there are no serious barriers to the genetic utilization of this species.

POTATO GERMPLASM COLLECTION

Collecting activities. A third CIP-INIAP (Instituto Nacional de Investigaciones Agropecuarias) joint potato collecting expedition, funded by the International Board for Plant Genetic Resources (IBPGR), went to the provinces of Bolivar, Chimborazo, Tunguragua, and Cotopaxi in Central Ecuador. A total of 151 samples were collected, representing up to 97 different genotypes of native cultivars. These materials are being compared with the samples collected in the two previous expeditions, as well as with the other accessions from Ecuador maintained in the CIP germplasm collection.

A donation of 651 samples of native cultivars from Argentina was received from the potato collection maintained at the Obispo Colombres station in Tucuman. Electrophoretic analyses of duplicate groups, established on the basis of tuber characteristics, showed that these 651 samples may represent 145 different genotypes. This number, however, will probably be further reduced as a more detailed characterization on plants grown in Tucuman is carried out by CIP.

The world potato collection. This collection of clonally maintained cultivated potato germplasm comprises 5165 accessions, which represent nine species and one group of diploid interspecific hybrids. Of the total of 5165 accessions, 764 are diploid, 310 triploid, 4053 tetraploid, and 38 pentaploid. The number of accessions for each species as well as for the group of interspecific hybrids is listed in Table 1.

Elimination of duplicates. Electrophoretic analyses of accessions from previous donations of native potatoes from Peru and Bolivia confirmed the duplicate status of 497 of them. Thus the number of accessions that still have to be compared with accessions in the world potato collection has been reduced considerably, and only those genotypes that are not represented in this main collection will be incorporated.

Progress was made in converting duplicate accessions into true seed, facilitating the elimination of these duplicates from the collection. Controlled pollinations made on plants growing in the field were compared with pollinations made on inflorescences of cut stems maintained in bottles in a screenhouse. The field pollinations gave significantly ($P = 0.95$) higher berry and seed set than the screenhouse pollinations. As a result of this massive pollination program, 410 duplicate accessions were discarded from CIP's clonal collection. For each discarded clonal accession, more than 4000 seeds were obtained for storage in the seed collection.

Study of genetic diversity. Preliminary studies on measuring genetic diversity within *S. tuberosum* ssp. *andigena* on the basis of isoenzyme analyses were carried out using 629 accessions. The enzyme systems used were phosphoglucomate isomerase, 6-phosphogluconate dehydrogenase, isocitrate dehydrogenase, malate dehydrogenase, acid phosphatase, gluconate oxaloacetate transaminase, and alcohol dehydrogenase. This research will be continued.

In vitro collection of potato germplasm. During 1987, further progress was made on the introduction of new accessions to the in vitro gene bank. More than 2900 accessions are now maintained under long-term storage conditions. Of this total, 1670 clones are being kept as duplicates in a laboratory of INIAP in Ecuador, with whom CIP has a contract for maintaining the duplicate collection. The INIAP laboratory sends quarterly reports indicating the growth status of the duplicates. In one year, the number of clones in the INIAP duplicate collection outside CIP has doubled as a result of increased distribution from CIP, Lima.

Table 1. The present status of the collection of cultivated potato species at CIP.

Ploidy level	*Solanum* species	No. of accessions
Diploid	*S.* x *ajanhuiri*	26
	S. goniocalyx	99
	S. phureja	43
	S. stenotomum	449
	Natural interspecific hybrids	147
Triploid	*S.* x *chaucha*	235
	S. x *juzepczukii*	75
Tetraploid	*S. tuberosum* ssp. *andigena*	3,789
	S. tuberosum ssp. *tuberosum*	264
Pentaploid	*S.* x *curtilobum*	38
Total		5,165

In an attempt to have better control of the increasingly large in vitro collection, CIP has set up a computerized labeling system which will save time and minimize the risk of human error in labeling during the subculture steps.

Monitoring the in vitro collection. During 1987, PSTV testing was carried out on all accessions of the in vitro collection (the part of the world collection transferred to in vitro as well as the pathogen-tested collection). Only one in more than 3000 accessions was found to be positive and had to be discarded. The one positive sample was found in the world collection.

In a CIP-funded contract with the Rothamsted Experimental Station, U.K., research concentrated on optimizing the tools for determining genetic stability of in vitro-stored potato germplasm. It is anticipated that in 1988 the frequency, if any, of gene modification during in vitro storage can be clearly defined. Restriction fragments patterns were found effective in determining possible genetic changes of in vitro-stored material.

POTATO GERMPLASM ENHANCEMENT

Diploid germplasm. One of the major objectives of potato germplasm enhancement at CIP is to develop diploid populations with combined specific resistances to diseases, genetic diversity, acceptable tuber traits, and a relatively high frequency of 2n pollen production in order to facilitate 4x-2x crosses. Such germplasm enhancement at the diploid level is designed to facilitate the use of wild species—of which the majority are diploid—with specific resistances and the hybridization of these species with tuberosum haploids.

A new 2x population was developed by intermating 2x clones that had been selected previously for their disease resistances. These 2x clones were evaluated for 2n pollen production and tuber traits in Huancayo. More than 50% of the 4554 seedlings from 126 families were found to produce 2n pollen. This is a significant increase over last year's population in which only about 20% of the genotypes produced 2n pollen. This increase is almost certainly due to a higher frequency of the *ps* gene in the new population. This gene determines the formation of parallel spindles (*ps*) during meiosis which, in turn, leads to the formation of 2n first division restitution (FDR) gametes. Out of the 2554 genotypes that produced 2n pollen, 402 had tubers with acceptable characteristics. It was therefore possible to carry out selection for good tuber traits exclusively within the group of 2n pollen producers (Table 2). This material will now be screened for the resistances that had been identified in its parents, and the resistant genotypes will then be used in 4x-2x crosses.

A separate 2x population was developed by intermating 2x clones that had been selected previously under the tropical conditions of San Ramon. Only 14 of 244 clones from 20 families were selected, and these selections will form the basis of a new population with 2n pollen production and better adaptation to San Ramon conditions.

A large number of diploid clones were evaluated for their potential resistance to important diseases and pests. Sixty clones were found to have resistance to the root-knot nematode, 69 to bacterial wilt, 28 to early blight, and 19 to PVY. The majority of these clones produce 2n pollen. Table 3 lists the 2x clones with their respective resistances and adaptation, which are now available at CIP on request. The clones selected at San Ramon are expected to have some heat tolerance.

Table 2. Number of 2x seedlings selected for 2n pollen production and their potential resistances to pests and diseases. Huancayo, 1987.

Potential resistance[a]	No. of selected seedlings with 2n pollen[b]
Root-knot nematode	21
Root-knot nematode and bacterial wilt	75
Root-knot nematode and early blight	29
Root-knot nematode and late blight	26
Root-knot nematode and heat tolerance	30
Bacterial wilt	15
Bacterial wilt and early blight	33
Bacterial wilt and heat tolerance	19
Early blight and heat tolerance	12
Late blight and early blight	17
Late blight and bacterial wilt	8
Late blight and heat tolerance	12
PVY (hypersensitivity and other types)	2
PVX, PVY, PLRV	35
Cyst nematode	68
Total	402[c]

[a] Indicates resistances of parents for which seedlings should segregate.
[b] Clones with a 2n pollen frequency of more than 1%.
[c] This total includes 157 genotypes that did not produce 2n pollen.

Germplasm derived from 4x-2x crosses. Experiments were conducted in Lima, San Ramon, and Huancayo to determine the parental value of 4x-2x crosses of the diploid populations developed in CIP's program of germplasm enhancement. The results of this and previous years demonstrated the superior parental value of diploid clones that produce 2n pollen. Most of their progenies derived from 4x-2x crosses outyielded the checks, which were highly competitive 4x progenies derived from 4x-4x crosses of progenitors well known for their ability to produce excellent high-yielding progenies.

Since CIP's diploid progenitors have been developed with the use of wild species, they have often displayed unacceptable tuber traits. The tuber traits of the 2x progenitors, however, have been improved considerably. Some progenies derived from 4x-2x crosses have tuber traits comparable to or better than those of some 4x-4x hybrid combinations known for their excellent tuber characteristics.

Protoplast culture and fusion. Through a collaborative research project with the Weizmann Institute, funded by the Agency for International Development (AID), asymmetric protoplast fusions are being carried out in Israel. One of the aims is to transfer nuclei of specific *S. tuberosum* clones into cytoplasm that confers the tetrad type male sterility through cytoplasm-nuclear interaction. Such male-sterile potato clones are needed to produce hybrid true potato seed (TPS). Anthers that produce pollen with tetrad type male sterility would still attract insect pollinators such as bumble bees.

A number of protoplast fusions have been carried out successfully, involving

Table 3. Diploid clones with confirmed resistances to pests, diseases, and stress.

Resistances	No. of resistant clones	No. of clones with 2n pollen
Potato tuber moth	25	0
PVY	28	0
PVX	3	0 (ms)[a]
PLRV	25	7
Bacterial wilt	20	10
Root-knot nematode	27	16
Early blight	30	5
Heat tolerance (SR)[b]	18	7
Erwinia	19	1
Late blight	20	8
Cyst nematode	5	2
PVY/PVX	1	0 (ms)
PVY/PVX/PLRV	1	0 (ms)
PLRV (SR)	4	4
PLRV/RKN (SR)	1	1
Bacterial wilt/root-knot nematode	22	not checked
Erwinia/early blight	1	1
PLRV/root-knot nematode	2	1
PLRV/late blight (SR)	1	1
(PVY or PVX)/PLRV	2	0 (ms)

[a] Male sterile.
[b] Selected under conditions of mid-elevation tropics of San Ramon

four *S. tuberosum* clones and seven different *Solanum* species. Many cybrids have been regenerated. From two of the fusion products between a male-sterile and two male-fertile tuberosum clones, flowering cybrids have been obtained and tested for the tetrad type male sterility. Fourteen out of 21 fusion products of the combination Y245.7 (the male-sterile cytoplasm donor with cytoplasm from the wild species *S. stoloniferum*) x Atzimba (the male-fertile recipient) produced male-sterile cybrids in Israel. Parallel experiments at CIP in Peru did not give the same results, which suggests that the expression of male sterility of at least some clones is influenced by environmental conditions.

Genetic engineering. During 1987, CIP initiated a research contract with Louisiana State University in the United States to produce gene constructs for pest and disease resistance. A number of cDNA constructs have already been prepared and are being inserted into *Agrobacterium*. These include constructs for the production of the toxin protein of *Bacillus thuringiensis*, the production of chitenase for insect resistance, and the production of the family of Cecropins for bacterial resistance.

SWEET POTATO GENETIC RESOURCES

Collecting activities. During 1987, 16 collecting expeditions visited seven Latin American countries to collect cultivated as well as wild sweet potato germplasm. During 127 days of field work, collections were made in 476 localities (Figs. 3-4).

A total of 579 cultivated accessions were collected. These included samples of weedy material, native cultivars, improved varieties, and advanced breeding lines. Duplicates of all collections were left with the respective national institutions in the seven countries visited, and donations were received from these national programs.

The understanding of the geographical distribution of sweet potato germplasm is important for the use of this material as well as for planning future collections. Areas of high genetic variability were identified in each of the countries visited. Of all the material collected, 84% was found between sea level and about 2000 m above sea level, and the rest was found at altitudes above 2000 m. Ninety percent of all collections were made in southern latitudes, and of these, 80% were found between 0 and 16 degrees. A high degree of phenotypic variability was observed, particularly in the cultivated material.

Apart from the cultivated material, 92 accessions representing 8 wild *Ipomoea* species from the section Batatas were

Figure 3. Market in the south of Colombia with sweet potato genetic resources.

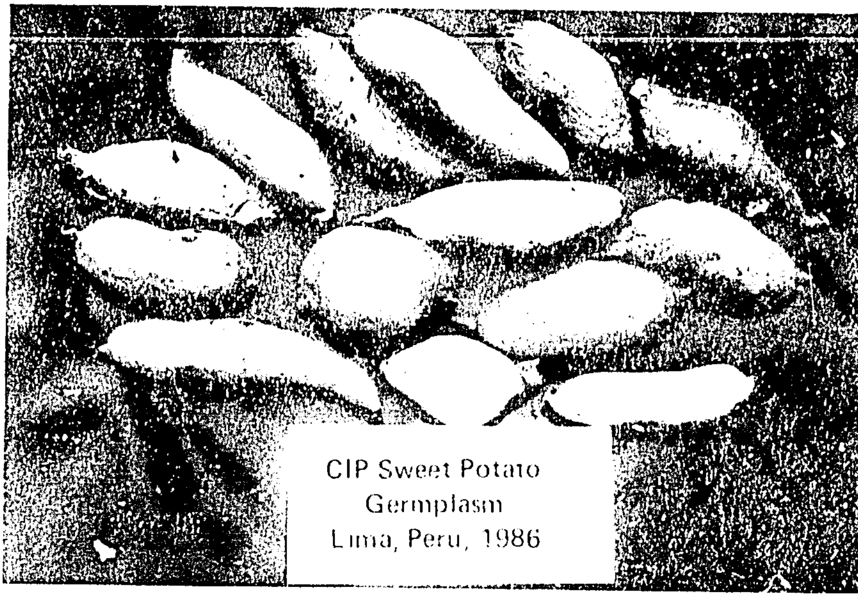


Figure 4 A sample of cultivated sweet potato storage roots from Peru now in CIP's germplasm collection

also collected. Also from the section Batatas, one accession of a natural interspecific hybrid (*I. trifida* x *I. triloba*) and two potentially new species were collected. Twenty-nine other wild *Ipomoea* species from other taxonomic sections were collected for basic germplasm research. In total, about 830 new accessions have been included into CIP's sweet potato gene bank.

All of the collecting activities were carried out in close collaboration with scientists from the countries visited and with the help of IBPGR. The information provided by these collecting expeditions has enabled IBPGR to prepare maps of geographic distribution of sweet potato genetic resources in Latin America.

Sweet potato germplasm collection. The sweet potato germplasm collection comprises a total of 2900 cultivated and 488 wild *Ipomoea* accessions. The cultivated germplasm is maintained by asexual propagation and consists of 2424 accessions of cultivars from 23 countries as well as 476 breeding lines from Peru (Table 4). For quarantine reasons, the accessions from Peru are basically the only ones that can be grown in the field, while the accessions from other countries are maintained either in vitro or in pots in quarantine screenhouses. Of the 488 accessions of wild species from which seeds are available, 50 represent 8 species and one natural hybrid from section Batatas, 209 accessions represent 52 species not related to *I. batatas*, and 229 accessions have yet to be identified taxonomically.

Duplicate identification. All Peruvian cultivated accessions that can be grown in the field at Lima have been characterized according to key morphological characters, using a revised list of descriptors for sweet potatoes which has been developed at CIP. According to the data obtained through the use of these descriptors, about 66% of the Peruvian cultivated collection represents duplicates. Preliminary electrophoretic analyses to verify duplicate groups obtained through morphological classification have confirmed the high degree of accuracy of the morphological analyses. These electrophoretic procedures were developed, and are being further refined, at the Institute for Biochemistry in Braunschweig, West Germany.

Germplasm evaluation. Observational trials to determine the yield potential of 1193 Peruvian accessions on the Pacific Coast of Peru showed that 134 accessions were extremely late maturing. Some had not formed commercial-sized storage roots even after ten months in the field.

The yield potential of a sample of 770 accessions, of which 300 were native Peruvian cultivars, 421 advanced Peruvian breeding lines, and 49 foreign hybrids, was tested in San Ramon, representing the mid-elevation tropics, and at Yurimaguas, representing a lowland tropical site. These trials were carried out in two successive years during the wet and dry seasons. Of the 770 accessions tested, 120 were selected at San Ramon and 54 at Yurimaguas. The native Peruvian cultivars were at a clear disadvantage in comparison with the advanced Peruvian breeding lines as well as the foreign

Table 4. Number of living accessions of *Ipomoea batatas* maintained in the CIP sweet potato collection.

	Germplasm maintained		
Country	In quarantine house	In vitro	Total
Argentina	–	5	5
Bolivia	69	1	70
Brazil	44	7	51
Chile	–	1	1
Colombia	147	31	178
Costa Rica	–	29	29
Dominican Republic	14	21	35
Ecuador	134	72	206
Guatemala	–	6	6
Honduras	–	4	4
Jamaica	–	6	6
Mexico	–	4	4
Panama	–	1	1
Peru	–	–	1670[a,b]
Puerto Rico	–	19	19
El Salvador	–	1	1
U.S.A.	–	60	60
Venezuela	60	1	61
China	–	7	7
Burundi	–	6	6
Others	–	4	4
Total	468	286	2424

[a] Of this total, 317 accessions are additionally maintained in vitro.
[b] The Peruvian accessions are the only ones maintained in the field.

hybrids due to the late maturity of the native cultivars. A significantly (P < 0.95) higher yield potential was observed in the Peruvian breeding lines as well as in the foreign hybrids with early maturity. Replicated yield trials for definite selections are now in progress.

In vitro collection of sweet potato germplasm. Significant progress has been made on the introduction of materials to the in vitro bank, and more than 700 accessions are now stored in vitro. Transfer of sweet potato material to in vitro will slow down somewhat until new storage and transfer facilities are constructed in Lima (due for completion in 1989). The storage of duplicates outside Peru is being planned.

During 1987, new culture media which had been devised the previous year were tested on a wide array of genotypes. In every case, material was introduced to in vitro without subsequent callus formation. This is an important result because sweet potato is well known to be highly prone to callus formation, which can affect the genetic stability of the stored material.

Experiments with growth inhibitors were carried out to increase the time between transfer and subculture of the material. Sorbitol at 4% was found to be the most effective additive to the media; however, further research is needed in this area. If in vitro sweet potato material cannot be stored at 14°-18° C, a temperature which clearly inhibits growth of the culture, periods between subcultures become too short.

Exploitation of sweet potato germplasm. ***The production of 4x interspecific hybrids.*** A total of 28,866 hand pollinations were carried out in order to obtain 4x interspecific hybrids between 6x cultivars and 2x *I. trifida*. Ten to 15 days after pollination, 11,390 fruits were harvested to study techniques of embryo rescue. The rest of the fruits were left until maturity, and 375 seeds were harvested. The hybrids to be grown from these seeds will be evaluated in the field for their ability to form storage roots.

***The development of 6x clones from 2x and 4x* I. trifida.** One rapid, efficient way to transfer 2x and 4x *I. trifida* germplasm into cultivated sweet potato is to produce 3x hybrids between 2x and 4x *I. trifida* and to subsequently double the chromosome number of the 3x hybrids. The resulting synthetic hexaploids should cross easily with cultivated sweet potato clones. A total of 7900 *I. trifida* seeds were produced in order to find efficient ways of doubling the chromosome number of this triploid hybrid material. The results of this study, being carried out under a M.S. Thesis, will be reported at a later date.

Evaluation of 5x hybrids. Pentaploid hybrids obtained from crosses between 4x *I. trifida* and cultivated sweet potato clones were evaluated for their ability to form storage roots. Eleven families derived from crosses between accessions of 4x *I. trifida* and some Japanese sweet potato clones were evaluated in Lima. Of the 341 seedlings harvested, 298 had produced storage roots, and two genotypes had yields exceeding 2 kg/plant (Fig. 5). These results indicated that the majority of the 5x hybrids produce storage roots and that evaluation of the hybrids for traits such as dry matter and protein content, as well as resistance to pests that attack storage roots, can be carried out at this stage.

Production of 2n pollen. The production of 2n pollen in a 2x *I. trifida* population was studied to investigate the possibility of sexual polyploidization in *Ipomoea*. The identification of 2n pollen was relatively easy because this type of

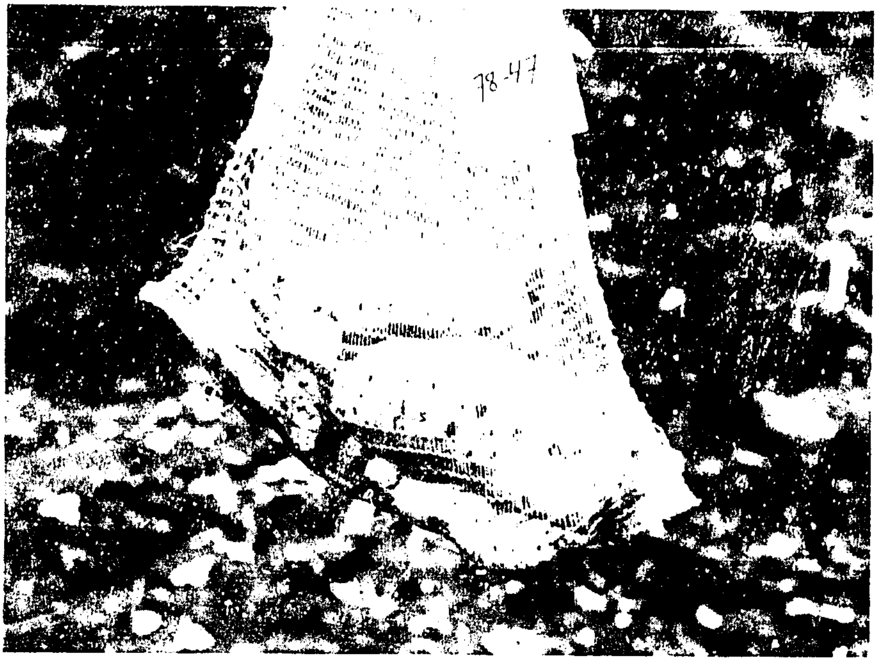


Figure 5 Storage root of a pentaploid sweet potato hybrid obtained from a cross between 6x cultivated sweet potato and 4x K51 *Ipomoea trifida*

pollen was approximately 28% larger than normal pollen (120µ for 2n pollen versus 94µ for normal pollen). Out of 672 plants from Central and South American accessions, 47 plants (7%) representing 36 accessions produced 2n pollen. The existence of dyads at the tetrad stage was also confirmed, indicating that pollen was produced without chromosome reduction. Some plants that produced 2n pollen were crossed with 4x *I. trifida* material, and the hybrids that resulted from these crosses are at present being checked for their ploidy level. If tetraploid progenies can be identified from these 4x-2x crosses, a further means of gene introgression from the 2x to the 4x level by sexual polyploidization will have become available.

Since *I. trifida* is regarded as the ancestor of the cultivated sweet potato and thus most closely related to it, sexual polyploidization through 2n pollen would enhance considerably the prospects of using this species for the transfer of important characteristics from wild to cultivated sweet potato germplasm.

Production and Distribution of Advanced Breeding Material

Development of tetraploid populations combining resistances or tolerances to diseases, pests, and stresses was emphasized. Introduction into these populations of immunity to potato viruses X and Y (PVX, PVY) and resistance to potato leafroll virus (PLRV) has been achieved. Eighteen duplex PVY-immune clones have been identified to produce, upon intercrossing, progenies with 97.2% immunity to PVY. At present, intensive research is in progress to identify duplex genotypes at loci for immunity to both PVY and PVX. The intercrossing of these genotypes will increase the joint immunity from the present 56% to 94.5%.

Selection of early blight-resistant progenitors has continued, and the clones 378676.6 and Maine-47 will be cleaned up for regional distribution and used in breeding for early blight resistance. Genetic studies have confirmed that the heritability of early blight resistance is high (h^2 = .8), which explains the rapid progress achieved in selecting clones with resistance to this disease.

In 1987, various CIP breeding populations, which combine tuber yield and several resistances or tolerances, were evaluated for processing quality. It has been found that there is sufficient genetic variability to select high-performing clones with sufficient processing quality for the warm environments of tropical countries. Ten true potato seed (TPS) progenies that maintain a stable yield from the F_1 generation through four generations of successive open-pollination have been identified. These will permit farmers to produce their own open-pollinated berries and TPS.

During 1987, CIP materials were evaluated in several developing countries. Selections of promising clones, with potential for future varieties, have been made. The main characteristic of CIP materials is the resistance to biotic and abiotic stresses. This will enable farmers in the developing world to grow potatoes better adapted to their growing conditions. In 1987, CIP's genetic materials were made available to 18 developed and 63 developing countries.

As part of the international germplasm evaluation, CIP material is being harvested and selected at Munshiganj, Bangladesh.

POTATO POPULATION DEVELOPMENT

For the past three years a tetraploid population has been developed that combines factors controlling resistances or tolerances to diseases, pests, and stresses. Introduction of immunity to potato viruses X and Y (PVX, PVY) and resistance to potato leafroll virus (PLRV) has been achieved. The breeding strategy for PVY + PVX + PLRV resistances was started by making PVY and PVX immunity inputs into the hot and warm tropic population. This population already had other attributes, i.e., heat tolerance, yield, earliness, and several other resistances. Three cycles of recurrent selection were applied to this population to increase the gene frequencies for PVY and PVX, as well as for the other attributes. Highly selected clones from this population were crossed to selected PLRV-resistant clones to combine all of these attributes (*see* Fig. 1).

An intensive assortative mating system using progenitors previously subjected to progeny testing has permitted selection of 18 PVY-immune progenitors, which carry the PVY immunity allele at the duplex stage, YYyy. These progenitors, when mated to PVY susceptible clones (i.e., yyyy), still produce 83% of the progenies with PVY immunity. However, when the duplex progenitors are intermated (i.e., YYyy x YYyy), 97.2% of the progenies are immune.

A group of 36 clones with one allele for immunity to each virus, PVX and PVY (i.e., YyyyXxxx), has been identified. When one of these clones is mated to a clone susceptible to both PVY and PVX, only 25% of the progeny are immune. When these clones are intermated (i.e., YyyyXxxx x YyyyXxxx), however, 56% of the progenies are immune to both viruses. Intensive research is now in progress to identify duplex genotypes at both loci. Intermating of such duplex genotypes should increase the frequency of immunity in the progenies from 56% to 94.5%.

In 1987, 35,000 seedlings were inoculated with a combination of PVY, PVX, and PLRV. The yield performances of selected clones grown in ten-hill plots in San Ramon are presented in Table 1, which shows the progress obtained in selecting for a combination of at least five traits: high yield, earliness, heat tolerance, and immunity to PVY and PVX.

Table 1. Yield performance of heat tolerant, early maturing, PVY- and PVX-immune potato clones grown in San Ramon (winter, 1987).

Clone	Yield (t ha)	Growth period (days)
(LT-8 x C83.119).8	24.0	75
(Atlantic x Y84.007).5	23.3	75
(LT-8 x C83.119).6	20.0	75
(LT-8 x C83.119).7	20.0	75
(LT-8 x 377838.8).5	20.0	75
(LT-8 x 377964.5).13	43.3	90
(Y84.007 x Atlantic).10	41.7	90
(LT-8 x LT-7).2	36.7	90
(Bzura x LT-7).12	30.0	90
(LT-8 x C83.551).11	28.7	90

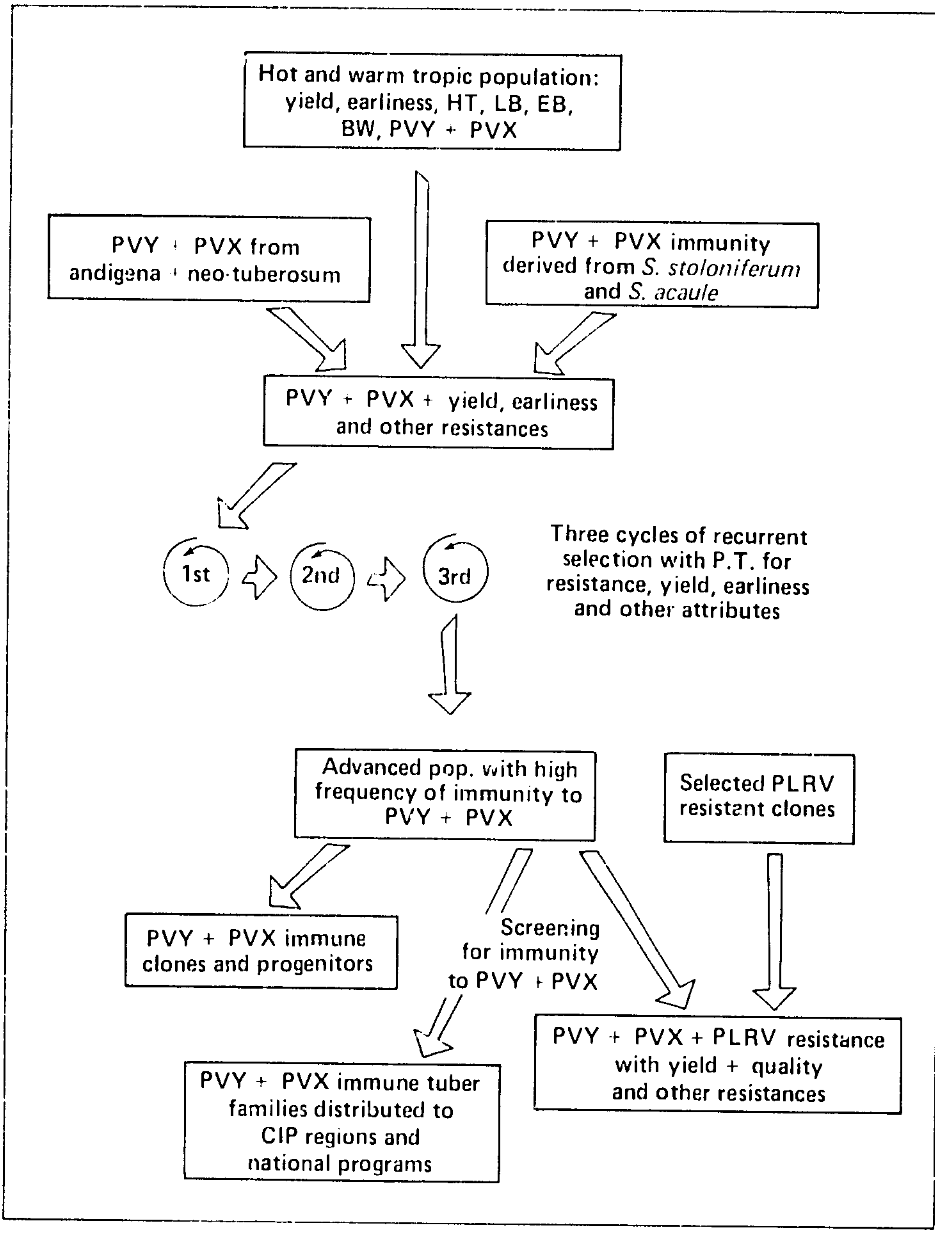


Figure 1. Breeding strategy for combining PVY + PVX + PLRV resistances with other attributes. PVY = potato virus Y, PVX = potato virus X, PLRV = potato leafroll virus, HT = heat tolerant, LB = late blight, EB = early blight, BW = bacterial wilt, PT = progeny testing, pop = population.

Selections for resistance to PLRV, early blight, late blight, and bacterial wilt have been taking place in the heat tolerant, early maturing population. During the last two years the tuber families produced for export, under quarantine conditions at Lima, have been indirectly screened (cuttings taken from mother plants) for immunity to both PVY and PVX. The main goal of this population development is to provide potato programs in the developing world with genetic materials from which new potato varieties, carrying several resistances (including resistance to viruses) can be selected.

The development of tetraploid populations with several resistances requires the selection of adequate tetraploid progenitors. It is also important, however, to build up diploid populations in which the valuable attributes of the cultivated primitive germplasm, as well as those of the wild relatives, can be combined to produce a usable genetic resource (Table 2). To transfer the characteristics of these genetic resources to the tetraploid level, it was also necessary to select clones producing 2n-pollen, which made the 4x-2x transfers possible. It was found that the diploid population had a frequency of 20% of 2n-pollen production. In the present population, the frequency has increased to 50%. The effect of selection in increasing the frequency of the allele *ps* has, therefore, been very significant. Some of the resistances present in diploids have a particular importance in potato breeding, i.e., resistances to PLRV, root-knot nematode, bacterial wilt, and soft rot. These resistances may be present at the tetraploid level either at very low frequencies or at low levels.

Soft rot. Work on identifying sources of resistance to *Erwinia* spp. (bacterial soft rot) indicates that both the frequency of resistance and the level of resistance are low in progenies of crosses among andigena (adg) clones as well as tuberosum (tbr) and tbr x adg hybrids. There is no reliable screening method that identifies resistant and susceptible genotypes among populations at early stages of development, which is a constraint to breeding work. The infectivity titration method with a suspension of 8.8×10^5 cells/ml was used to reevaluate 26 diploid and 31

Table 2. Diploid potato clones with confirmed resistance to pests and diseases.

Resistance to pest/disease stress[a]	No. of resistant clones	No. of clones with 2n-pollen production
PTM	25	0
PLRV	25	7
BW	20	10
RKN	27	16
EB	30	5
SR/HT	18	7
Erwinia	19	1
LB	20	8
CN	5	2
PLRV/SR	4	4
PLRV/SR/RKN	1	1
BW/RK	22	not checked
Erwinia/EB	1	1
PLRV/RKN	2	1
PLRV/SR/LB	1	1

[a] PTM = potato tuber moth, PLRV = potato leafroll virus, BW = bacterial wilt, RKN = root-knot nematode, EB = early blight, SR = soft rot, HT = heat tolerance, LB = late blight, CN = cyst nematode.

tetraploid genotypes previously found to be resistant to soft rot. Good levels of resistance were observed in 19 diploids, and moderate resistance was found in 8 tetraploids. These results underscore the importance of using diploid species in potato breeding to introduce those traits that might be missing or insufficient at the tetraploid level.

Late blight. In the Peru-Colombia-Mexico system of selecting for resistance to late blight (*Phytophthora infestans*), earliness, and other attributes, 1200 clones produced under quarantine conditions in Peru were field-tested by the national potato program of ICA at the Rionegro site in Colombia. Of those tested, 150 clones were selected for late blight resistance, earliness, and good tuber appearance. Trials to test for stability of resistance to late blight were carried out in Colombia and Peru (Huanuco) in a set of clones that had been previously selected in Peru, Colombia, and Mexico. Despite the late blight infection in Huanuco not having been intense (many clones were not infected), the genotype by environment interaction for yield was very strong. Some of the high-yielding clones at Huanuco performed poorly at Rionegro, but their late blight resistance was satisfactory. Under both environments, clones 381382.34 and 381381.9 gave excellent performance: they showed a reduced late blight rate and ranked in the top five for yield.

Early blight. The selection of progenitors with resistance to early blight (*Alternaria solani*) for population development has continued at San Ramon. Previous results were confirmed, showing that early blight reduces yield and that there is a tendency for the latest maturing genotypes to be the most resistant. A 7 x 7 diallel mating design was evaluated in San Ramon, and among the tested parents, clone Maine-47 was found to be highly desirable. It transmits two traits to its progenies, earliness and early blight resistance, which are normally negatively correlated. Clone CIP 378676.6 continues to be an outstanding progenitor for early blight resistance and it also transmits late maturity to its progenies.

In other trials, clones BL-2.9, 575049, and Atzimba also transmitted a useful level of resistance to their progenies. These clones are of particular importance since they are also good progenitors for late blight resistance. Clones 378676.6 and Maine-47 will be introduced into the CIP seed program for cleanup and distribution to the regions for early blight resistance breeding.

In earlier experiments, it was determined that the heritability (h^2) for early blight resistance was about .7. This year's research has confirmed these results, as h^2 values of .8 and .9 have been estimated for early blight resistance at 65 and 75 days after transplanting, respectively. These high heritability estimates would indicate that rapid selection progress can be made selecting for early blight resistance and would explain the rapid progress already achieved in CIP's breeding program.

The performances of clones with early blight resistance selected in previous years has been assessed at San Ramon, evaluating the resistance at 55, 65, and 75 days after planting (Table 3). Data show that it is possible to select medium to medium-early maturing clones with an adequate level of resistance to early blight.

Processing quality. In April 1987, a survey of CIP's breeding populations was initiated to evaluate these materials for their processing quality (i.e., chips and French fries) Advanced materials from various breeding projects were evaluated in Huancayo and Lima. A sample of 79 highly selected clones with resistances to

Table 3. Performance of advanced clones with early blight resistance, reevaluated at San Ramon at 55, 65, and 75 days after planting (summer, 1987).

Clone	Pedigree	Earliness[b]	Early blight (days)[a]		
			55	65	75
C85.012	(Beauvais x LT-7).41	5	2.5	3.0	4.0
C85.010	(India-1035 x LT-7).62	7	2.0	3.5	4.0
C85.031	(377887.25 x 377964.5).41	5	1.5	2.5	3.5
C85.054	(Maine-47 x 378015.16).66	7	2.0	3.5	5.0
C85.002	(Desiree x LT-7).42	5	2.5	3.0	3.5
C85.009	(India-1035 x LT-7).54	7	1.5	2.5	3.0
C85.102	(C83.621 x Katahdin).51	5	1.5	3.0	3.5
C85.051	(Maine-47 x 378015.16).51	5	2.0	3.0	3.5
C85.036	(377843.3 x 377964.5).51	5	2.0	3.0	3.5

[a] Early blight resistance: 1 = no damage, 3 = up to 10%, 4 = up to 25%, 5 = up to 50%.
[b] Earliness rating: 1 = very late, 5 = medium, 9 = very early.

late blight, cyst nematode, bacterial wilt, and root-knot nematode were evaluated at Huancayo. From these, 13 clones with high dry matter content and low reducing-sugar content were selected as prospective progenitors.

During summer 1987, a breeding population with heat tolerance, earliness, and immunity to PVY was field-tested under the environmental stress conditions at Lima. From this population, 169 PVY-immune clones were selected. The range of specific gravity was from 1.060 to 1.109 and the reducing-sugar content varied from 0% to more than 2%. Despite high temperatures, which have the tendency to produce significant reductions in dry matter content, the population for the hot and humid environments exhibited sufficient genetic variability for processing attributes (Table 4). In this population, a negative association was found between dry matter content and reducing sugar content.

Table 4. The eight best potato clones from a PVY-immune breeding population selected for processing quality at Lima (summer, 1987).

Clone	Dry matter content	Reducing sugars[a]
(Y84-007 x Y84-012).15	24.35	1
(Y84-005 x Y84-016).2	24.31	2
(Y84-053 x Y84-004).6	23.93	2
(Y84-020 x Y84-007).30	23.56	1
(Y84-012 x Y84-007).11	22.69	2
(Y84-007 x Y84-020).19	22.10	1
(Y84-020 x Y84-012).18	22.05	1
(Y84-005 x Y84-016).13	22.00	2
Desiree (control)	17.80	4
Revolucion (control)	17.70	4

Mean for selected clones: dry matter = 21.28, reducing sugars = 2.69.
[a] Reducing-sugar content estimated using the gluco test strip: scale from 1 = 0% to 5 = more than 2%.

During winter 1987, a diploid *S. phureja-S. stenotomum* population selected for high dry matter content, heat tolerance, and adaptation to tuberize under long days was field-tested at Lima for yield, tuber characteristics, and processing quality. The specific gravity ranged from 1.035 to 1.134 and reducing-sugar content ranged from 0 to more than 2%.

Salt tolerance. In a collaborative effort with the University of Tacna in southern Peru, selection of potato clones

Table 5. Yield performance of the best salt-tolerant potato clones evaluated at one site in Tacna, Peru (winter, 1987).

Clone	Plant survival (%)	Yield (t/ha)
ST-14	90	23.6
ST-6	100	20.0
ST-16	90	18.0
ST-1	90	16.6
ST-13	90	16.6
ST-20	90	15.6
ST-4	100	15.0
ST-2	90	14.1
Tomasa (control)	100	10.0

adapted to arid conditions and with salt tolerance has continued. In early 1987, a sample of 10 salt-tolerant clones was given to three agricultural institutions in Tacna for further testing. The results obtained in a trial carried out by one of these institutions (Table 5) indicated that there was strong potential to select potato cultivars with good levels of adaptation to the arid and saline areas, which are present in many developing countries.

Research to develop a seedling screening technique for salt tolerance was started by germinating open-pollinated (OP) seed of several clones in NaCl solutions with increasing electrical conductivity (EC). Percent germination and growth in length of roots were measured. Seeds of *Lycopersicum chilensis*, which is a well-known salt-tolerant species, served as resistant checks. Considerable variability was observed for the characteristics measured. The OP seed of clone C84.128 was most notable in showing a high percentage (84.3%) of germination even at an EC of 15.8 mmhos. Studies to measure the correlation between seedling behavior and adult plant performance under saline soil conditions are underway.

Argentina. A new project was initiated with the National Institute of Agricultural Technology (INTA) to select materials with earliness and short dormancy. Four series from INTA breeding materials (INTA 84 to INTA 87) and one series from CIP materials, having PLRV resistance and immunity to PVY, are being screened at Balcarce, Tucuman, and San Pedro. The objective is to increase the frequency of favorable genes for both characteristics. The INTA 87 series has CIP parentage in some of the families.

West Africa. Selected CIP clones were sent in 1987 to Cameroon, Senegal, Togo, and Equatorial Guinea for evaluation by the national potato programs. The major objective was to identify clones with late blight and bacterial wilt resistance, adaptation to warm climates, and suitability for intercropping. Results from a set of clones previously introduced into Senegal indicated that seven selected clones appeared to be well adapted with yields ranging from 21 to 33 t/ha. Results from the other three countries were not yet received at the time of this reporting.

East and Central Africa. In Kenya, a project was started in 1987 to produce specific hybrid progenies that will incorporate traits for environmental adaptation from the best local cultivars and clones. Crosses are made in Kenya and the hybrid seed is distributed to those countries of the region where national scientists have been trained to make selections. Presently, these countries include Burundi, Ethiopia, Kenya, and Rwanda.

In Burundi, the national program of ISABU planted on-farm trials of new varieties released to farmers to assess the continued performance of this material. A total of 24 on-farm trials of four new varieties were planted, with the variety Ndinamagara yielding twice as much as any other variety (15 t/ha). This high performance shows why farmer demand for this variety is so great.

A new potato research project has started in 1987 in Ethiopia in collaboration with the Institute for Agricultural Research (IAR). The scientists of IAR had previously screened in 1985-86 a wide range of material, and two CIP clones, 378367.4 and 378501.16, were selected. These clones were entered into the variety verification trials planted in 1987 at three locations and compared with the local control. The final decision of the National Variety Release Committee will be available when the final harvest has been evaluated. A total of 53 varieties and advanced clones, selected in previous years, were evaluated under irrigation conditions at the main research center at Holetta. Tubers from this multiplication were again grown during the rainy season (June-October). Results are still being evaluated, but several clones were extremely susceptible to late blight, indicating that low pathogen pressure during the previous dry season permitted them to escape the screening process.

Asia. There is an ongoing program for potato germplasm evaluation in Pakistan, carried out by the Pakistan Agricultural Research Council. From 62 clones evaluated in macro plots for yield and late blight resistance, 5 clones yielding more than one kilogram per plant maintained their resistance 120 days after emergence. Twenty-five clones outyielded the three commercial varieties used as controls. This program will continue at the high-altitude station of Kalam (2300 m) and on the plains at Faisalabad. Two clones selected from the macro plots will be tested in on-farm trials in 1988.

Large numbers of partially selected and advanced clones have been introduced into China during the past few years. Evaluations to select superior cultivars are being implemented at research institutes in the provinces of Keshan, Inner Mongolia, Datong, Beijing, Gan Su, and An Hui. Major attributes being selected for are high yield, high starch content, late blight resistance, and resistances to PVY, PVX, and PLRV. In Inner Mongolia, four clones are ready for release and have been coded as CIP-32 (BL-61.77.16 x XY 15.4), CIP 36 (Serrana x 377999.1), CIP-30 (Serrana x 377999.1), and CIP-25 (Serrana x XY 14.7). Major attributes are high yield and resistances to PVX, PVY and late blight. The clone B-71.240.2 (origin INTA, Argentina), recently selected and released as a variety, is gaining popularity among potato producers in China. In Inner Mongolia Province, this variety is now being grown on more than 60 ha, in Shanxi Province on more than 4000 ha, and in Gan Su Province there are more than 20,000 ha of this variety. In the latter province, the clone CFK-69.1 is also becoming important and now occupies more than 6700 ha.

TRUE POTATO SEED

Performance of open-pollinated (OP) progenies. In the San Ramon 1987 winter, a sample of 20 F_1 TPS progenies were tested for yield performance and agronomical characteristics in comparison with their successive OP_1, OP_2, OP_3, and OP_4 generations. In this trial, ten progenies (i.e., 50% of the population) did not show any major yield reduction in successive generations of open-pollination. Open-pollinated seed results from both selfing and cross-pollination and selfing generates inbreeding, which should be reflected in yield reduction. Those progenies that did not show inbreeding depression originated from crosses of progenitors previously selected for general combining

Table 6. Average yield per plant (g) of five generations of selected potato progenies that did not show inbreeding depression.

Progeny	Generations				
	F_1	OP_1	OP_2	OP_3	OP_4
379643.3 x C83.551	404	430	617	423	450
C83.494 x 377964.5	395	411	475	483	439
C83.551 x Katahdin	233	338	358	236	738
Serrana x LT-7	522	672	531	493	543
377830.2 x 378015.16	537	630	657	810	822
376918.2 x 575049	447	400	592	524	730
Serrana x C83.119	499	516	604	823	718
377871.34 x C83.551	479	481	601	422	513
378017.8 x Atlantic	435	532	435	447	658
C83.494 x Katahdin	517	451	517	526	565

Table 7. Comparison of various traits for the 15 highest-yielding potato families at San Ramon.

Progeny	Yield/plant (g)	No. of berries/plot	Weight of berries/plot (g)
GS-18	611 a	101 bc	375 bcde
GS-19	538 ab	57 bc	203 cde
GS-15	511 ab	18 bc	49 de
GS-6	509 ab	32 bc	109 cde
GS-24	498 abc	121 abc	558 abcde
GS-14	471 abcd	23 bc	58 cde
GS-30	462 abcd	69 bc	163 cde
GS-11	459 abcd	150 abc	682 abc
GS-40	456 abcd	91 bc	334 bc
GS-13	420 abcd	276 a	1140 a
GS-34	411 abcd	266 a	951 ab
GS-41	404 abcd	129 abc	418 bcde
GS-26	396 abcd	161 abc	504 bcde
GS-5	391 abcd	56 abc	162 cde
GS-39	366 abcd	40 bc	131 cde

ability (GCA) for yield and tuber uniformity (Table 6). When the progenitors do not have a high GCA for yield, the effect of open-pollinating, i.e., inbreeding, frequently reduces their performance.

The progenies that do not show depression by open-pollination may be very useful for farmers in developing countries who could use the F_1 hybrid and then produce seed of the successive OP generations in their own fields.

Experiments were performed in San Ramon and Huancayo to study the cause of yield reduction in OP generations. Six families with three generations of OP for each were included. The families were harvested at 60, 75, and 90 days after transplanting. At each date, ten plants per row were harvested and different characters were measured such as number and weight of big and small tubers, yield per plant, and total weight. The performance of different OP generations showed that initiation and bulking of tubers were slower in advanced generations of OP than in OP_1, especially under high stress conditions (Figs. 2 and 3). Some of the families exhibited constant performances for different OP generations, irrespective of harvest date.

Evaluation of progenies. Experiments were conducted in Lima, San Ramon, and Huancayo to evaluate progenies from selected parental lines adapted to the warm tropics. In a comparison of the 15 highest-yielding families for different characters, some of the families (GS-18, GS-19, GS-6, GS-24, and GS-11) showed

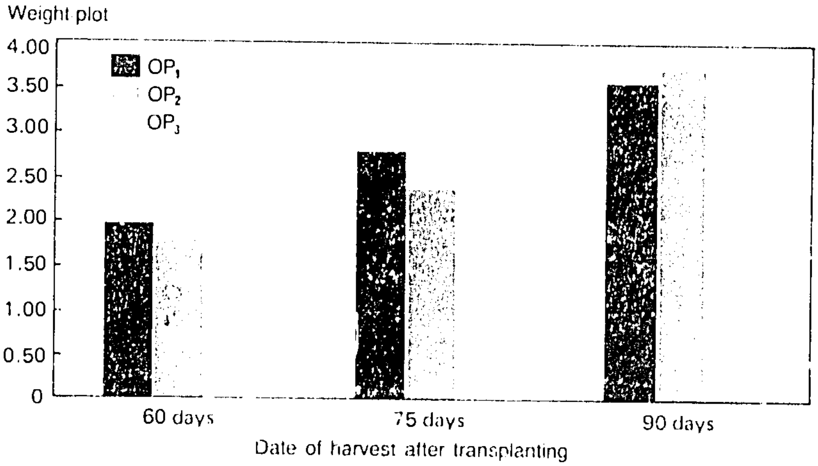


Figure 2. Yield comparisons of OP_1, OP_2, and OP_3 generations at three dates of potato harvest, Huancayo.

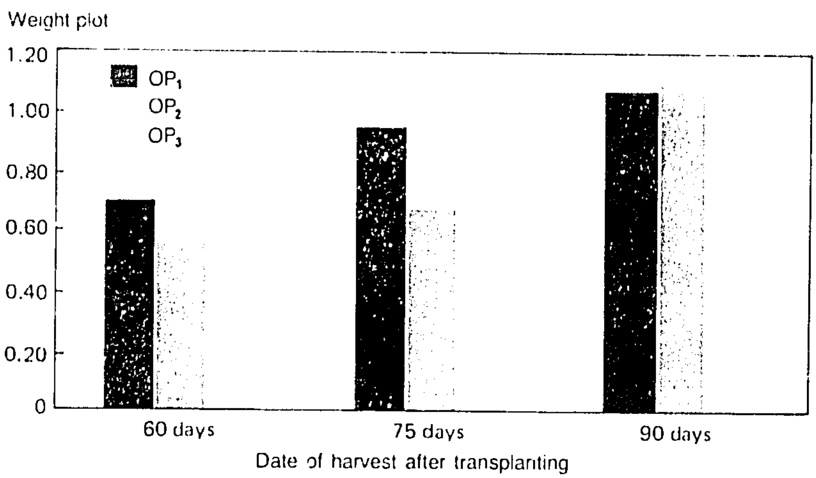


Figure 3. Yield comparison of OP_1, OP_2, and OP_3 generations at three dates of harvest, San Ramon.

good performance for TPS and agronomical characters (Table 7). The results indicated that these families are suitable for both hybrid and OP type of TPS production. These families have been screened for bacterial wilt resistance in plastic trays with promising results.

Evaluation of advanced TPS parental lines. A total of 305 advanced TPS parental lines were evaluated in San Ramon and Lima for reproductive and agronomical characters. The performances of these clones were excellent in both locations and clonal elimination to reduce the population size was very difficult. From these clones, 176 were selected and grouped according to their characters. Some will be used for transplanting and others for seedling tuber production. The clones were evaluated for resistance to blackleg, soft rot, and leafminer fly. Screening for leafminer fly identified 3 clones with high resistance and 14 with medium resistance. Eighty-three clones have been selected for use in a project on potato breeding for processing in tropical countries. Some have high dry matter content and a low content of reducing sugars.

Selection of TPS progenitors. In 1987, three TPS progenitors (C83.119, 377964.5, and Maine-28) were introduced to the seed program for cleanup. After several testing cycles, two new TPS progenitors (377250.7 and C83.551) will be introduced for cleanup. All of these progenitors transmit yielding ability, earliness, and tuber uniformity.

POTATO GERMPLASM DISTRIBUTION

CIP tested 2332 samples from the seed program with an indicator host range and ELISA for PVS, PVX, PVY, PLRV, Andean potato latent virus (APLV), and Andean potato mottle virus (APMV). All samples were virus-free, indicating that eradication measures taken to prevent contamination in export materials have been successful. During 1987, CIP distributed genetic materials to 81 countries worldwide (Table 8). More than 1200

Table 8. Distribution of potato germplasm from CIP headquarters in Lima, Peru, during 1987.

	Clones		Tuber families		In vitro plants		True potato seeds		Seed progeny		In vitro tubers	
CIP region	Accessions	Units	Accessions	Units	Accessions	Units	Accessions	Units	Accessions	Units	Accessions	Units
I (5)[a]	231	1,672	141	3,570	35	1,138	27	5,400	28	145,000	2	320
II (19)	413	3,840	241	6,417	187	393	332	71,890	86	290,890	6	360
III (6)	25	72	169	2,714	41	89	81	13,949	15	84,150	–	–
IV (8)	27	410	185	3,981	40	90	76	19,795	20	1,412,000	–	–
V (11)	67	1,373	40	2,546	–	–	35	12,400	60	259,000	–	–
VI (7)	33	1,168	115	2,661	143	315	55	16,500	49	1,578,000	4	40
VII (6)	86	552	8	628	57	115	102	30,700	21	381,100	4	465
VIII (1)	–	–	–	–	24	48	349	68,900	–	–	–	–
Others (18)	234	1,876	52	1,050	436	884	228	49,157	10	24,100	–	–
Total	1,116	10,963	951	23,567	963	3,072	1,285	288,691	289	4,174,240	18	1,185

[a] Numbers in parentheses indicate the number of countries within each region, and for "Others" the number of developed countries to which shipments were made.

TPS families have been distributed to 25 countries.

CIP germplasm distribution during 1987 has had a major change with respect to distribution in 1986 and in previous years. There has been a decrease in requests for clonal material (tubers) and tuber families, but a significant increase in the export of in vitro plants. Likewise, the requests for TPS progenies have tripled since 1986. This is an indication that the expertise to manage segregating populations has increased and is being carried out more efficiently.

SWEET POTATO RESEARCH

Research on field plot techniques. ***Determination of optimum plot size and adequate number of replications to evaluate yield.*** Uniformity trials were conducted at Lima, San Ramon, and Tacna with well-adapted sweet potato cultivars. The results indicated that in Tacna and San Ramon the optimum plot size was 90 plants while at Lima it was 60 plants. These results coincide with the magnitude of the coefficient of soil heterogeneity (B_2), which in the cases of Tacna and San Ramon was

Table 9 Determination of optimum plot size and adequate number of replications to evaluate yield in sweet potato.

Cultivar	Location	Plot size		No. replications	Coefficient of soil heterogeneity (B_2)
		No. BU[a]	No. plants		
Morado de los Palos	Tacna	15 (22.5 m²)	90	4	0.4147
Nemañete	La Molina	10 (15.5 m²)	60	4	0.2067
Jewel	San Ramon	15 (22.5 m²)	90	4	0.4757

[a] BU = basic units.

Table 10 Yield of 12 top-performing sweet potato cultivars under normal and restricted irrigation conditions, Tacna, Peru.

Cultivar	Average yield (t/ha)	Average performance	
		Normal irrigation	Restricted irrigation
Inglés	47.9	1	1
De Zapallo	35.1	5	5
Pacarenero	34.8	–[a]	2
Perotito	33.6	–	3
Chancleta de Chilca	33.1	11	4
Japones	33.0	3	7
Jonathan	31.1	7	11
Juan Sanchez	29.4	–	6
Guiador	28.9	–	9
Pisqueño	28.8	12	–
Negrito del Ihuanco	28.6	–	–
Chancleta	28.5	9	–

[a] Cultivars with a dash (–) were not among the top 12 clones.

greater than 0.4 and at Lima it was 0.2 (Table 9).

Evaluation of cultivars and tolerance to salinity and drought. This evaluation was carried out in Tacna as part of a research contract with the University of Tacna on a sample of 106 cultivars from CIP's germplasm collection. The soils are saline with values up to 18 mmhos/cm of electrical conductivity (EC). A split plot design was used, applying to the main plots two irrigation regimes: normal irrigation, applied every week; and restricted irrigation, applied every two weeks. In the subplots, the 106 cultivars were distributed with four replications. Data on the average performance of the top 12 cultivars is presented in Table 10.

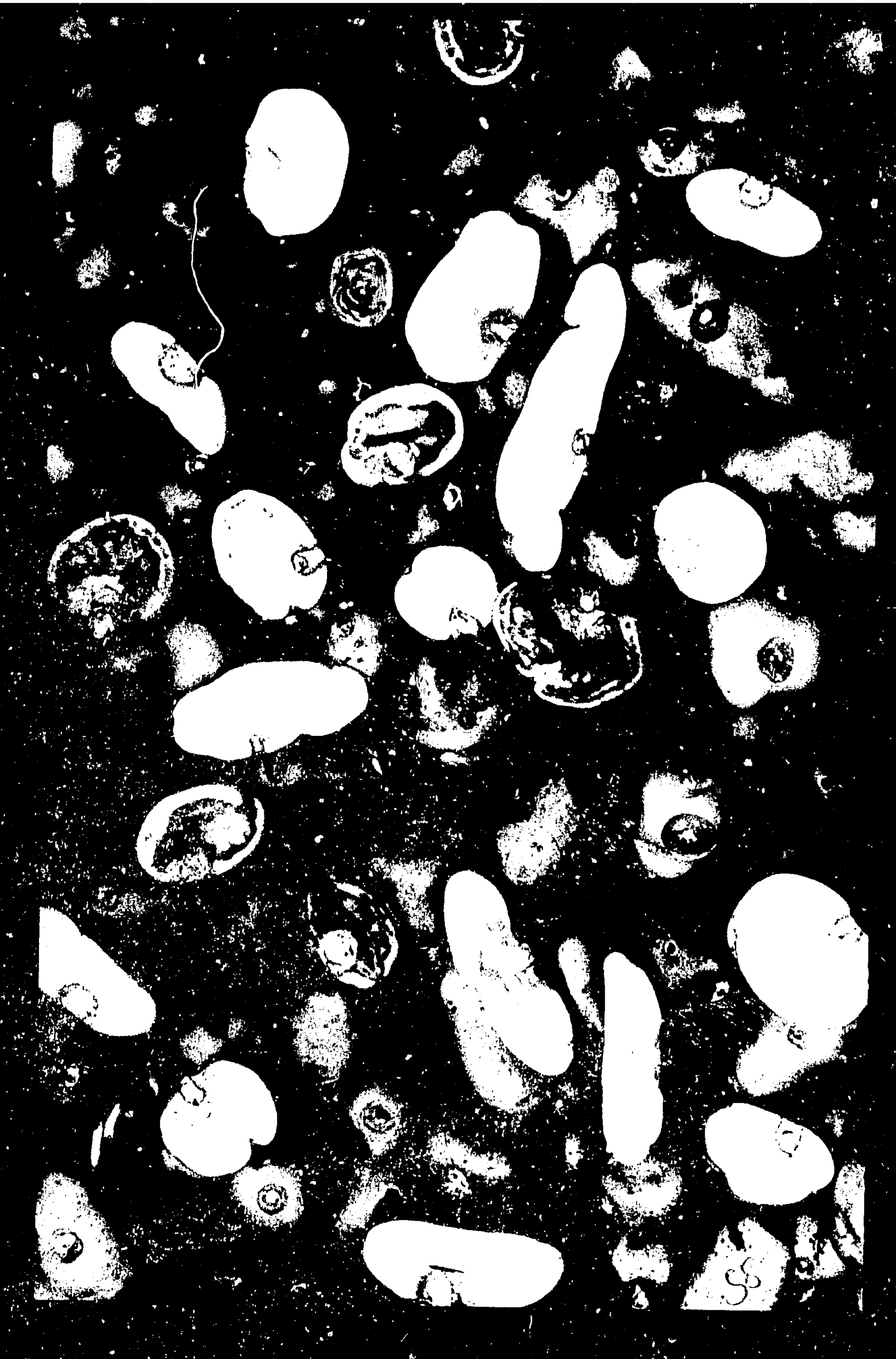
The cultivar Inglés produced the highest yield (47.9 t/ha) and was the best performer at both normal and restricted irrigation regimes. The rest of the cultivars performed well, particularly De Zapallo, Chancleta de Chilca, Japonés, and Jonathan, indicating that genetic variability exists for adaptation to salinity and water stress.

TRAINING

Over 100 scientists attended meetings during 1987 on germplasm enhancement for potato and sweet potato. Fifteen countries were represented at a regional workshop on potato germplasm utilization and distribution in Tropical Africa, held in Kenya with the objective of strengthening ties between CIP's breeder stationed in Kenya and national potato programs involved in germplasm screening. Researchers in eastern and southern Africa are now more conversant with CIP's breeding strategy and know which CIP germplasm is available and the methods for evaluating it for adaptability and resistance.

The third regional course on potato germplasm management in the Philippines had 33 participants for South and Southeast Asia and the Pacific, and a similar national course in China was attended by researchers from 11 provinces. Fourteen scientists also received individual training on various aspects of breeding, including TPS, at headquarters in Lima and in the Philippines.

As CIP enters into sweet potato research and improvement of the crop worldwide, it is vital to know the current status of research and development in the countries with whom CIP will be collaborating. The meeting at CIAT and CIP in June for South America and the Caribbean and the joint CIAT-CIP-IITA meeting in Kenya in late September for Africa brought together researchers to report on sweet potato production in their respective countries. Recommendations were drawn up to facilitate improvement of the crop through germplasm evaluation and distribution, research on biotic stresses, and physiologic, agronomic, and socioeconomic studies.



Control of Bacterial and Fungal Diseases

Breeding for greater bacterial wilt resistance in potato has progressed significantly at several locations around the world. A new source of resistance was received from a breeder in Austria. Through contract research at the University of Wisconsin, useful monoclonal antibodies against *Pseudomonas solanacearum* were developed, and callus tissue cultures from resistant and susceptible potato clones were grown that showed the same differential responses to *Pseudomonas* as the clones themselves. The bacterial wilt-resistant clone, 800224, was released to farmers in Kenya as a variety. In the Philippines at Intavas, several advanced clones showed good wilt resistance and gave yields from 27 to 45 t/ha. In China, clone MS-42.3 continued to show resistance to *P. solanacearum* Biovar II race 3, while CIP clone 377852.2 (BR-63.74 x WRF 1923.1) was resistant to all races.

Studies on the ecology of the bacterial soft rot Erwinias showed that weeds growing in water-logged soil support large populations. A rapid screening test for resistance to *Erwinia chrysanthemi* was developed. Interactions between Erwinia and fungal pathogens were found to contribute to the severity of soft rot in potato tubers.

A new population with field or horizontal resistance to late blight is under development. Several high-yielding clones were selected for late blight resistance in the Philippine highlands by the Mountain State Agricultural College. Development of resistance to early blight seems promising, although it is sometimes linked to lateness. Collaboration with the National Center of Horticultural Research in Brazil to improve resistance to early blight resulted in selection of 74 clones by Brazilian scientists and 12 clones (for global use) by CIP scientists. In the Philippines, chemical control of early blight has given good results.

Differences in resistance to *Verticillium dahliae* were found in clones evaluated from the CIP pathogen-tested list. Several andigena clones with resistance to *V. dahliae* were identified in Colombia. In a second survey on potato diseases in Colombia, this fungus and several others were rated as serious. Four out of 50 cultivars tested for powdery scab resistance were immune. Resistances to *Fusarium oxysporum* and *F. solani* that cause dry rot were identified.

Composite view of andigena tuber types and their reactions when inoculated with *Fusarium oxysporum*, the dry rot fungus.

Breeding for resistance to bacterial wilt. ***Peru.*** A large population of new tetraploid material with resistance to bacterial wilt (*Pseudomonas solanacearum*) became available in the form of subsets representing combinations of varying levels of strain- and site-specific resistances with varying degrees of earliness and adaptation. This material was tested in Peru as well as in CIP's regions for resistance to bacterial wilt, agronomic performance, adaptation to specific sites, and in some instances for dry matter content.

Groups of this material were tested by CIP in Huancayo, San Ramon, and Lima and in collaboration with the Peruvian national potato program of INIPA at sites in Huaraz and Cajamarca. Further emphasis was placed on the reevaluation of material previously found resistant to one or more strains of *P. solanacearum.*

In a triple 8 x 8 lattice design carried out in Huancayo, a group of 7680 seedlings were evaluated for yield and agronomic characteristics. Applying strict standards, CIP selected 368 clones (4.8% of the total) for their outstanding yield performance (1.5 kg per plant average) and tuber characteristics.

Material with the same genetic background was sent to Rwanda, Burundi, Philippines, Egypt, Indonesia, and Brazil. Results returned from Indonesia indicated that out of 760 genotypes representing 63 families, 96 genotypes from 23 families were selected for further evaluation of resistance and agronomic performance. A breeding program for resistance to bacterial wilt, suited specifically to local conditions and to be carried out on site in Indonesia, has been planned during 1987 in an effort to breed for more site-specific resistance.

A population evaluated under hot and humid conditions and natural *P. solanacearum* field infestation in San Ramon exhibited resistances ranging from 10% to 80% per family, however, many of these genotypes may have escaped infection. Furthermore, the San Ramon results were confused by a 10% to 20% incidence of *Erwinia* infection. This potentially wilt-resistant material yielded satisfactorily in 88 days under highly adverse conditions. Family averages ranged from 0.56 to 1.16 kg/plant, in a total of 25 families. Of these, 150 highly selected clones are being tested under conditions of high natural soil infestation. A further population of 6000 genotypes representing 50 families was evaluated at San Ramon, but only 48 clones (or 0.8%) were selected due to high losses from causes other than bacterial wilt.

At Lima, work concentrated on maintaining resistant material and screening genetic material in the greenhouse. In one case, field evaluation was carried out for yield and agronomic characters of a population of about 2000 clones, evaluated in a previous clonal generation also at Lima. Of this population, 109 clones were selected with yields ranging from 0.29 to 1.92 kg/plant, and 35 clones yielding more than 1.0 kg/plant.

A tetraploid population, consisting of 455 genotypes representing 14 families, was screened against a *P. solanacearum* strain from Brazil, and resistance ranged from 40% to 77.3% per family. Among these materials, four tuberosum true potato seed (TPS) families from Austria showed surprisingly high levels of resistance. The best family from the whole population, with 77.3% of resistant genotypes, was from the Austrian group. When the same population of 455 genotypes was tested against a strain from Peru, the same Austrian family (STANM SL-24 983) that performed well against the Brazilian strain was again the best with a resistance level of 88.9%. This material had been received from an Austrian breeder of the Niederösterreichische Saatbaugenossenschaft in a germplasm exchange program.

Sixty-five of the best early maturing and bacterial wilt-resistant materials were tested for dry matter content and found to contain an average of 23.39% dry matter per clone, the best clone containing almost 30%. Within this group of 65 clones, 8 were resistant to *Fusarium oxysporum* and a further 4 were resistant to both *F. oxysporum* and *F. solani*.

In field tests of some of the most advanced wilt-resistant materials carried out at sites in Peru in collaboration with the Peruvian national program, 130 clones were sent to Cajamarca and 283 to Huaraz. Results are not yet available from Cajamarca. In Huaraz, wilting in the suscep-

Figure 1. A plant pathologist at the University of Huanuco in Peru, trained at CIP in the late 1970s and who is now the Rector of the University, proudly shows the harvest of his new variety, "Huanuqueña," developed from CIP clone BR-63.15.

tible local checks ranged from 9% to 100%, which is a clear indication of the enormous variability of soil infestation. Yields of the clones ranged from 0.3 to 1.1 kg/plant and between 0.35 and 0.6 kg/plant in the local checks. Ten clones were completely resistant under field conditions at Huaraz and yielded between 0.38 and 0.8 kg/plant. The highest yielding clone had purple tubers, making it especially acceptable to farmers in that region.

The process of developing superior cultivars through a research contract with the University of Huanuco has led to the multiplication of the variety Huanuqueña (Fig. 1), which has resistance to bacterial wilt, late blight, and potato leafroll virus (PLRV). Three additional wilt-resistant clones are being multiplied because they are also high yielding and resistant to late blight (800224, 800950 (Amapola) and 800941).

Tropical Africa. In Kenya, screening of CIP germplasm for bacterial wilt resistance continued under a contract with the National Agricultural Laboratories in Nairobi. The screening method used involved pouring a suspension of biotype 2 of *P. solanacearum* over the plant roots in the field, and recording the wilt symptoms for 40 days. The most resistant clone, Cruza 148, now a named variety in Burundi (Ndinamagara) and Rwanda (Cruza), was used as the resistant control, and two clones, CIP 380577.7 and 800224, were found to be resistant. Clone 800224 has now been released to Kenyan farmers as the variety, "Kenya Dhamana."

In Rwanda, ten tuber families were field-evaluated by the national potato program (PNAP) for bacterial wilt resistance and general adaptation to local conditions. Although fungicides were used to control late blight, many clones failed to survive the severe attack and, in general, these families did not carry sufficient late blight resistance. No artificial population of *P. solanacearum* was established in the field and pathogen pressure was low.

Southeast Asia. In the Philippines, in collaboration with the Bureau of Plant Industry, CIP evaluated 67 clones with possible resistance to bacterial wilt at Bukidnon (250 m) and Intavas (1200 m) on the island of Mindanao. At Bukidnon, only one clone, 384488.2, had 0% infection but yielded only 7 t/ha and several clones had less than 20% infection. Yields at Intavas were higher, averaging 15 t/ha, but all clones became infected with *Erwinia* and bacterial wilt. The local control (the German var. Cosima) yielded only 0.7 t/ha of which 0.6 t consisted of infected tubers. More advanced breeding material from Lima was planted at Intavas in May of 1987. The majority of clones showed low wilt infection and yields ranged from 27 to 45 t/ha. Clones with symptoms of root-knot nematode damage were eliminated. The other increasingly important problem was *Erwinia* infection either as blackleg or soft rot.

In 1987, a rotation experiment in Mindanao to control bacterial wilt in potato was in its fourth season and the soil bacterial population was examined. Included in the rotation were a monocrop of maize, and mixtures of beans plus sweet potato and beans plus maize. The soil population of *P. solanacearum* was highest after monoculture of potato and lowest after continuous maize and mixed maize-sweet potato cultivation. In the fifth season, when potatoes were planted in all plots, there was a high incidence of bacterial wilt for all treatments, indicating that the soil bacterial population was still adequate to cause severe wilt even after rotation.

Development of monoclonal antibodies against *P. solanacearum*. At the University of Wisconsin in the United

States, with support from a CIP research contract, work continued on obtaining additional hybridomas that produce monoclonal antibodies against strains of *P. solanacearum*. The hybridomas were obtained by immunizing mice. Four hybridomas have activity against most strains of *P. solanacearum* tested to date. One reacted in ELISA tests with 24 of 24 race 1 strains, 15 of 16 race 2 strains, and 23 of 24 race 3 strains. No other bacteria, common in potato tubers, reacted with these antibodies, nor did another 11 bacteria tested. By using the Western blot technique, three of the four monoclonal antibodies tested reacted similarly to three race 3 strains but also with strains of other races.

In an attempt to produce a race 3-specific antibody, tolerization was practiced whereby newborn mice were injected with bacteria of race 1 of *P. solanacearum* and later, as adults, with a race 3 strain. The expectation was that the race 1 antigen would be recognized as "self" and that when the mice were injected with the race 3 strain, the antibodies produced would be those not shared with the race 1 strain. Unfortunately, this specificity was not evident, and the reverse procedure is now underway (i.e., tolerization with race 3 followed by injection of mice as adults with race 1).

At the Institute of Plant Protection in Beijing, China, three hybridoma cell lines were studied, which secrete monoclonal antibodies specific for different strains of *P. solanacearum*. Fusion work was initiated and new hybridoma cell lines are expected to be selected.

Restriction fragment length polymorphisms of DNA. At the University of Wisconsin an attempt was made to produce a race 3-specific diagnostic method. Restriction fragment length polymorphisms (RFLP) of the genomic DNA were prepared for 53 strains of *P. solanacearum*, representing four biovars and three races, to assess their relatedness by Southern blot analysis involving cloned DNA fragments in plasmids as probes. Ten probes, containing sequences affecting virulence, were used to probe Southern blots of chromosomal DNA digested with the enzymes *Eco* R1 and *Bam* H1. The probes demonstrated the distinction between many strains of *P. solanacearum* by both race and biovar simultaneously. Race 3 strains behaved as a homogeneous group; race 2 strains from bananas fell into two distinct groups that have different geographical origins; and race 1 strains exhibited highly variable patterns which is in keeping with the known heterogeneity of physiological characteristics and broad host range.

Biochemistry of resistance to *P. solanacearum* in potato. Work with callus tissue cultures at the University of Wisconsin demonstrated that when these cultures were derived from five individual clones of the cultivated diploid, *Solanum phureja*, they exhibited the same differential responses (resistance or susceptibility) to inoculation with different strains of *P. solanacearum* as did intact plants. The genes responsible for the browning (hypersensitive) reaction in incompatible combinations of host and pathogen have been identified and cloned with respect to two strains of *P. solanacearum*. Mutants lacking the browning reaction had this function restored by complementation with the cloned genes. The bacterial peptides that reproduce the browning response have been isolated.

BACTERIAL SOFT ROT OF POTATO

Ecology and epidemi[illegible] [illegible]ation water in San Ramon was con[illegible]nated throughout the year with more [illegible]han

100,000 cells per liter of *Erwinia carotovora* ssp. *carotovora*. Weed species growing in shallow streams had significantly higher populations of rhizosphere *Erwinias* than the same species growing away from the water. Thus *Amaranthus* sp. had 190,000 colony forming units (CFU) per gram of root in wet soil, 173 times greater than in soil away from streams. The proportions for *Canna indica* and *Commelina diffusa* were 62 and 41 times, respectively (data based on means for 15 plants per site for each weed species).

Water emerging from underground sources, from deep wells, or flowing through uninhabited low jungle areas was not contaminated. Enrichment procedures and incubation at high temperatures (37°-40° C) failed to demonstrate the presence of *E. chrysanthemi* (Echr) in surface waters.

When TPS transplants were irrigated with chlorinated water (5 ppm active chlorine) in raised beds for seedling tuber production, the tubers had less *Erwinia* latent infection at harvest time than when *Erwinia* contaminated water was used (Table 1). Phytotoxicity was not observed with this chlorine concentration. Differences in tuber latent infection were more pronounced during the dry season than during the wet season, probably due to greater dispersal of *Erwinia* from other sources during rainy weather. The use of a sand filter reduced the contamination slightly (*see* Ann. Rep. 1986-87).

Disinfection of freshly harvested potato tubers by dipping in 0.5% sodium hypochlorite solution (with an added wetting

Table 1. Percentage tuber latent infection by *Erwinia* from irrigation water

Irrigation water treatment[a]	Percent latent infection[b] Dry season (1986)	Wet season (1986-87)
Control (no treatment)	85.0	82.2
Chlorinated (5 ppm Cl_2)	10.0	42.2
Sand filtered	40.0	73.3
Well water (*Erwinia*-free)	–	35.6
LSD (0.05)	28.9	48.6

[a] Irrigation applied at 20 liters per m², twice per week.

[b] Detected by enrichment procedures in 5 x 10 tubers per treatment.

Table 2. Mean number of tubers from two cultivars rotting after dipping in chemical treatments at harvest or one week later to control tuber latent infection by *Erwinia*.[a]

Chemical treatment	Cv. Revolucion At harvest	Cv. Revolucion One week after harvest	Cv. DTO-33 At harvest	Cv. DTO-33 One week after harvest
Sodium hypochlorite, 5000 ppm active Cl_2, for 10 min	1.1 e[b]	1.1 e	1.9 cd	2.2 bcd
Copper oxychloride, 5000 ppm, for 10 min	2.5 abcd	1.8 de	1.9 cd	2.6 abc
Control: water dip for 10 min	2.9 ab	3.0 a	2.8 ab	3.2 a

[a] Five replicate samples of five tubers tested by damaging lenticels and incubating anaerobically at 25° C for four days.

[b] Numbers followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test; LSD (P = 0.05) = 0.70.

agent) followed by thorough drying, significantly reduced the percentage of tubers latently infected by *Erwinia*; copper oxychloride was generally less effective (Table 2).

The virulence of different *Erwinia* spp. under San Ramon conditions was studied after vacuum-infiltrating basic seed tubers with bacterial suspensions and planting in pots of sterile soil. Although all test strains had been isolated from blackleg stems and caused extensive rotting when stab-inoculated with toothpicks into potato stems, only one strain of *E. chrysanthemi* (Echr), CIP 367 (Fig. 2), caused extensive disease. Other strains of Echr and *E. carotovora* ssp. *atroseptica* caused stunting but little or no stem rot. Symptoms were not observed in plants inoculated with *E. carotovora* ssp. *carotovora* or with sterile water.

A rapid test was developed to screen for resistance to tuber soft rot and blackleg diseases using the virulent strain of Echr inoculated into potato tubers by vacuum infiltration. A wide variation in relative susceptibility to the two diseases was observed when 287 advanced clones (TPS progenitors) were tested. Preliminary results suggested that among the 287 advanced clones, 6.0% were relatively resistant to soft rot (<5% rotting per tuber, by weight), whereas 6.3% were very susceptible (>30% rotting per tuber,

Figure 2. The highly virulent strain of *Erwinia chrysanthemi*, CIP 367, under electron microscopy (× 10,000), used in screening potato for resistance to blackleg and soft rot.

by weight). Screenhouse testing revealed 8.4% of clones with potential resistance to blackleg with 7.0% being very susceptible. No significant correlation was observed between levels of resistance to soft rot and blackleg diseases when resistance to blackleg was determined for clones which had assayed either less than 5% rot per tuber or more than 30%. An initial study of 107 clones from the CIP pathogen-tested list resulted in a tentative classification into 3 being very resistant and 8 resistant to tuber soft rot (Table 3).

Damage by potato tuber moth (*Phthorimaea operculella*) significantly increased susceptibility to rotting after tubers were vacuum-infiltrated with Echr CIP 367 at a low or high inoculum level (10^5 or 10^7 CFU/ml). At the low inoculum level the mean percent rot per tuber on a weight basis (mean of 50 clones, 5 tubers per clone), when the moth was present or absent, was 11.33 and 5.31, respectively. At the high inoculum level, the mean percent rot per tuber was 20.18 and 14.30, respectively. Statistical comparisons determined that soft rot susceptibility was not affected by tuber greening, tuber size, the number of lenticels per tuber or whether or not tubers of the same chronological age were sprouted or dormant.

Table 3. Relative resistance to *Erwinia* tuber soft rot of 107 potato clones from the CIP pathogen-tested list, following inoculation by vacuum infiltration with 10^6 CFU of *E. chrysanthemi* and anaerobic incubation at 25° C.

Clone/cultivar		Tuber incubation 4 days	5 days	Level of resistance[a]
377924.1	F-7	0[b]	0[b]	VR
575045	POO5-16	0	0	VR
800268	Up-to-date	0	0	VR
676037	AMR-69.1	0	0.3	R
800034	P. Crown	0	1.0	R
800098	Kennebec	0	0.3	R
800174	DTO-33	0	0.7	R
800258	Kufri Jyoti	0	0.7	R
800926	MS-35.22	0	1.0	R
800946	AL-624	0	0.3	R
800048	Desiree	1.0	1.3	S
90 other clones		1.8	2.9	S
720092	MEX-21	4.3	5.0	VS
800085	Ultimus	4.7	4.7	VS
800956	Shang Feng	4.7	5.0	VS
573079	I-1035	4.7	5.0	VS
80[illegible]49	Sangema	4.3	4.3	VS
800951	IVP-35	5.0	5.0	VS
CV (%)		51	33	
LSD (0.05)		1.5	1.5	

[a] VR - very resistant (no rotting after 5 days); R - resistant (no rotting after 4 days, up to 1 rotting after 5 days); S - susceptible (1-4 rotting after 4 and 5 days); VS - very susceptible (4-5 rotting after 4 and 5 days).
[b] Number of tubers rotting out of five (3 replications per clone).

MYCOPLASMA YELLOW DISEASE

Potato plants with purple top or yellows symptoms, including the rolling of apical leaves and the presence of axillary aerial tubers, were collected at Lima, Cañete, Ica, Arequipa, and the Callejon de Huaylas valleys in Peru. Grafts were made onto *Datura stramonium* which when positive developed characteristic dwarfing, interveinal chlorosis, and upturning of leaf margins. Plants that also became infected with viruses or the potato spindle tuber viroid (PSTV) were discarded. Infected plants had pleomorphic bodies, 70-600 nm in diameter, present in the phloem as observed microscopically in microtome slices treated with Diener's stain or lead citrate stain. The five isolates representative of the surveyed valleys were tested on both *D. stramonium* and the potato cultivar Mariva. The most aggressive isolate is being used to inoculate cultivars by grafting or dodder transmission in an attempt to find resistance.

INTERACTION OF FUNGAL AND BACTERIAL PATHOGENS IN POTATO

Post-transplanting wilting and early dying of potatoes grown from TPS (Desiree OP) at San Ramon caused a 24.9% loss of stand during the wet season (1986-87) and a 26.4% loss of stand during the dry season (1987). Isolations from wilting plants two to four weeks after transplanting revealed the principal causal agent to be *Pythium* sp. (accounting for 13% of the loss) in the wet season and *Rhizoctonia solani* (accounting for 40% of the loss) in the dry season. However, after hilling, *P. solanacearum* was isolated from all wilting plants in both seasons.

Symptoms of mycoplasma yellows in two Peruvian potato varieties. Observe aerial tubers among the foliage and at base of stem on plant at left, *and defoliation on plant at* right.

Wilt incidence was significantly higher during the wet season when seed tubers from the same stocks were planted in the same land immediately following a potato crop, than in land rotated for one year with beans and fallow (Table 4). Causal agents were identified as *P. solanacearum* (62.8%), *Erwinia* spp. (34.7%), and *Sclerotium rolfsii* (2.5%). Similarly, in the dry season, *P. solanacearum* alone had caused 28% wilting 60 days after planting in the rotated land but no wilting at all when seed from the same stocks was planted in nearby land in which potatoes had never been grown. Significant differences were observed between wilt incidences in several clones and cultivars planted in infested land in the CIP station (Table 5). All clones were susceptible, but Atzimba and Rosita consistently wilted earlier, whereas Desiree was more tolerant.

Progeny tuber rotting, observed when potatoes were grown in ster - soil outdoors in San Ramon, was caused by *Pythium* sp. Secondary bacterial soft rot always occurred after some days, obscuring typical symptoms of *Pythium* leak and the presence of the fungus itself. Similarly, soft-rotting tubers in the field contained *Erwinia* and other soft-rotting bacteria, which prevented isolation of fungal causal agents even on selective media containing antibiotics. In a few cases, *Pythium* sp. and *Macrophomina phaseoli* were isolated. When these fungi were inoculated into healthy tubers, both induced a watery grey rot that turned pink on exposure to the atmosphere. Secondary bacterial soft rot was observed after seven days, which developed more rapidly at temperatures above 28° C, from which *Erwinia* spp. were only occasionally isolated. *M. phaseoli*, but not *Pythium* sp., could be isolated from tubers with secondary soft rot.

Table 4. Percent emerged potato plants wilting 30 and 60 days after planting crops grown from healthy seed tubers, either in rotated land or in land immediately following a potato crop. San Ramon, 1986-87 wet season.

	Rotated land		Non-rotated land[a]	
Clone	30 days	60 days	30 days	60 days
Desiree	2.2	10.9	7.4	43.0
DTO-33	9.3	23.4	3.8	100
Revolucion	5.1	18.4	11.0	100
Rosita	0.0	10.3	38.3	100
Average	4.1 a	15.7 b	15.1 b	85.7 c*

[a] Following potato crop with 50% wilting.

* Numbers followed by the same letter are not significantly different at the 5% level, according to Duncan's test.

Table 5. Clonal differences in percent bacterial wilt incidence in crops grown from healthy seed tubers in infested soil in San Ramon, 30 and 60 days after planting.

	Wet season 1986-87		Dry season 1987	
Clone	30 days	60 days	30 days	60 days
Atzimba	27.6	100.0	63.6	84.3
B-71-240.2	2.2	87.4	30.0	53.3
CFK-69.1	30.2	68.8	7.6	27.8
Desiree	7.4	43.0	0.7	2.7
DTO-28	11.2	85.7	3.4	51.4
DTO-33	3.8	100.0	1.3	4.0
LT-2	7.9	93.7	0.0	75.2
LT-7	0.8	100.0	0.0	50.0
Revolucion	11.0	100.0	25.7	42.8
Rosita	38.3	100.0	73.0	87.2
Serrana	6.8	80.6	17.2	53.1
LSD (0.05)	9.8	23.7	16.5	26.4

FUNGAL DISEASES OF POTATO

Breeding for late blight resistance. Efforts to produce cultivars resistant to late blight (*Phytophthora infestans*) were carried out by working with two breeding populations: 1) the traditional population (designated A) that has been developed primarily from *Solanum tuberosum* ssp. *tuberosum* germplasm, which includes resistance derived from *S. demissum*; and 2) a newer population (designated B) free of major genes for late blight resistance, which should eventually provide durable field or general resistance that could be screened effectively wherever late blight is a problem.

Population A. A total of 52,729 seedlings contained in 125 families (Group VII) were screened against a mixture of local race-complex isolates of *P. infestans* in a quarantine screenhouse at Huancayo. Of this group, 10,184 seedlings survived, and 5000 of these were transplanted to pots and grown to maturity in the quarantine screenhouse.

Prior to screening against the mixture of local isolates, 50% of the seedlings were screened with race 0. A total of 2227 seedlings were selected among the seedlings infected with race 0, as having some levels of resistance to late blight in the absence of R-genes. A sample of these seedlings will be tested in the field at Rionegro, Colombia, to assess their levels of horizontal resistance as adult plants. The majority of these seedlings will be tested against races 10 and 11 of the pathogen in Huancayo to make sure that the resistance shown at the seedling stage was not due to the partial incompatibility expressed by host genes R10 and R11.

In a collaborative effort between CIP and the Peruvian national potato program of INIPA, 970 clones were tested in 1987 for late blight resistance in Huanuco (2200 m). The majority of the clones were tested in 10-hill observation plots, although a sample of 100 of the most advanced clones were tested in a simple 10 x 10 lattice design, at a plant density of 41,667/ha. A total of 204 clones were selected for resistance to late blight in combination with earliness and desirable agronomic characters. From the clones tested in the lattice design, 41 were selected based on their late blight resistance, tuber yield, earliness, and tuber appearance (Table 6). The national program selected 54 clones for local and regional testing as potential cultivars with late blight resistance.

Population B. This effort began in Huancayo one year ago with intercrosses between *S. tuberosum* ssp. *andigena* clones identified as having some levels of horizontal resistance. Initially, 30,369 seedlings in 36 families were screened with race 0, resulting in 6715 survivors. These clones were grown to maturity in pots, but only 600 were maintained because of lack of greenhouse space. An additional 35,000 seedlings from crosses between "andigena" clones and "tuberosum" varieties without R-genes were screened later in the year against race 0. Population B will be expanded and is intended to eventually replace Population A.

Tropical Africa. More than 400 clones were tested for late blight resistance in three different environments in Kenya. At the highland station of Mau Narok (3100 m), 250 clones were tested for late blight resistance in 10, 20, 40, and 60-hill plots. Out of 50 new clones planted in 10-hill plots, 16 were selected. The remaining 200 advanced clones had already been screened in previous seasons. The best of these will enter the regional trials of the Kenya Agricultural Research Institute in 1988. Yields at all stations were generally low as a result of subnormal rainfall.

In Molo (2300 m), 55 clones entered their first evaluation for late blight resistance. Thirty-five clones in their second

Table 6. Tuber yield of the 16 best clones from 41 selected among 100 tested in a 10 x 10 lattice design under late blight infection in the field. Huanuco, Peru, 1987.

CIP no.	Late blight infection rate (r)	ABDPC[a] (%)	Tuber yield (kg/plant)
382140.3	.109	12.6	1.36
382178.1	.000	0.0	1.27
382146.2	.076	2.1	1.25
381406.6	.053	0.7	1.22
84PT57.1	.104	3.1	1.19
84LB9.3	.033	0.5	1.18
382146.3	.000	0.0	1.15
84PT103.1	.072	1.6	1.15
382153.4	.033	0.5	1.13
84PT178.3	.074	1.7	1.11
84LB4.2	.027	0.5	1.09
84PT63.2	.027	0.5	1.08
381102.4	.111	6.9	1.07
381135.103	.029	0.8	1.07
382130.2	.010	0.2	1.06
84PT186.2	.072	1.3	1.04
Controls			
Atzimba	.088	2.4	0.94
Revolucion	.153	30.7	0.36
Mariva	.106	47.3	0.19
Tomasa Condemayta	.027	67.9	0.15
SD			0.268
CV (%)		35.6	

[a] ABDPC = area below the disease progress curve.

evaluation were planted in larger plots. At Kabete (1800 m), a total of 70 clones were evaluated. Those best adapted at this site are subsequently screened for adaptation to lowland environments at the coastal sites. On the coast, it was observed that the majority of clones selected for further evaluation had the clone AVRDC 1287.19 in their parentage, which has shown heat tolerance on the Kenyan coast for several years.

Southeast Asia. In the Philippines, clones with resistance to late blight were evaluated by the Mountain State Agricultural College in the highlands from December 1986 to July 1987. Yields in the December trial were good, with six clones yielding over 20 t/ha and some yielding 39 t/ha. In a smaller trial based on five tuber plots, 31 clones were selected for good yield, tuber qualities, and late blight resistance. In contrast, two trials planted in March and harvested in July were unsuccessful, giving extremely low yields of less than 7 t/ha, which could be attributed to factors such as longer daylength, wet soil, and low light intensity. One clone, 381382.4, gave an exceptional yield of 32 t/ha. The new varieties Dalisay and Montañosa, grown from cuttings, also gave inferior yields. A third trial planted in December of advanced clones and varieties had a mean yield of 28 t/ha, with Montañosa giving 34 t/ha.

As part of a Masters Degree project by a Vietnamese student, superior clones selected from the CIP late blight breeding program in Lima have been used to improve late blight resistance by recurrent selection. Crossing within these clones produced 30,000 seeds of which 16,000 have been sent back to Vietnam for evaluation. A further 10,000 were screened by artificial inoculation in a screenhouse at Benguet and resistant seedlings were planted in the field for evaluation.

Early blight. *Peru.* Studies have continued on the evaluation of new sources of early blight (*Alternaria solani*) resistance from the CIP germplasm collection. Of 425 open-pollinated true seed accessions of "andigena" tested in the screenhouse in Lima at the seedling stages, 100 (23.5%) were rated as resistant after three evaluations. Twenty-three of the 100 *Alternaria*-resistant accessions evaluated as clones were early maturing under field conditions in Huancayo, indicating that the association between resistance to *A. solani* and late maturity is not absolute. A diploid population, studied under greenhouse conditions in 1986 at the seedling stage, was evaluated during the 1987 season under field conditions in San Ramon. Results from the field evaluation showed that at 75 days after planting, 48 out of 50 clones were rated as resistant; while at 85 days, 14 out of 50 clones were still very resistant. Most of the resistant clones were late maturing and low yielding.

A group of 30 progenies (from Idaho, U.S.) segregating for early blight resistance were field-tested for resistance in San Ramon with a group of 19 CIP progenies in a 7 x 7 triple lattice. The plants were inoculated twice with an *A. solani* suspension, 45 and 55 days after transplanting. The readings for early blight incidence were made 55, 65, and 75 days after transplanting, and plants were harvested at 90 days. In this population the same association was found as in previous experiments with other populations, where early blight susceptibility was highly correlated to earliness. The level of resistance, yield performance and earliness of the top-ranked families are presented in Table 7. It is noticeable that CIP progenies are the most resistant but are medium- to late-maturing. The Idaho progenies are all of medium maturity but their disease rating indicates an average damage of more than 50% of the foliage. The yields in this trial were poor due to heavy bacterial and fungal infection by soil-borne pathogens.

During the 1987 summer, a sample of CIP progenitors were mated in a 7 x 7 diallel design and evaluated at San Ramon. The experiment involved 21 progenies evaluated in a randomized complete block design (RCBD) with three replicates of 40 plants each. There were marked differences among the progenitors in transmitting the various characters. Clone Maine-47 does not transmit a high yield potential but it transmits a good level of resistance. Conversely, clone 378676.6 transmits a very high yield and good resistance but also lateness. The early maturing cultivar Katahdin and clones 377964.5 and 378015.16 transmit earliness but are relatively susceptible.

The last experiment carried out during the summer of 1987 at San Ramon was a 4 x 5 clone x tester mating design to investigate the general combining ability (GCA) for early blight resistance and other attributes. The experiment involved 20 progenies evaluated in a RCBD with three replicates of 40 plants each. Two artificial inoculations were made at 40 and 50 days after transplanting. Disease

Table 7. Performance of top-ranked CIP and Idaho progenies for yield, earliness, and early blight resistance at San Ramon (summer, 1987).

Progeny	Origin	Yield (g/plant)	Earliness[a]	Early blight[b] (days) 55	65	75
CFS-69.1 x 378676.6	CIP	329	3.0	2.0	3.2	4.7
BL-2.9 x F73008	CIP	322	3.0	2.5	3.2	4.3
378015.16 x 378676.6	CIP	298	5.0	2.8	4.2	5.7
C83.119 x BL-2.9	CIP	232	3.0	2.8	4.2	5.7
A8023	Idaho	232	5.7	3.2	5.0	5.8
377887.25 x 575049	CIP	232	3.7	2.8	4.0	5.7
A84524	Idaho	215	5.0	2.7	4.5	5.3
377250.7 x 378676.6	CIP	213	5.0	3.2	3.3	4.7
Atzimba x Bulk PVY(A)	CIP	210	5.0	2.5	4.0	5.5
A82634	Idaho	206	5.0	3.3	4.0	5.2
LSD (0.05)		116.4	1.8	1.1	1.2	1.1

[a] Earliness rating: 1 = very late, 5 = medium, 9 = very late.
[b] Early blight rating: 1 = no damage, 4 = up to 25%, 9 = 100%.

incidence ratings were made 50, 60, and 75 days after transplanting and harvesting was carried out at 90 days. Cultivar Atzimba and clone BR-63.65 had a tendency to transmit resistance to their progenies in spite of a relatively low g_i value. Among the testers, clone 378676.76, and to a lesser extent clone 575049, showed a high capacity to transmit resistance to their progenies. The early CIP clone 377964.5 transmitted good earliness but also susceptibility to early blight. Clone LT-7 had a high GCA for yield and also transmitted a moderate level of resistance to its progenies.

A sample of 29 highly selected *A. solani*-resistant clones were evaluated at San Ramon in the summer. Results for nine of these (*see* Table 3, Thrust II) indicate that it is possible to select clones with a high level of resistance (foliar damage ranging from 10% to 25%) and with medium to early maturity. Therefore, the correlation between earliness and susceptibility is not absolute and exceptions can be found.

During the 1987 winter in San Ramon, a 7 x 5 clone by tester design was evaluated for resistance to early blight and other attributes in a RCBD with three replicates and 40 plants per replicate. The progenitor Maine-47 showed a high ability to transmit resistance to early blight and earliness. The clone WNC521.12, which is resistant under long day conditions in the United States, did not transmit resistance to its progenies under San Ramon conditions. The tester 575049 was also a good combiner for early blight resistance. Finally, the tester 378676.6 was once more confirmed as the best CIP progenitor for early blight resistance. This clone, however, transmits lateness to its progenies. Table 8 shows the 12 highest-yielding families and their respective early blight ratings. Yield was good and the earliness of the majority of the progenies was medium. The average early blight resistance of this group of progenies was also improved with respect to earlier evaluations, which resulted from using highly selected progenitors.

During the 1987 winter in San Ramon, a sample of 32 second generation clones were tested for early blight resistance. Results indicated that most of these clones have medium maturity (90 days) and some have good levels of resistance. Selected clones from the progeny Utatlan-69.1 x Alwin appeared to have shorter growing periods than the rest.

A sample of 20 progenies were used to produce early blight-resistant tuber families, which will be used to test the stability of resistance in three different environments, such as in Israel, Brazil, and San Ramon.

Seventy cultivars from the pathogen-tested list were evaluated as adult plants under field conditions at San Ramon. At 75 days after planting (30 days after inoculation), 51 cultivars were rated as resistant (score ≤4.0) but at 85 days only 18 cultivars remained resistant. The majority of the resistant cultivars were late maturing.

Results of a field trial on chemical control of early blight conducted in San Ramon during the 1987 rainy season confirmed preliminary results on the efficiency of Dyrene (anilazine) in controlling early blight. The best control and highest yield, in the early maturing cultivars DTO-33 and the late maturing Revolucion, were obtained when Dyrene was applied together with Dithane M-45. Differences in infection and yield were more significant in the early maturing cultivars. The application of the two fungicides together resulted in yield increases of 5.5 and 3.8 t/ha for DTO-33 and Revolucion, respectively, when compared to the increase of the untreated control.

Latin America. Genetic materials developed to improve resistance to early blight continue to be tested in Brazil under a contract with the National Center of Horticultural Research (CNPH). Separate and combined evaluations by CIP and CNPH are made during foliage attack and at harvest. From 23 clones selected in 1986, two were re-selected in 1987. In 1986, 845 clones were multiplied for testing in 1987. CIP scientists selected 74 for further testing, while CNPH scientists selected 12. Criteria used by CNPH

Table 8. Performance of the 12 best progenies for early blight resistance of the 7 x 5 clone x tester experiment at San Ramon (winter, 1987).

Progeny	Yield (g/plant)	Earliness	Early blight (days)		
			55	65	75
WNC521.12 x 378676.6	688	4.7	3.2	4.3	4.0
CFK-69.1 x 575049	670	5.0	2.7	3.8	4.0
Maine-47 x 378676.6	660	6.0	2.7	3.3	3.7
WNC271.12 x LT-7	645	5.0	4.0	5.2	4.3
CFK-69.1 x LT-7	604	5.0	3.2	5.0	5.0
Atzimba x 378676.6	603	3.0	2.7	3.5	3.8
Maine-28 x 7XY.1	589	5.0	3.7	4.8	4.3
65-ZA-5 x 378016.16	584	4.3	3.3	4.8	4.7
MS-35.22 x 378015.16	583	4.7	3.2	4.8	4.7
Maine-28 x LT-7	569	4.7	3.8	4.8	4.0
Atzimba x LT-7	569	4.0	2.7	4.3	4.3
Maine-47 x 378015.16	566	6.7	3.0	4.2	4.2

staff are somewhat different from those of CIP staff who are looking at the worldwide usefulness of selected clones.

SOIL-BORNE DISEASES OF POTATO

Control of soil-borne pathogens. In San Ramon during the dry season (June-November 1986), nine soil treatments were compared with respect to their effect on a complex of soil-borne diseases including *Pythium* sp., *Rhizoctonia solani*, *Fusarium* spp., *Erwinia* spp., and *Pseudomonas solanacearum*. Methyl bromide (MB) together with tolclofos methyl (TM), and MB and TM alone, increased the yield of TPS transplants (Atzimba x R-128.6) to 23.9 (MB + TM), 20.1 (MB), and 16.8 (TM) kg/13.5 m^2, compared to the average yield of the control plots which was 7.9 kg. Out of 60 seedlings per treatment, on the average, 47 survived in the case of MB + TM, and 46 with MB alone, compared with 19 seedlings surviving for the control.

In a similar trial carried out at Lima (January-April 1987), transplants yielded higher (20.04 kg/27 m^2) when soil was treated with Basamid (Dazomet 98%) + tolclofos methyl (TM) than with Busan 1020 (sodium N-methyldithio-carbamate) + TM, or TM alone. However, there was no significant difference between the treatments Basamid + TM and Busan 1020 alone.

Verticillium wilt. ***Peru.*** Clones from the CIP pathogen-tested list were evaluated for resistance to *Verticillium dahliae* under greenhouse conditions at Lima. Five tubers of each clone were used, four were inoculated, and one served as the control. The inoculum was a mixture of microsclerotia + perlite, which was added at 20 g per pot at planting time. Of 94 clones evaluated, 13 were rated as resistant. These included the cultivars Esperanza, Cruza-148, LT-1, Mariva, and Yungay. Microsclerotia formation and mycelium were detected only on the stem bases, and slight chlorosis occurred in the lower leaves. Susceptible clones died early, microsclerotia covered the entire stem, and heavy chlorosis and defoliation occurred.

Colombia. The increasing importance of *V. dahliae* and *V. albo-atrum* pathogens in many areas of Colombia has intensified the search for sources of resistance to this disease. An evaluation of *Solanum tuberosum* ssp. *andigena* clones in the Colombian central collection was made using a root dip method of inoculation in the greenhouse. Resistance to *V. dahliae* was detected in four clones, compared with that of the standard variety Monserrate, which only survived for two months. Moderate tolerance was detected in two clones both of which showed resistance to *V. dahliae*. In a second test with 29 hybrids, preliminary observations showed tolerance in a further six clones.

Powdery scab. Fifty cultivars were evaluated for resistance to powdery scab (*Spongospora subterranea*) by planting five tubers per cultivar in infested soil from Huancayo in a Lima greenhouse. At harvest, tubers were rated on a 0 (immune) to 5 (highly susceptible) scale based on severity and percent area affected: cultivars G-2, Katahdin, Gabriela, and Esperanza were immune; cultivars F-3, BI-1.5, and Imilla were resistant (rating of 1); nine were moderately resistant (rating of 2); and the remaining 34 had scores from 3 to 5.

In an experiment to establish a rapid and effective seedling screening test, 20-day old seedlings of OP-Revolucion were transplanted with 25 plantlets per plastic pot or individually to "Jiffy-seven" peat pellets. The transplants were then inoculated with resting spores of *S. subterra-*

Figure 3. Typical reaction of two resistant *Solanum tuberosum* ssp. *andigena* clones (*left*) and two susceptible clones (*right*) when inoculated with *Fusarium oxysporum* at 3-mm depth inside the tuber. Note the internal pigmentation in the susceptible clones.

nea collected from diseased tubers in late 1986. Roots were evaluated after a 90-day incubation period at an average temperature of 18 C. All of the seedlings in the peat pellets developed considerable root galling, whereas those in pots had low or no symptoms.

Fusarium dry rot. Through collaboration with the French National Agronomic Research Institute (INRA), a visiting scientist from the Vegetable Pathology Station at Rennes spent nine months working at CIP in Peru. During this period, studies on Fusarium dry rot confirmed that the principal fungi causing dry rot are *Fusarium oxysporum* and *F. solani*. Screening for resistance to tuber dry rot in *S. tuberosum* ssp. *andigena* and in advanced breeding clones was performed by removing a 3-mm diameter by 3-mm deep skin and tissue plug from tubers, followed by inserting young fungal mycelia growing in potato dextrose agar, replacing the plug, and incubating the tubers in plastic bags at 22-25 C in darkness. Clone 379597.1, which had been selected in diffused-light stores in the Philippines because of its apparent resistance to storage rots, was found to be resistant to both Fusaria. The relative resistance and susceptibility of two andigena clones are shown in Figure 3.

Rust disease. In a collaborative study with Ecuador's National Institute of Agricultural Research (INIAP), research continued on determining the host range and resistance of cultivars to potato rust (*Puccinia pittieriana*). In the INIAP greenhouse, 54 species of possible host plants were inoculated with strains of the rust fungus from three localities in Ecuador. Susceptible species included tomato, tzimbale (*Solanum caripense*), *Datura stramonium*, and *Solanum nigrum*. At two of the localities, 140 potato clones were tested and six were found tolerant.

SURVEYS OF POTATO DISEASE INCIDENCE

Colombia. As part of the agreement with the Research Institute of Plant Protection (IPO), Netherlands, a survey was conducted in November 1986 on potato diseases in Colombia. The survey, a follow-up to the one made in 1984, covered the Departments of Antioquia, Boyaca, Caldas, Cundinamarca, Nariño, Santander del Norte, and Tolima.

Verticillium albo-atrum was widespread and its incidence was greater than that of *V. dahliae*, a finding contrary to the results of the 1984 survey, especially for Boyacá and Nariño. It was recommended that crop rotation and the use of *Verticillium*-free seed be practiced. Seed grown at high altitudes from basic seed produced by the national program of ICA at San Jorge was disease-free.

Rosellinia black rot was present in many of the fields surveyed, with a greater incidence than in 1984. Gray mold, caused by *Botrytis cinerea*, was common at higher elevations and appeared to colonize foliage previously damaged by the late blight fungus (*P. infestans*). The incidence was greater in Caldas and Tolima, but occurred in a few fields in Boyacá and Santander. Cool temperature, heavy precipitation (1000 mm), and permanent mists favored the fungus. Some farmers, however, were able to control it successfully with fungicides but at great expense.

Late blight (*P. infestans*), known to be a limiting factor to potato production in Colombia, was found to cause severe attacks in some fields, while control was achieved in others by chemical spraying.

Powdery scab (*S. subterranea*) was observed frequently, but farmers felt it was of little importance except in fields where crop rotation was not practiced. Among the bacterial diseases, *E. carotovora* var. *atroseptica* was prevalent at higher elevations and roguing plants with blackleg symptoms was not practiced. Bacterial wilt (*P. solanacearum*) was encountered at low levels of incidence in the warmer growing areas.

Bhutan. Through a collaborative effort with the Bhutanese national potato program, it was possible to determine the cause of potato tuber rotting during seed production, especially in the variety Kufri Jyoti. Tubers had symptoms like those of pink rot caused by *P. erythroseptica* or *P. cryptogea*. The latter fungus was isolated and considered to be the causal agent. This disease is associated with waterlogging, consequently measures to improve drainage and soil structure were recommended.

China. A survey was conducted on bacterial wilt disease of potatoes in the provinces of Hunan and Guizhou. Guizhou Province grows about 200,000 ha and bacterial wilt causes severe damage (over 40% wilted plants in several fields). Sixteen cultures of *P. solanacearum* were isolated and all were identified as race 3. A total of 47 clones were evaluated for bacterial wilt resistance. Clone MS-42.3 continued to show resistance to *P. solanacearum*, race 3. CIP clone 377852.2 (BR-63.74 x WRF 1923.1) was resistant to all races.

TRAINING

Training was focused on bacteriology, especially bacterial wilt, which was the subject of a course in China and the main theme of a seed production workshop held in Burundi for the PRAPAC network countries. The large number of scientists from Burundi, Rwanda, and Zaire attending the PRAPAC meeting emphasizes the importance of this disease in Central Africa, and the problems that it creates in government seed production schemes and in farmers' attempts to improve the quality of their own stocks through positive selection methods. The meeting formulated recommendations to help seed production specialists improve seed tuber production practices to ensure better quality stocks. Six visiting scientists and one student from the Netherlands studied bacterial wilt and *Erwinia* diseases at CIP's three research stations in Peru.

Control of Virus and Virus-like Diseases

Studies were continued on understanding the phenomenon by which cultivars with resistance to potato leafroll virus (PLRV) become susceptible to PLRV due to previous infection with potato viruses X and Y (PVX, PVY). Infection with PVX two days before challenge inoculation with PLRV was the minimum period required to induce PLRV-susceptibility in the resistant cultivars Pentland Crown and Mariva. In contrast, susceptibility to PLRV was exhibited immediately after inoculation with PVY. These results and previous findings on the lesser damage by PLRV in clones resistant to both PVX and PVY indicate that in order to develop long-lasting PLRV-resistant genotypes a background resistance to PVX plus PVY is required. New sources of resistance to PLRV, PVX, and to PVX strain HB have been identified and selected. Resistances to PLRV, PVY, and PVX, alone or in combination, are being evaluated in advanced clones under field conditions in Peru, Uruguay, Brazil, and Tunisia. Variability among geographically different isolates of PLRV was found in their transmission (acquisition) by aphids but not in their serological properties.

A study on potato virus epidemiology in Tunisia produced useful information on aphid vector population dynamics and on the spread of PVY, PLRV, and PVS. It was found that third generation seed in Tunisia produced yields comparable to those of imported seed. The whitefly, *Trialeurodes vaporariorum*, was identified as the vector of the agent causing yellow vein disease of potatoes in Colombia. The characterization of SB-22 virus from potatoes has been completed. This virus is morphologically similar, but serologically distinct, from alfalfa mosaic virus. SB-22 causes true potato seed necrosis, and 25% to 93% reduction of germination. It can be transmitted to a small proportion of germinating seedlings. A nonradioactive test for potato spindle tuber viroid (PSTV), developed in collaboration with the University of Inner Mongolia in China, will facilitate sensitive testing in the absence of adequate radioactive supplies and facilities.

The identification of a strain of sweet potato feathery mottle virus (SPFMV) has now been completed. A polyclonal antiserum produced against this strain is being used in ELISA serology for routine detection and comparison of other Peruvian isolates of SPFMV. A new kit using nitrocellulose membranes as a supporting medium in ELISA has been developed to detect potato and sweet potato viruses.

Galls in in-vitro plantlets of cultivar Mariva produced by *Agrobacterium tumefaciens*, which carries the Ti plasmid containing PSTV constructs.

RESISTANCE TO POTATO VIRUSES AND VIROID

Interaction of potato viruses. Studies were continued to determine the mechanism by which resistance to potato leafroll virus (PLRV) in cultivars is broken due to previous infection with potato viruses X and Y (PVX, PVY). The time lapse between infection with PVX and PVY and loss of resistance to PLRV was studied in cultivars Pentland Crown and Mariva. The day of inoculation with PVX or PVY was taken as day 0. From day 0 to day 9, PLRV was inoculated by means of 25 or 50 viruliferous aphids. After a 24-hour access period, aphids were killed by spraying insecticide. Two weeks after inoculation with PLRV, plants were tested for virus infection by means of ELISA serology. As expected, PVX- and PVY-free control plants of Pentland Crown and Mariva were not infected with PLRV. Susceptibility to PLRV was found in plants infected two days before with PVX, whereas susceptibility to PLRV was shown immediately after inoculation (day 0) with PVY (Table 1).

Since both PVY and PLRV are transmitted in nature by aphids, an experiment was conducted with aphids carrying both viruses simultaneously. Results confirmed previous experiments on increased susceptibility to PLRV due to interaction with PVY and showed that Pentland Crown can be infected with PLRV when both viruses are inoculated simultaneously. In a similar experiment with Mariva, neither PVY nor PLRV infected the plants by aphid inoculation.

These data on virus interactions confirm that sustained PLRV resistance should be developed on a genetic background of resistance to PVX plus PVY.

Sources of virus resistance. Previous findings on the multicomponent nature of PLRV resistance have made it necessary to determine the type of resistance available in CIP germplasm. During the year, 122 clones or cultivars were tested to determine their reaction to PLRV. In order to identify resistance to virus multiplication and tolerance as well as resistance to infection, the testing procedure used in the past was modified. The modified procedure involved determination, after inoculation with the virus, of ELISA absorbance values for each clone. Clones showing a value at or below 0.175 were selected for further precise determination of resistance to virus multiplication. To determine tolerance, all tubers from infected clones were grown under field conditions to observe symptoms and yield decreases. Eight clones showed a high level of resistance to PLRV infection and nine showed only moderate resistance. Very low ELISA readings were obtained for five clones, which will be further tested to determine resistance to virus multiplication.

Table 1. The relationship between inoculation time of potato virus X (PVX) and potato virus Y (PVY) and susceptibility to potato leafroll virus (PLRV) in the PLRV-resistant cultivar Mariva.

Days after inoculation with PVX or PVY	Healthy		PVX		PVY	
	25[a]	50	25	50	25	50
0	0[b]	0	0	0	20	60
1	0	0	0	0	40	80
2	0	0	40	60	80	80
3	0	0	40	80	60	80
4	0	0	20	100	60	60
5	0	0	20	40	20	20
6	0	0	20	20	20	20
7	0	0	40	100	60	100
8	0	0	80	80	60	100
9	0	0	80	80	80	100

[a] Number of PLRV viruliferous aphids per plant.
[b] Percentage of plants infected with PLRV.

Twenty clones immune to PVY were selected from a group of 36,470 seedlings screened in 1985. In addition, two (PW31 and PS1001) out of three tetraploid clones, received through a research contract from Dr. Swiezynski, Potato Research Institute, Poland, were immune to PVY. These clones will be used as parents in CIP's breeding program as new cycles of recurrent selection are continued.

CIP clone 379706.34, designated as LT-9, was selected because of its earliness (75-90 day growing season), high yield (1-1.5 kg plant), tolerance to heat (18-35°C min-max), good general combining ability, pollen fertility, and immunity to type isolates of PVX and PVY. It was tested against several PVY isolates and other potato potyviruses. It was immune to three isolates from each of the PVY^O, PVY^N, and PVY^C groups of strains of PVY and to one isolate of PTV-p. However, like other sources of immunity to PVY derived from *S. tuberosum* ssp. *andigena*, it was hypersensitive to the two isolates of potato virus A (PVA) tested.

Since the genes that confer immunity to PVX are known to be inoperative against the HB strain of PVX (PVX_{HB}), resistant genes against PVX_{HB} are being sought. Clone DTO-28 showed a high level of hypersensitivity to this strain and cultivars Bzura and Atlantic carry genes that confer relative resistance. Mechanically inoculated plants of Bzura and Atlantic were asymptomatic, and slow virus multiplication was detected in the low percentage (5%) of plants that became infected. Relative resistance to PVX_{HB} is therefore an additional attribute to the immunity against other strains of PVX found in Bzura and Atlantic.

Development of virus resistance. ***Peru.*** Previous results on the resistance of cultivars to PLRV were obtained by aphid inoculation of plants grown from apical cuttings. This method is time consuming and requires high labor input. The inoculation of sprouted tubers was therefore investigated as a more efficient approach. In general, inoculation with 50 viruliferous aphids per plant or sprouted tuber resulted in higher levels of infection in tubers than in plants. For clone BR63.15 and cultivar Serrana, the results were the same (Table 2), and for Mariva and Pentland Crown the percentages of infection with both methods fell into an acceptable range. Therefore, inoculation of sprouted tubers appears to be a better alternative than plant inoculation for rapid screening of potato germplasm.

Table 2. Average[a] percentage of infection of PLRV-resistant and susceptible potato clones when inoculated as plants or tubers with viruliferous aphids.

CIP no.	Clone cv.	Plants (%)	Tubers (%)
800942	BR63.15	13.0	0
720025	Mariva	0	6.6
800144	DTO-2	53.3	53.3
800174	DTO-33	60.0	93.3
800034	P. Crown	0	6.6
720087	Serrana	6.6	0

[a] Average of three experiments in which plants or sprouted tubers were each inoculated with 50 viruliferous aphids. PLRV infection was tested in secondarily infected plants.

Several sources of germplasm were screened for PLRV resistance. Forty clones from the haploid breeding program were screened under greenhouse conditions during 1985 and 1986. This year, 15 of the selected clones were exposed to PLRV in field trials on the coast of Peru at Ica and Cañete. Three clones showed percentages of infection below those found in Revolucion (control) and they have been selected for further field exposure trials.

In another field trial in Ica, 28 clones were tested for PLRV infection: 14 haploid clones obtained from tetraploid advanced clones having resistance to PLRV, 11 4x-2x clones derived from *Solanum chacoense* from INTA, Argentina, and 3 2x hybrids. The 14 clones that did not become infected or showed a low percentage of infection have been selected for further tests. Several clones showed higher percentages of infection than the susceptible control.

Development of, and screening for, combined resistances to viruses was emphasized during the year. A total of 1945 seedlings from populations combining late blight, PVX, and PVY resistances obtained from Dr. J. G. Hermsen, I.V.P. Agricultural University, Netherlands, were screened for PVY or PVX + PVY resistance. Of this group, 37% of the seedlings were selected as putatively immune to the viruses. Intercrosses among PVY-immune advanced clones were aimed at increasing the frequency of the gene controlling immunity to PVY. From these intercrosses, 160 clones were selected on the basis of their agronomic attributes. About 50 of these clones are expected to be duplexes. These duplexes will be very important in combining PVY + PLRV resistance since it is expected that 83% of the progeny resulting from crosses between duplex-carrying genes with PLRV-resistant clones will be immune to PVY and will segregate for PLRV resistance.

Screening for PVX and PVY in one population (86D) that combines PVX + PLRV and PVY + PLRV resistances was completed. From a total of 16,658 seedlings, 44% were immune to PVY or PVX + PVY. The selected genotypes are under field evaluation for PLRV resistance and agronomic characteristics.

A new population that combines resistance to *Globodera pallida* with PVX and PVY immunity was obtained and screened. Of the 2424 seedlings screened, 50% were immune to PVY or PVX + PVY.

Uruguay. In Uruguay, two clones (381371.8 and 382284.16) selected by the Agricultural Research Center (CIAAB) in 1984 from tuber families multiplied in 1983 continue to be evaluated for agronomic characteristics. Both clones show good resistance to PLRV and PVY, are early, and have short dormancy. They also have acceptable resistance to early and late blight and will be used as parents in breeding programs.

Brazil. Virus resistance testing in Brazil was carried out in Brasilia and in Brazlandia by CIP and the National Center of Horticultural Research (CNPH). There was a considerable difference in the levels of PLRV pressure at the two sites; however, the pressure level in Brasilia was better than that at Brazlandia for selections to be made. Among the cultivars tested, Serrana, B-71-240.2, Pentland Crown, LT-1, CFS-69.1, BR-63.65 x Atlantic, BR-63.65 (Molinera), and Santa Fe showed good resistance. In addition, LT-1, CFS-69.1, Pentland Crown, and Serrana showed resistance to PVY.

Tunisia. From a large number of clones introduced into Tunisia in 1985, 23 clones were selected for agronomic qualities and resistance to PVX, PVY, and PLRV. After three consecutive seasons, eight clones continue to show resistance. The yields of these clones ranged from 640 g/plant to 1.122 g/plant. From a total of 469 clones of three different families previously selected in 1986, 54 clones were selected for good agronomic attributes and virus resistance. It is noteworthy that this material is early, a necessary attribute in Tunisia.

Mechanisms of resistance to PVY. Observations in the transmission electron

Figure 1. Reaction of immune (LT-9) and susceptible (Flor Blanca) cultivars after being grafted with a potato virus Y-infected scion from *Nicotiana occidentalis*. Deposition of callose (**A**) in sieve plates and accumulation of p-protein (**B**) in the immune cultivar (*upper*) is not observed in the susceptible one (*lower*).

microscope of compatible (plant infected) and incompatible (plant not infected) interactions indicated that immunity to PVY involves a virus-induced mechanism of resistance rather than constitutive resistance (Fig. 1). It appears that after grafting a PVY-infected scion from *Nicotiana occidentalis* on a PVY immune stock (e.g., LT-9), deposition of callose in sieve plates occurs. This callose probably blocks the translocation of PVY. Accumulation of p-protein is also observed at the sieve plate in the incompatible interaction, but its function is not yet understood.

Studies on "engineered" resistance to PSTV. Attempts to confer resistance in potato to viruses by molecular cross-protection was initiated by using potato spindle tuber viroid (PSTV) as a model. Experiments are underway in an attempt to incorporate into the genomes of cultivars Mariva and Ticahuasi (highly susceptible to PSTV) a PSTV cDNA copy that may generate protecting, noninfectious PSTV transcripts.

Agrobacterium tumefaciens is being used as a vector and the regeneration of transgenic plants follows procedures reported in the literature. The constructs used (pCGN 162a and pCGN162b) to transform potato are monomeric, full-length copies of PSTV under the control of a 5S Kan promoter. These constructs differ in orientation in the plasmid, and after repeated *Agrobacterium*-mediated inoculations they were unable to generate infectious transcripts. A set of PSTV constructs has been generously donated to CIP by Calgene Inc. of the United States. Potato tissue whose genome is supposedly transformed by incorporation of the above-mentioned PSTV cDNA constructs has been selected by culturing in medium MS 13, containing 100 μg/ml of Kanamycin. Confirmation of transformation depends upon tests for opines and Southern/Northern blot analyses to detect the presence of PSTV cDNA sequence and the corresponding RNA in cells.

VARIABILITY OF POTATO VIRUSES

Variability of PLRV. The variability of different isolates of PLRV was studied in three Peruvian isolates (code-named 10, 01, and 29) and in single isolates from China, Nepal, Uruguay, Korea, and Kenya. The virus-vector relationships of these isolates was studied using a colony of *Myzus persicae* derived from a single aphid. The acquisition period showed no variation in isolate 10 or in the Chinese and Korean isolates, since all of these isolates can be acquired from an infected plant within 15 minutes. The isolate from Uruguay could only be acquired after 30 minutes and isolate 29 after 6 hours of access. The isolate from Nepal could not be transmitted even after 48 hours of access to an infected plant. These results, showing that PLRV shows high variability in transmissibility, are of considerable practical importance in relation to testing and development of sustained resistance.

Variability of PVY. In recent years several potyviruses have been isolated from potato fields in Europe and elsewhere and reported as deviating strains of PVY. It is important in breeding for sustained resistance to PVY to understand the relationship of potyviruses to PVY. In collaboration with Dr. B. D. Harrison, of the Scottish Crops Research Institute, Scotland, it was found that the UF isolate and other European isolates reported as potato virus V (PVV) reacted with eight monoclonal antibodies (MA) prepared in Dr. Harrison's laboratory to an isolate of PVV from the United Kingdom. Peru tomato virus (type isolate from Peru, which is not virulent on potatoes) reacted with seven of the MA. As expected three of the MA also reacted with PVY (a serologically related but different potyvirus). The other four MA seem to be specific for PVV. These studies support the concept that PVV isolates are members of the potato strain of PTV (PTV-p). The MA kindly supplied by Dr. Harrison are now being tested against a broad spectrum of potyviruses at CIP.

Characterization of potato viruses. Experiments have shown that the SB-22 virus is transmitted by *Myzus persicae* in a nonpersistent manner and also through the botanical seed of potato and *Capsicum annuum*. Even though the virus causes seed necrosis, and seed germination is also reduced by 25-93%, low percentages of virus transmission to seedlings have been detected. Virus SB-22 shares no serological relationship with alfalfa mosaic virus, which has morphologically similar virus particles to SB-22 (Fig. 2). A serologically related strain of SB-22 (SB-25) has been found in potatoes in the Peruvian Andes.

In Colombia, the most important new disease of recent years is the "yellow vein" syndrome presumably caused by a virus. This problem is closely associated with adjacent bean crops or intercropping of potatoes and beans. It was confirmed that the principal vector is the whitefly, *Trialeurodes vaporariorum*, which acquires the ability to infect potatoes after only 30 minutes feeding time on an infected bean plant. Inoculation feeding for seven hours is necessary to infect potato, in which symptoms first appear within 19 days after inoculation. Several naturally occurring enemies in the orders *Hymenoptera* and *Diptera* were identified parasitizing the whitefly larvae. Yield reductions as high as 50% have been observed in infected plants.

POTATO VIRUS EPIDEMIOLOGY

Research in Tunisia on the correlation of aphid populations and virus spread in potato seed tubers multiplied in consecutive generations showed the following: 1) vector pressure does not increase constantly, the observed peaks of aphid population are regularly followed by a rapid decline;

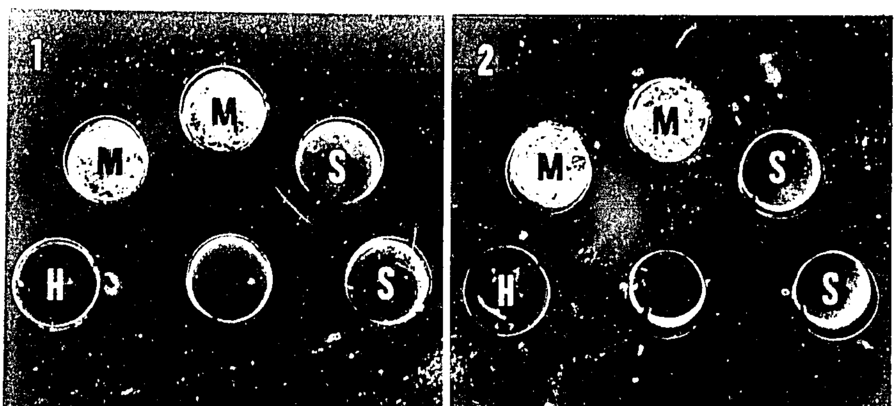


Figure 2. Serological relationship between SB-22 virus and alfalfa mosaic virus (AMV) in gel immunodiffusion. Central wells contain antiserum to SB-22 (1) and AMV (2). Peripheral wells (H) contain healthy *Physalis floridana* sap. The remaining wells contain *P. floridana* sap infected with SB-22 (S) and AMV (M).

2) spread of PVY and PLRV remains very limited; 3) buildup of PVS is important, it reaches 20% in the second generation and close to 50% in the third generation; and 4) yield of third generation seed in Tunisia is comparable to that of imported seed, although tuber number per plant is higher in locally multiplied seed.

BIOLOGICAL ASPECTS OF PSTV INFECTION

Previous observations have shown that when potato seedlings are inoculated with PSTV, varying efficiencies of transmission can be obtained. To determine the factors involved in efficiency of PSTV transmission two experiments were carried out. One of them indicated that efficiency of transmission depends on the size of the potato seedling at the time of inoculation. Maximum transmission was obtained in plants 5 cm in height and lower transmission occurred in plants smaller or larger than 5 cm (Fig. 3). This behavior may be related to the differing physiological state of seedlings at different ages.

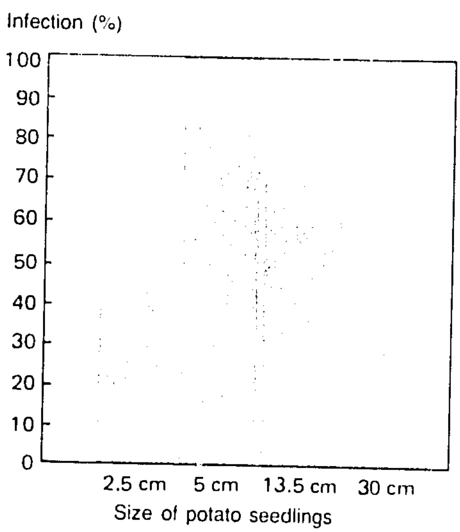


Figure 3. Relationship between size of potato seedlings at the time of inoculation with potato spindle tuber viroid (PSTV) and the percentage of infection.

Appropriate selection of samples is crucial for detecting PSTV. Therefore a second experiment was conducted to find the relative concentration of PSTV in actively growing plantlets. As shown in Figure 4, maximum viroid concentration was obtained in the growing tips, including roots; whereas minimum concentration was obtained toward the middle of the plant.

The distribution of PSTV in potato plants after infection was monitored by a procedure developed at CIP. Plants of different ages were inoculated with PSTV, and infection was determined in stem segments excised at different intervals during the incubation period. The first leaves to be infected in a plant, regardless of the site of inoculation, were those at the top. Thereafter, infection progressed acropetally. This seems to be a general phenomenon with viruses and viroid and apparently differs from previous reports in the literature.

IDENTIFICATION OF SWEET POTATO VIRUSES

The host range of isolate C-1 of sweet potato feathery mottle virus (SPFMV) was found to include species in the families Convolvulaceae, Solanaceae, and Chenopodiaceae. This virus infected systemically *Ipomoea velardei*, *I. dubia*, *I. dumetorum*, *I. quamoclit*, *Nicotiana benthamiana*, *N. clevelandii*, *N. occidentalis*, *N. clevelandii* x *N. bigelovii*, and *Datura metel*, and it caused symptomless local infection on *Chenopodium murale*, *D. tatula*, and *Spinacea oleracea*.

The stability of this isolate in leaf extracts of *N. benthamiana* was as follows:

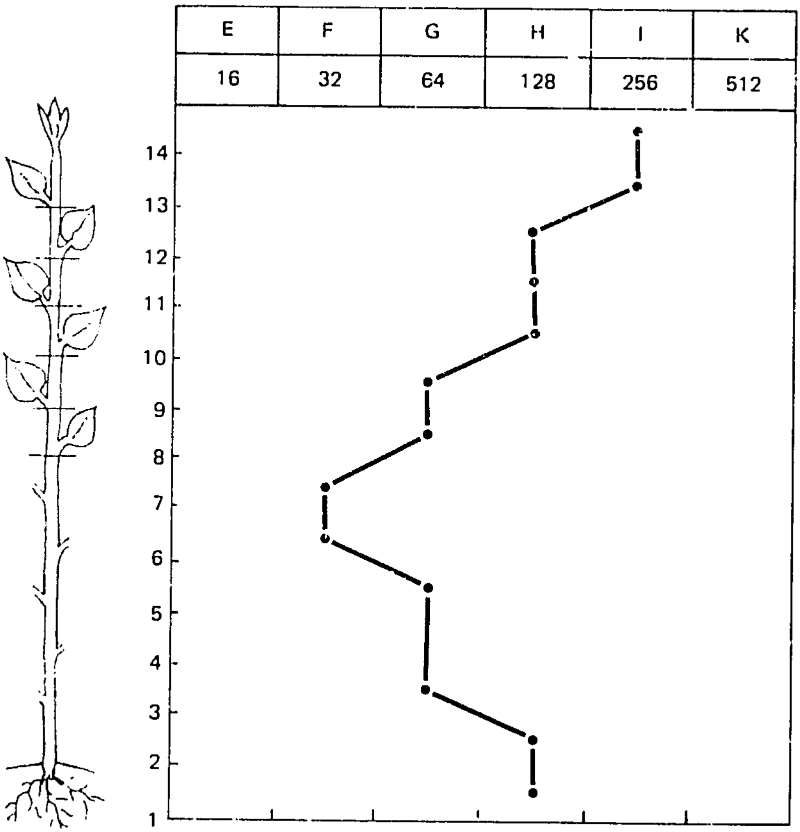


Figure 4. Relative concentration of potato spindle tuber viroid (PSTV) in a secondarily infected potato plant. The numbers 1-14 represent sections of the plant where the viroid was detected. E to K = reciprocals of sap dilutions at which PSTV was detected.

dilution end point was 10^{-2} to 10^{-3}, the thermal inactivation point was 50° C, and longevity in vitro was less than 24 hours. It was nonpersistently transmitted by both *Aphis gossypii* and *M. persicae*, but it was not transmitted by whiteflies.

The virus was not transmitted to true seed from infected plants in Solanaceae, but experiments are now being continued in sweet potatoes and other related species. Isolate C-1 was purified from systemically infected *N. benthamiana* leaves harvested about 18-28 days after inoculation. The leaves were homogenized in 0.2 M potassium phosphate buffer containing 0.05 M ethylenediaminetetraacetic acid (EDTA), 0.5% 2-mercaptoethanol, and 0.5 M urea (1:2; w/v). Clarification with carbon tetrachloride, followed by two cycles of precipitation in sucrose cushions and sedimentation in cesium chloride gradients, yielded a purified preparation.

An antiserum of low titer in immunodiffusion tests has been produced and is being used to define serological relationships with other isolates of SPFMV from Peru. Due to the great variation observed among field isolates of SPFMV, studies on the variability of this virus have been initiated. Another filamentous virus found in some sweet potato plants in Peru is under identification.

NC-ELISA for potato virus detection. The detection of the most important potato viruses with an ELISA protocol, which uses nitrocellulose (NC) membranes as the support medium (NC or dot blot ELISA), has been evaluated and a kit is being developed for distribution in 1988. Higher virus-specific reactions and lower nonspecific reactions were obtained by the use of 0.01 M EDTA (disodium salt) and 0.01 M diethyldiethiocarbamic acid (DIECA) in the extraction buffer, and 1% of nonfat milk and 0.5% of bovine serum albumin as blocking agents.

The technique has been used to detect PVA (Fig. 5), PLRV, PVY, PVX, and other potato viruses, as well as some sweet potato viruses. At CIP this technique is considered as a potential tool to monitor sustained resistance to viruses in germplasm sent to different countries.

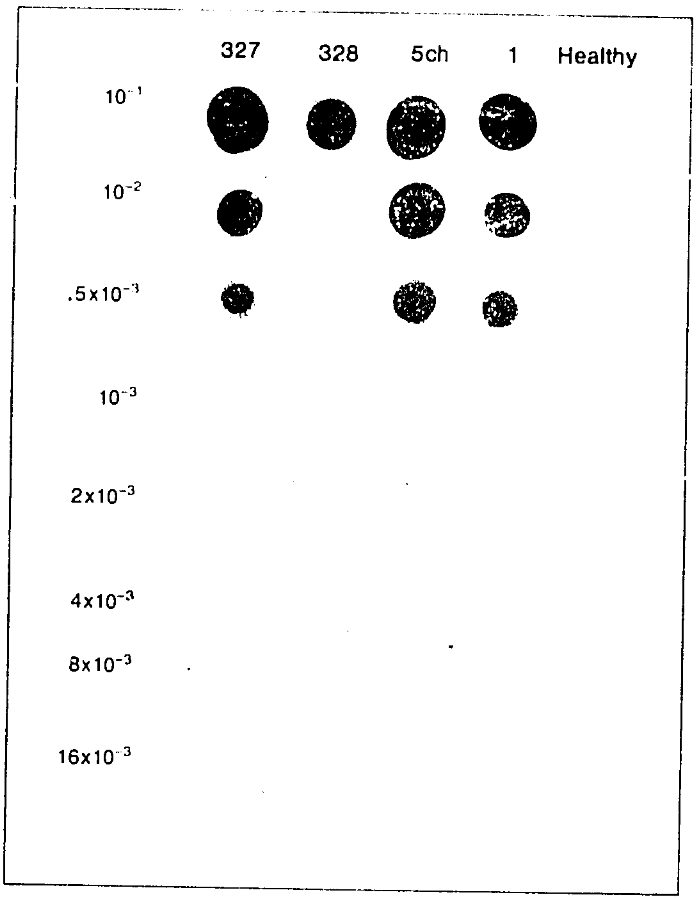


Figure 5. Sensitivity and specificity of NC-ELISA for detecting potato virus A (PVA) isolates. Fifty μl of diluted crude sap from infected and healthy plants was spotted on a nitrocellulose (NC) filter and the virus [illegible]cted with $F(ab')_2$ fragments of the IgG. Detection of bound $F(ab')_2$ was done by a goat anti-rabbit globulin enzyme conjugate.

Production and distribution of antisera. From November 1986 through September 1987, immunoglobulins and enzyme conjugates were distributed from CIP headquarters for use in ELISA tests of about 45,000 samples for PLRV and PVY, 40,000 samples for PVX and PVS, and 32,500 samples for Andean potato latent virus and Andean potato mottle virus (APLV, APMV). Reagents for testing around 500,000 potato samples for the most important viruses have been sent to CIP's eight regions to date. A considerable increase in the use of serological techniques for virus detection has occurred in CIP Region III (East and Southern Africa). This year they received almost 30% of the total number of ELISA kits sent from headquarters.

A project was developed several years ago to improve serological detection of viruses in developing countries. This project has two phases: In phase I selected countries in each CIP region receive whole or fractionated antisera and training to develop the reagents required for ELISA and latex tests. In phase II, the selected countries receive training to produce their own antisera. A large amount of antisera or globulins and enzyme conjugates were sent mainly to countries where phase I of the proposal for antiserum production is in operation. In Region II (Non-Andean Latin America), CNPH-EMBRAPA of Brazil has already successfully completed phases I and II of the proposal (i.e., production of sensitized latex and ELISA reagents using CIP's antiserum and production of their own antisera). Argentina's National Institute for Agricultural Research (INTA) has completed phase I of the proposal with the preparation of a prototype ELISA and latex kit and is beginning phase II with the preparation of their own antisera. In Region IV (North Africa and Middle East), the National Agricultural Research Institute (INRAT) has already completed phase I of the proposal and is entering phase II. A virologist from the country network PRECODEPA (Central America-Caribbean) was trained during the year at CIP headquarters in latex sensitization and immunoglobulin and enzyme conjugate preparation, using the antisera produced by them at CIP.

Plasmid and probe development. Several plasmids containing viroid inserts have been developed and cloned. Plasmid pSP65 containing inserts for PSTV (+ and −) and the viroids Citrus exocortis and Tomato planta macho, is available. In addition, a plasmid containing avocado sunblotch viroid has been kindly donated by Dr. R. Symons, of Adelaide University Centre for Gene Technology, Australia.

Virus inserts from pBR 322 (PLRV, PVX, and PVY), originally from Dr. D. C. Baulcombe, of the Plant Breeding Institute, Cambridge, U.K., have been transferred into a pUC9 vector as an intermediate step for incorporation into pSP65 vectors.

Preparation of probes by labeling cDNA or cRNA with ^{35}S proved less efficient than ^{32}P for routine diagnosis of PSTV. A new nonradioactive system has been used for PSTV detection and compared to the use of ^{32}P-labeled RNA probes. Though the nonradioactive probe facilitates clear detection of PSTV (Fig. 6), it is tenfold less sensitive and equally or slightly more expensive per sample tested than the ^{32}P-labeled RNA-probe. The nonradioactive probe is therefore only good as a backup to our present radioactive system.

A collaborative research project was implemented in 1985 between CIP and the University of Inner Mongolia, China, to develop a PSTV detection method that

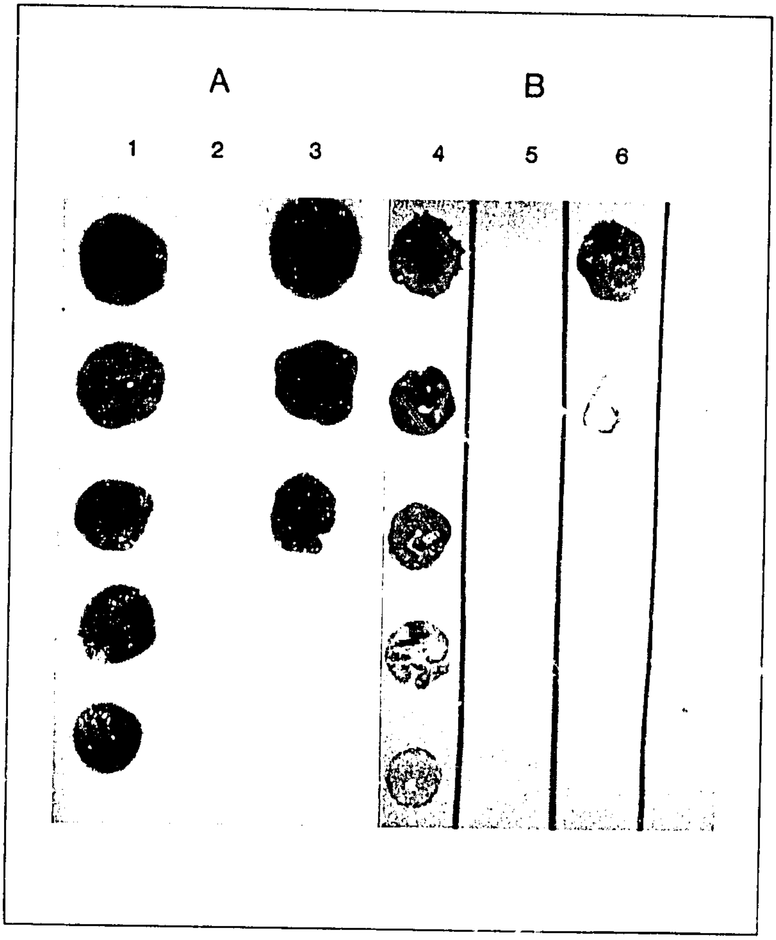
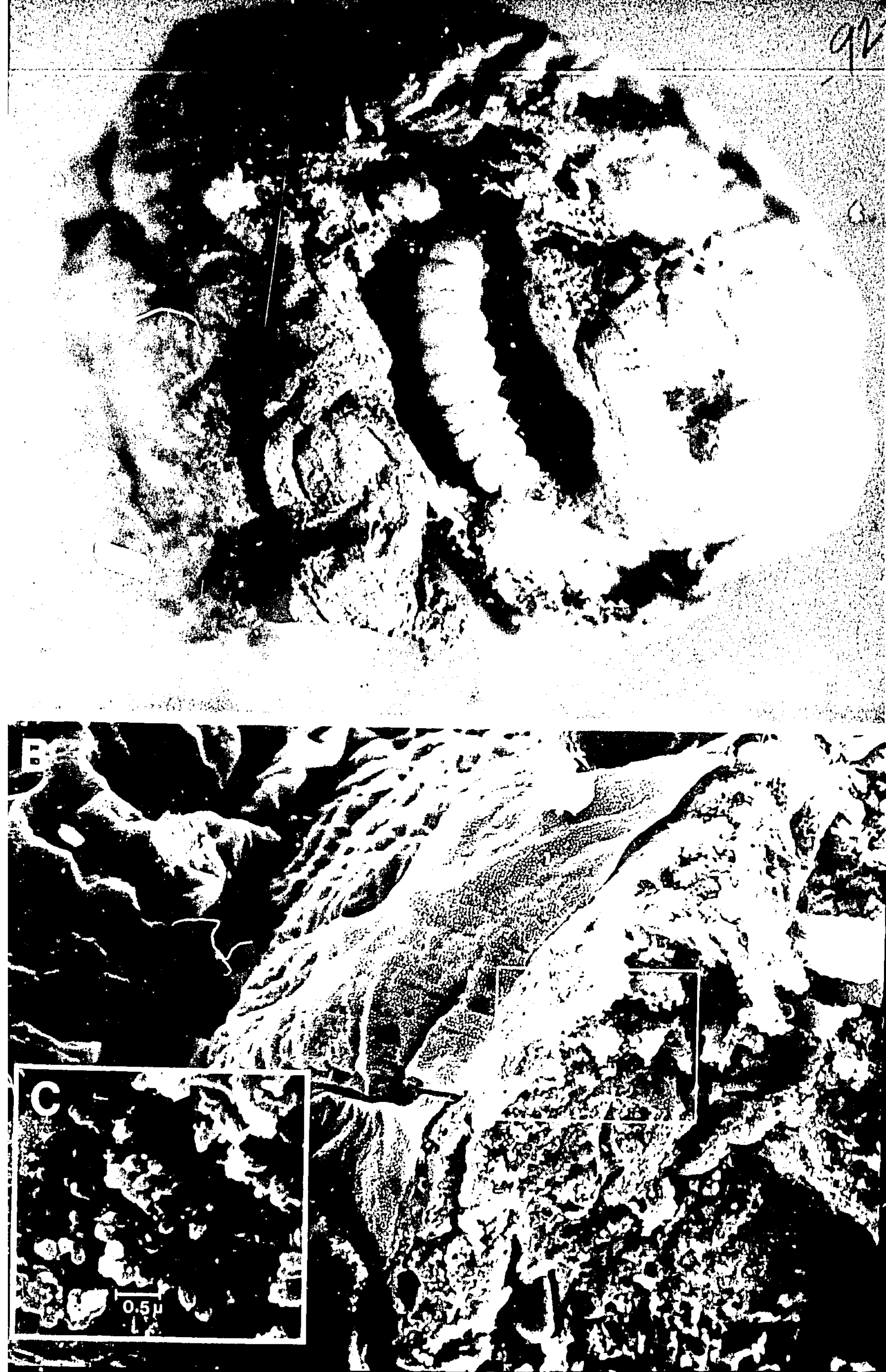


Figure 6 Detection of potato spindle tuber viroid (PSTV) by ^{32}P-labeled RNA probe (**A**) and a nonradioactive probe (**B**). Columns 1 and 4 from top to bottom are dilutions of purified PSTV: 25 ng, 1 ng, 200 pg, 40 pg, and 8 pg. Columns 3 and 6 are undiluted (top spot) and dilutions of PSTV-infected potato sap, 1/5, 1/25, 1/125, 1/625. Columns 2 and 5 contain twofold dilutions of healthy sap (top three spot places) and buffer (last two spot places).

does not require the use of a radioactive probe. The latter has disadvantages because of difficulties in obtaining adequate supplies as well as lack of laboratory facilities suitable for handling radioactive materials. The research results indicated that PSTV in potato and tomato can be hybridized with a biotinylated DNA or RNA probe. Hybrids can then be detected by an alkaline phosphatase-labeled streptavidin molecule. This procedure is now being implemented in CIP germplasm redistribution centers in Africa and the Philippines.

TRAINING

The major effort during the year was centered on individual training at CIP headquarters in Lima where 19 visiting scientists spent a total of 53 weeks. The work covered three categories: basic research, antisera production, and biological and serological identification methods. Virus identification is taught as one of the components of prebasic seed production technology.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THRUST V

Integrated Pest Management

Research on potato cyst nematode, *Globodera pallida*, has resulted in the release of a new resistant variety, named "Maria Huanca," by the Peruvian national potato program. This new variety is resistant to races P_4A and P_5A of *G. pallida*, tolerant to late blight, immune to potato virus X, hypersensitive to potato virus Y, resistant to races 1 and 2 of potato wart, is oblong-shaped with red skin, and a high yielder. A new group of advanced clones were sent to the national programs of Colombia, Ecuador, and Peru to select for resistance to potato cyst nematode and agronomic traits under their respective environmental conditions.

Clones resistant to the root-knot nematode, *Meloidogyne incognita*, have been identified in potatoes and sweet potatoes. In potatoes, 0.7% to 5% of the recent 4x-2x crosses and 5% to 10% of 74 diploid clones were found resistant to three distinct populations of *M. incognita*. A total of 28 out of 1245 accessions of the sweet potato germplasm were resistant to *M. incognita* and 26 of these were also resistant to the root lesion nematode, *Pratylenchus flakkensis*.

A total of 111 selected clones showed moderate resistance to low levels and 71 to high levels of infestation by potato tuber moth (PTM), *Phthorimaea operculella*. In another test, the progeny of diallel crosses comprising more than 2000 diploid clones showed a high frequency of resistance to this pest. The application of granulosis virus isolates from Peru, Tunisia, Australia, and India gave good protection against PTM in stored tubers. When tubers were infested 90 days after virus application, 78% of the larvae became infected. In stores, two applications of microencapsulated PTM pheromone reduced the reproductive rate of the moth, and the level of infested tubers in the treated store was three times lower than that in the nontreated store. Sources of resistance to potato Andean weevil, *Premnotrypes suturicallus*, and the potato leafminer fly, *Liriomyza huidobrensis*, have been identified.

Screening for resistance against the sweet potato weevil, *Euscepes postfasciatus*, in 700 accessions of CIP's sweet potato germplasm has led to the identification of 15 resistant clones. The occurrence of sweet potato foliage feeders and their natural enemies in the Cañete Valley of the coast of Peru was studied as an integral part of a sweet potato ecosystem.

A. Diseased potato tuber moth (PTM) larva in tuber. B. Transverse section of this larva under SEM with box showing location of granulosis virus (GV). C. Insert showing enlarged GV particles under SEM.

POTATO CYST NEMATODE

Release of a new resistant variety. The Peruvian national potato program of INIPA has released the first variety with resistance to races P_4A and P_5A of the potato cyst nematode, *Globodera pallida.* This clone (279142.12) was selected from a group of advanced clones developed by CIP (Fig. 1). Additional attributes of this new variety, named "Maria Huanca," are tolerance to late blight, immunity to potato virus X (PVX), hypersensitivity to potato virus Y (PVY), resistance to races 1 and 2 of potato wart, and other characteristics such as red skin, oblong shape, and high yields.

In on-farm trials carried out jointly by staff of the national program and the Swiss Development Cooperation (COTESU), this variety did not allow nematode reproduction under low nematode populations and reduced nematode numbers in fields with high levels of infestation (Fig. 2).

Three additional clones of similar background (andigena x vernei-tuberosum) and performance, which are in the final stages of evaluation for resistance to potato cyst nematode and agronomic traits in Ecuador and Peru, also have the potential of being released as new varieties.

Advanced clones. Ten of 40 selected clones tested by the Peruvian national program inhibited the development of female nematodes in systematic trials for four years and are under agronomic evaluation. None of the clones sent to Ecuador in 1984 were selected as promising cultivars.

From a new cycle of selection, 88 advanced clones were sent to the Peruvian national program and 100 to the Colombian and Ecuadorian national programs for evaluation and selection under their

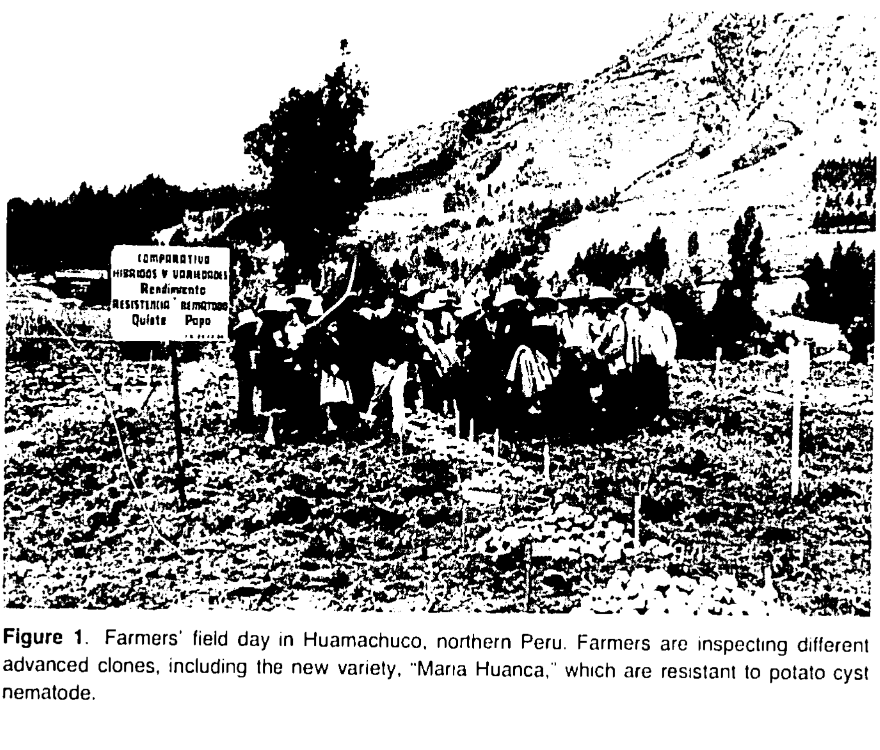


Figure 1. Farmers' field day in Huamachuco, northern Peru. Farmers are inspecting different advanced clones, including the new variety, "Maria Huanca," which are resistant to potato cyst nematode.

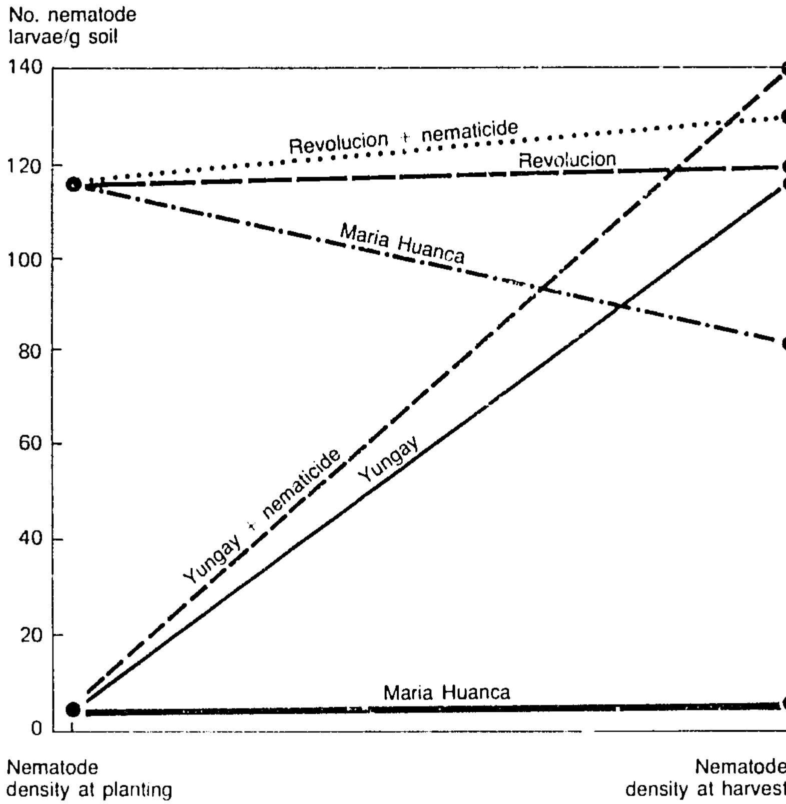


Figure 2. Effect of one resistant (Maria Huanca) and two susceptible varieties (Yungay and Revolucion) on potato cyst nematode populations when planted under high and low initial nematode densities in soil. INIAA-COTESU Special Project, Peru, 1987.

respective agroecological conditions, including the occurrence of local nematode races (Fig. 3). The occurrence of high frequencies of resistance to both races of *G. pallida* in the current breeding material will place greater emphasis on their adaptation to local conditions in Peru, Ecuador, Colombia, Panama, and Pakistan. A high correlation (95%) was found between greenhouse and field tests for P_4A resistance in the Mantaro Valley of Central Peru.

New breeding material. In Peru, 902 clones were selected in Huancayo from 10,000 seedlings subjected to resistance tests in 1987. Half of these seedlings were outcrosses to materials with resistance to PVY, PVX, late blight, and with tuberosum-like characteristics in order to comply with the requirements of the non-Andean countries. From observation plots, 144 clones were selected and entered into replicated yield trials for further evaluation of resistance and agronomic characters.

Screening for resistance. Thirty-three families consisting of the crosses made with some wild tuber-bearing *Solanum* species were checked in a mass seedling screening test in Huancayo to determine their resistance to races P_4A and P_5A of *G. pallida*. Twenty-four families were

Figure 3 A scientist from the Ecuadorian National Institute of Agricultural Research is evaluating a trial for adaptation of nematode resistance [illegible] in a farmer's field, Carchi Province, 1987.

found to be highly resistant to race P_4A while 25 were resistant to race P_5A. A summary of the material evaluated in 1987 from CIP's and other breeding programs is shown in Table 1.

In clones 279130-5, 276038-5, 278050-3, and 280613-13, tolerance to potato cyst nematode was reconfirmed. These clones produced well in fields infested with *G. pallida*.

Biological control. Nematopathogenic fungi isolated from cysts collected from various potato-growing areas of Peru were inoculated into naturally infested fields to determine their efficiency as biocontrol agents. No significant differences in yields or nematode multiplication rates were recorded. An unidentified *Paecilomyces* species tended to reduce the nematode multiplication rate more than others and will therefore be tested again to determine its real potential as a biocontrol agent.

Effect of manure and fertilizers. The addition of manure to a *G. pallida*-infested soil significantly increased the yield of a susceptible cultivar (Mariva) but the addition of extracts containing alkaloids from *Lupinus mutabilis* did not improve the effect of manure (Fig. 4). No significant differences in nematode multiplication rates were found. Mineral fertilizers, NPK and NP, favored plant growth and yields despite an increase in the nematode population.

Chemical control. Application of the nematicides, isazophos and oxamyl, significantly increased potato yields 82% and 53%, respectively, in naturally infested fields, but the effects on nematode multiplication rates were not significant.

Table 1. Screening for resistance to P_4A and P_5A races of *Globodera pallida* (PCN) in potato genetic material classified according to their source and purpose. Huancayo, 1987.

Material group	No. families (F)/clones (C)			
	(P_4A)		(P_5A)	
	Tested	Resistant	Tested	Resistant
I. Crosses of wild species				
OCH-86	5018 (C)	637	–	–
OCH-86	100 (F)	25	100 (F)	24
II. PCN breeding program				
G-84	68 (C)	59	89 (C)	81
G-85	537 (C)	438	482 (C)	396
G-86	120 (F)	53	120 (F)	46
III. Other breeding programs				
Cornell 86	70 (C)	60	42 (C)	22
Cornell 86	71 (C)	50	66 (C)	44
Cornell 86	13 (F)	6	13 (F)	2
Wageningen	61 (C)	54	57 (C)	8
Pathogen-tested	83 (C)	8	75 (C)	2
Landeo 86	151 (C)	1	141 (C)	1
IV. PCN exportation program				
Set 7	36 (C)	36	42 (C)	39
Set 6	544 (C)	167	862 (C)	102

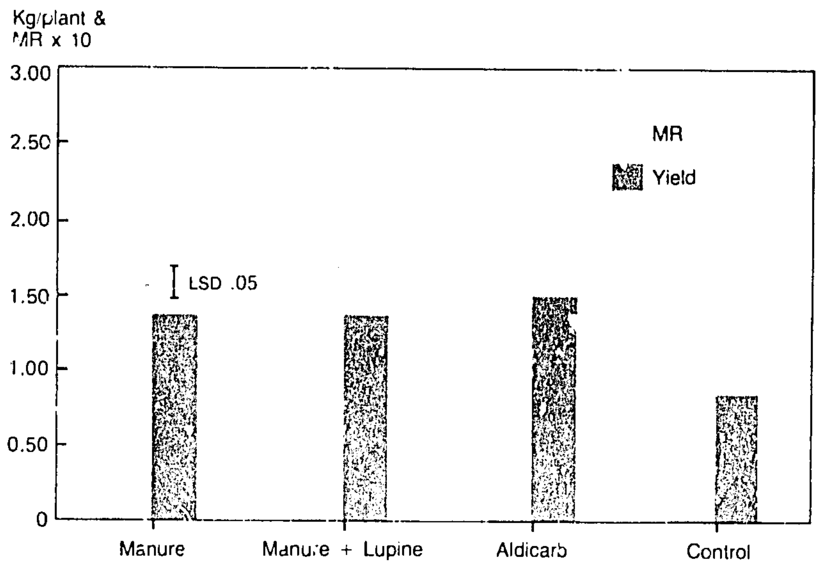


Figure 4. The effect of manure alone and manure plus extract of *Lupinus mutabilis* grains on 1) the yield (kg/plant) of potato cv. Mariva, and 2) the multiplication rate (MR = ePf/ePi) of *Globodera pallida*.

ROOT-KNOT NEMATODE ON POTATO AND SWEET POTATO

Potato. ***Screening for resistance***. Sixty-nine clones from the pathogen-tested list and 145 clones of the previously selected germplasm collection were tested for their reaction to root-knot nematode, *Meloidogyne incognita*. Most of these materials were found to be moderately resistant.

Approximately 1000 seedlings of each of 24 families of 4x x 2x crosses were exposed to three distinct *M. incognita* populations. There was an interaction between the reaction of the progenies and the three nematode populations, indicating the validity of previous results, leading to the conclusion of the presence of distinct adaptive races of *M. incognita*. Similarly, 75 diploid clones, originating from crosses of previously selected resistant material, were tested for their reaction to the above-mentioned nematode populations. Resistant reactions varied from 5% to 10% for the three populations.

In a reevaluation test, 75% of 177 clones, previously selected as resistant in a seedling screening test, maintained their high level of resistance.

Biological control. Preliminary results of field experiments using various combinations of aldicarb and *Paecilomyces lilacinus* indicated acceptable degrees of *M. incognita* control with no specific trend in relation to the various combinations of the nematicide and the fungus. Apparently, edaphic factors such as temperature, soil organic matter content, pH, and moisture play important roles in the efficiency of *P. lilacinus* to control nematodes.

Attempts were made to extract metabolites, which are inhibitory to nematodes, from different species of parasitic fungi. Metabolites present in different fractions obtained by the liquid gel chromatographic isolation method confirmed nematoxic activity. Results indicated the presence of active metabolites in fractions not containing the basic culture media components.

Control by rotation. A rotation experiment to control root-knot nematode damage on potatoes was started in Burundi in cooperation with the Plant Protection Department of ISABU. The crops to be included in the rotation are beans, cabbage, maize, peas, setaria, tobacco, wheat, vetch, lupins, and potatoes. Most of these crops are generally considered susceptible to attack but they are the most common crops grown in the Mugamba region of Burundi, where potatoes are extensively cultivated. Initially all bean plots were heavily infected with *M. javanica* and *M. hapla*, and all potato plots showed galling. Additional studies on crop rotation as well as on chemical control are underway.

Sweet potato. A total of 1245 accessions of CIP's sweet potato germplasm collection were tested for their reaction to *M. incognita*. Of these, 2.2% were rated as highly resistant while 17.6% were found resistant. Twenty-seven of the 28 highly resistant clones were accessions from Peru (Table 2).

ROOT LESION NEMATODE ON POTATO AND SWEET POTATO

Potato. The damage threshold of the root lesion nematode, *Pratylenchus flakkensis*, on two susceptible potato cultivars was established at the initial population level of 90 nematodes/100 cc of soil using field microplots. None of the inoculum levels affected the resistant clone 280284.11.

Sweet potato. Twenty-six sweet potato clones resistant to root-knot nematode were also found resistant to the root lesion nematode.

Table 2. Reactions of CIP sweet potato germplasm accessions to root-knot nematode, *Meloidogyne incognita*.

Origin	No. of accessions per reaction				
	Highly resistant	Resistant	Moderately resistant	Susceptible	Total
Brazil	–	2	3	–	5
Peru	27	200	53	920	1200
South Africa	1	1	–	–	2
United States	–	14	–	13	27
Venezuela	–	–	–	2	2
Others[a]	–	2	–	7	9
Total	28	219	56	942	1245
Percent	2.2	17.6	4.5	75.7	100

[a] Argentina, Australia, Bolivia, Chile, Ecuador, Japan, Mexico, Puerto Rico, and Taiwan.

CONTROL OF POTATO NEMATODES

In the Philippines, at the University of Los Baños, integrated control of nematodes by use of biological control agents and solarization was investigated. Solarization was effective in reducing the combined populations of *Meloidogyne incognita*, *Rotylenchulus reniformis*, and *Hemicycliophora* sp. In potato, the fungus *P. lilacinus* controlled 69.2% of potato cyst nematode (*Globodera rostochiensis*) and was more effective than the nematicide Furadan, which gave 47.5% control. A yield increase of 70.7% was observed in fungus-treated plots compared with that in the control plots. A study is in progress to evaluate the effectiveness of various local isolates of *P. lilacinus* as compared with that of Peruvian isolates.

POTATO TUBER MOTH

Screening for resistance. In Peru, 173 clones (previously rated as resistant and moderately resistant) originating from three different cycles of selection were re-tested in a four-month store trial in San Ramon by using two levels of initial infestations. A total of 111 clones were found moderately resistant at the lower infestation level while 71 clones were moderately resistant at both lower and higher infestation levels. Most of these clones were previously selected in a closed container no-choice test. Improving potato material at the diploid level was found to be effective. Progeny of a diallel cross consisting of 64 families and over 2000 clones showed a high frequency of resistance, implying relatively simple inheritance for this trait.

In a storage trial conducted jointly by CIP and the Tunisian programs of INRAT and CPRA at Saida, the clone TM-2, previously selected as moderately resistant in Peru, did not show any resistance. Also, in Tunisia, all ten commercial varieties tested for PTM resistance were found susceptible.

In Ethiopia, the Institute of Agricultural Research selected two clones, 575001 and AL 562, as resistant to PTM in storage.

Glandular trichomes. Ninety clones selected in San Ramon and 700 clones selected in Huancayo were evaluated visually for the presence of trichomes. A total of 25 clones from San Ramon and 100 from Huancayo were found to have high densities of glandular trichomes and are being tested further in observation plots.

Biological control. Two strains of a granulosis virus from Peru (the most effective strain, as observed under scanning electron microscopy (SEM) is shown in the Thrust photo) and one each from Tunisia, Australia, and India were tested to determine their efficiency in controlling PTM. Five and 20 crushed infected larvae per two liters of water were used to treat tubers: 91% and 78% PTM larvae, respectively, were diseased when tubers were infested with PTM 30 and 90 days after virus application. All larvae were killed at earlier tuber infestations, while at later infestations, the percentage of diseased larvae decreased (Fig. 5).

Surveys conducted in the highlands of Colombia indicated the absence of major parasitoids of PTM. The introduction of parasitoids under these conditions might change the population dynamics of the pest. Two parasitoids of potato tuber moth, *Eurysacca melanocampta*, were collected in Colombia and one has been identified as *Apanteles* sp.

Control by pheromones. Two applications of the microencapsulated PTM pheromone at a rate of 0.26% (at the time of storage and 50 days later) affected the rate of moth reproduction. The infestation of the untreated tubers was 96%, but the treated tubers were only 33% infested.

Control in stores. In Bangladesh, PTM control in consumer potato stores was tested at three locations in collaboration with the Bangladesh Agricultural Research Institute (BARI). The use of

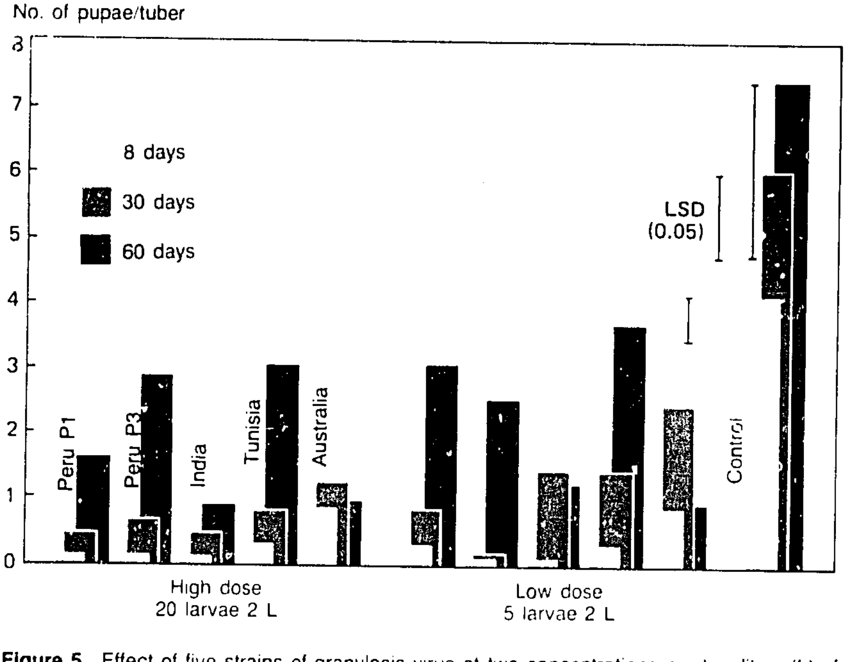


Figure 5. Effect of five strains of granulosis virus at two concentrations per two liters (L) of water on potato tuber moth pupation at 8, 30, and 80 days after viral treatment on tubers.

dried, crushed *Lantana camara* was effective against PTM in stores, as well as the insecticide Decamethrin (Decis). Control treatments against PTM damages are also being tested in rustic stores in Kenya. Included in the treatments are natural repellent materials such as *Lantana*, neem, eucalyptus, and various materials containing natural pyrethrum, such as flowers and liquid residual from the processing of the flowers.

Pest surveys. During 1987, the major potato pests in East Africa were monitored. The major problem encountered was PTM, but various other minor potato pests were also monitored, particularly on the Kenyan coast. Intensive training has been given to technicians in several countries to enable them to identify potato aphids at the species level and to regularly monitor aphid catches from the yellow traps surrounding the seed areas.

Extensive PTM damage was observed on some of the seed farms in Burundi, in some cases damage was as high as 100%. In both Burundi and Rwanda, the highest PTM populations occurred in early September. Surveys of the PTM situation in Ethiopia, Kenya, and Morocco are now in progress.

ANDEAN POTATO WEEVIL

In Peru, 83 potato clones from the highlands were field-evaluated for resistance to *Premnotrypes suturicallus* under unusually severe conditions of infestation due to a prolonged drought period. Only clone HPF 56.4 was found to be promising, with only 26% tuber infestation. Other sources of resistance have been identified among 1000 clones from the CIP germplasm collection, which were subjected to growth chamber screening tests.

Studies on the spatial distribution of *P. vorax* Hustache in Colombia indicated that this insect population follows a contagious distribution although the factors that cause the aggregation behavior are not known. Cultural practices such as deep planting and high hilling, and the application of insecticides aldicarb, carbofuran, and triflumuron were unable to lower the *P. suturicallus* damage below 50% infestation at harvest.

SWEET POTATO WEEVIL

Screening for resistance to the tropical sweet potato weevil, *Euscepes postfasciatus*, received major attention at CIP during 1987. Fifteen clones of 700 sweet potato accessions from CIP's germplasm were found resistant in the closed container test. Internal damage and adult develop-

Table 3. Sweet potato clones identified for resistance to sweet potato weevil, *Euscepes postfasciatus* Lima, 1987.

Clone	External damage (%)	Internal damage[a]	No. of adults
ARB 389	100	1	0
RCB 16	40	1	0
17	35	1	0
68	90	1	0
105	70	1	0
118	87	1	0
120	40	1	0
130	40	1	0
280	55	1	0
DLP 101	25	1	0
103	30	1	0
189	10	1	0
295	20	1	0
542	50	1	0
543	100	1	0
ARB 80	90	5	152
377	100	5	147

[a] Grade 1 = no damage; grade 5 = 75-100% of cut surface damaged.

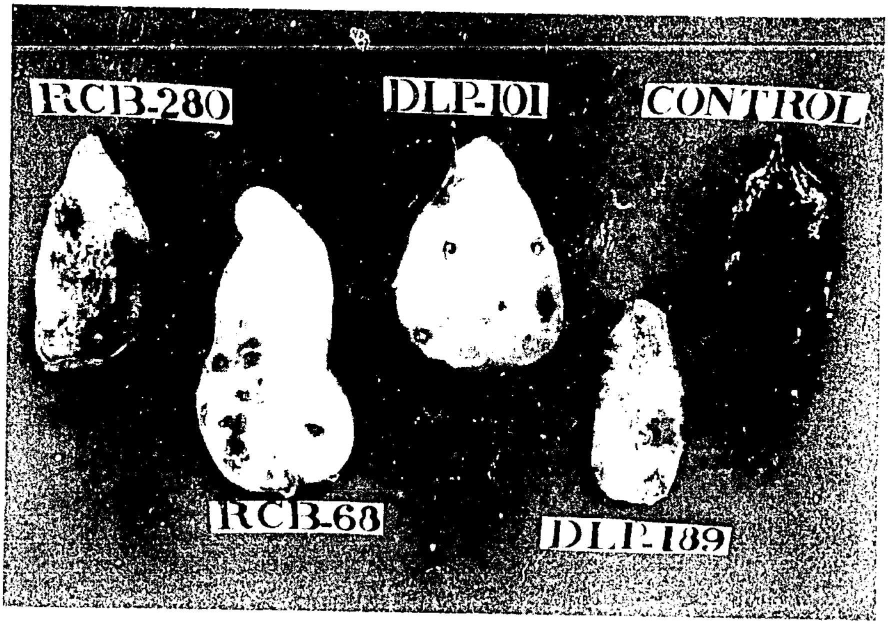


Figure 6 Sweet potato clones identified for resistance to sweet potato weevil, *Euscepes postfasciatus*

ment were reduced significantly in these clones as compared to damage and development in the susceptible clones, ARB 80 and ARB 377 (Table 3, Fig. 6). The resistant clones have been multiplied and are being field-tested in farmers' fields in Peru.

POTATO LEAFMINER FLY

Mass rearing techniques to produce leaf miner flies, *Liriomyza huidobrensis*, for screening tests were improved. Trials conducted in mesh-screened cages for evaluating resistance to this pest showed that plants with glandular trichomes (Types A and B) were the least damaged. Both oviposition and adult feeding damage in these clones were reduced by more than 50% in comparison to that in the susceptible variety, which lacked the Type B hair.

MITES

AT CIP's Sta. Lucia Station in the Philippines, 35 cultivars were tested for resistance to mites (species not yet identified); the cultivars 380584.3, DTO-2, Kufri Jyoti, I-1039, and Lal Pakri showed the least mite damage. From other field tests, 20 other cultivars with a low mite score were selected for further evaluation.

POTATO LEAF BEETLES

Diabrotica sp. has become a major potato pest during the rainy season at San Ramon. Adults feed on leaves while larvae damage the tubers. Studies on economic thresholds indicated that with an adult beetle infestation of three per plant, there was 51% tuber damage at harvest and 73% tuber damage with six adults per plant. Chemical control trials indicated that applications of carbofuran gave good control of the adults.

TRAINING

Two short courses on integrated pest management (IPM) in Ecuador and Kenya gave special emphasis to the biology of potato tuber moth (PTM) and its control in the field and stores. Although pest control has been one of the topics in previous East African storage courses, this is the first time IPM has been given in-depth treatment in a course specifically designed for entomologists. The identification of aphid species responsible for the spread of virus diseases and methods of monitoring aphid populations were also taught in both courses. Tuber moth was the subject of a course in India for South Asian countries in which participants developed projects for applied PTM research. They also worked on approaches for identifying and describing farming problems caused by PTM and discussed methods of communicating research results.

Warm Climate Potato and Sweet Potato Production

The use of progenitors with a high general combining ability for adaptation to the warm and hot climates has facilitated selection in San Ramon and Yurimaguas of several early maturing and heat-tolerant clones. Most of the highly selected progenitors have been cleaned of diseases and are available for export. Potato germplasm evaluation in four locations in Vietnam has led to the selection of clones with resistances to viruses and late blight and with good storage characteristics—storability under high temperatures for up to nine months.

Experiments to assess the role of nitrogen in the growth and development of potatoes were carried out in Peru at San Ramon and Puerto Bermudez, using the cultivars LT-7, Desiree, and Katahdin. In San Ramon, LT-7 outyielded the other two cultivars. In both dry and wet seasons, the amount of dry matter partitioned to the tubers decreased with increased application of nitrogen fertilizer. In Puerto Bermudez, the heat stress is severe with daily maximum air temperatures often higher than 35°C and minimum air temperatures rarely falling below 20°C. Despite this high level of heat stress, LT-7 produced 15.2 t/ha with a 19.3% tuber dry matter content while Desiree yielded only 3.5 t/ha with 10.1% dry matter.

Research on effects of duration of drought stress indicated that reduced canopy development contributed to the reduction in yield of plants exposed to longer drought periods. The effect of a two dimensional, continuous, and uniformly varying water supply on growth and production was studied. A gradual decline in the marketable yield was noted in the drier environments. Apparent water use efficiency in heat-adapted clones ranked lower in the dry environments.

Experiments in Vietnam and the Philippines on the use of cut seed for potato production showed that yields from plants of cut seed were as high as those from whole seed. This technique can provide farmers with a feasible approach to reduce the high cost of seed potatoes.

Farm children observe the harvest of a heat-tolerant potato clone, LT-7, near Puerto Bermudez in the central jungle of Peru.

CLONAL SELECTION

Peru. As in other CIP populations, selection of parental clones for high general combining ability (GCA) for yield, earliness, heat tolerance, and good tuber characteristics has continued. The use of highly selected progenitors such as Serrana, Atlantic, 377964.5, 378015.16, Maine-28, LT-7, and LT-8 produces clones with good adaptation to the warm and hot climates.

A sample of 745 first and second generation clones were tested at San Ramon and Yurimaguas (growing period of 90 days). The performances of the best clones evaluated at San Ramon for yield and earliness are presented in Table 1. At least one of the above-mentioned progenitors was present in the pedigree of most of the top-performing clones. This underscores the importance, in potato breeding, of the use of parental materials with high GCA for desirable attributes.

A group of early maturing clones were tested during the 1987 winter at both San Ramon and Yurimaguas. The growing period at both sites was 75 days. Table 2 shows the performance of the best early maturing clones at both sites. The yields were from medium to low but the growing season was very short; however, under such conditions, the relative potato yield is still competitive compared to yields of other short-duration crops.

Table 2. Yields of the best early maturing clones at San Ramon (SR) and Yurimaguas (Y) during winter, 1987.

Pedigree	Site	Yield (t/ha)
(378015.16 x Atlantic).36	SR	19.4
(Maine-47 x 378015.16).21	SR	15.3
(377964.5 x 378015.16).31	SR	14.7
(378015.16 x Atlantic).32	SR	10.0
(378015.16 x Atlantic).1	SR	9.5
(LT-8 x 575049).121	Y	9.3
(LT-8 x 575049).132	Y	9.1
(Santo Amor x 378015.16).21	SR	9.1

Vietnam. Potato germplasm has been evaluated for yield and adaptation by national scientists for the past three years in four locations: Red River Delta (sea level), Dalat (1500 m), Duc Trong (800 m), and Ho Chi Minh City (5 m). In the Red River Delta, 22 clones selected from the 1982-83 tuber families showed exceptionally good storage characteristics under high temperatures for nine months and resistance to viruses and late blight. Several

Table 1. Yield and earliness of top-performing clones evaluated at San Ramon during summer, 1987.

Pedigree	Earliness[a]	Generation	Yield (t/ha)
(Serrana x 575049).52	5	2	21.7
(C84.653 x 377964.5).21	5	2	17.1
(B75.86.8 x 377904.10).2	5	2	17.1
(Maine-47 x 378015.16).51	7	1	15.8
(Maine-28 x C83.463).22	5	2	15.8
(CFK-69.1 x 377964.5).51	7	1	12.2
(Maine-28 x LT-7).11	5	2	12.2
(377888.7 x C83.119).112	7	1	11.7
(C84.653 x 378015.16).43	5	2	11.7
(Maine-28 x M. Tropical).11	7	2	10.8

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

pedigrees from the 22 clones included the CIP progenitor 7XY.1 as a male parent. In Dalat, only two advanced clones were comparable in performance with the three recently released introductions from CIP material, B-71-240.2, CFK-69.1, and Atzimba. At Duc Trong, where bacterial wilt is severe, none of the germplasm tested proved to be resistant to the disease.

AGRONOMIC AND PHYSIOLOGICAL RESEARCH

Nitrogen utilization. In a series of experiments being carried out in the mid- and low-elevation tropics of Peru, the role of nitrogen (N) fertilizer in the adaptation of potato in these zones was examined. Experiments were conducted in San Ramon (800 m) during the wet and dry seasons, and in Puerto Bermudez (250 m) during the dry season only. The cultivars Desiree and Katahdin (SR dry season only) and the clone LT-7 were grown at four N rates: 0, 80, 160, and 240 kg/ha.

In the San Ramon dry season, LT-7 had higher tuber yields than either Desiree or Katahdin at all N fertilizer rates. Dry-tuber yield of LT-7 when no N was applied exceeded dry tuber yields of Desiree and Katahdin, regardless of the N applied (Fig. 1). Katahdin was earlier than either Desiree or LT-7, in that tuber dry matter production in Katahdin did not

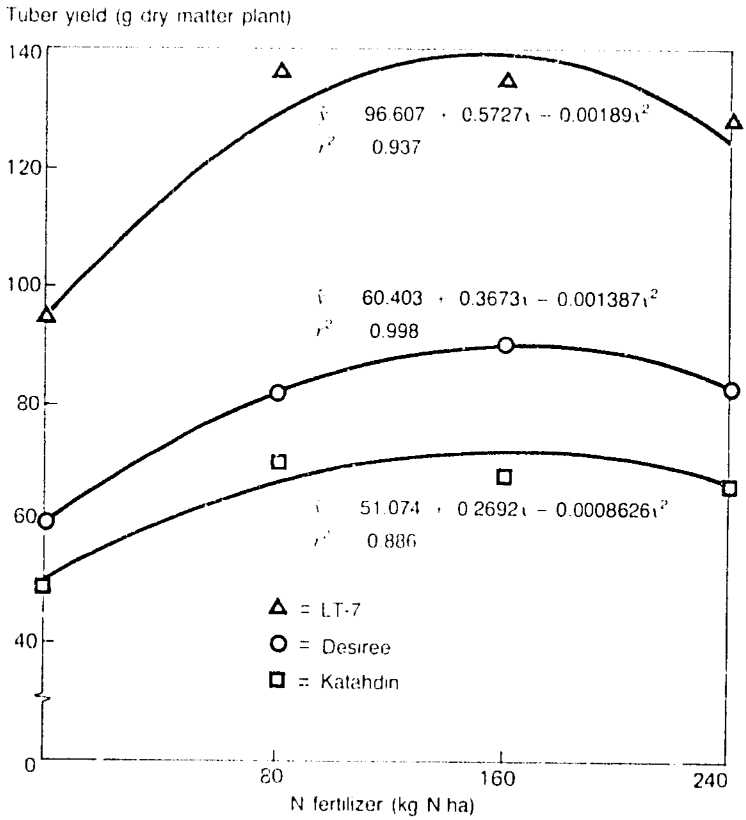
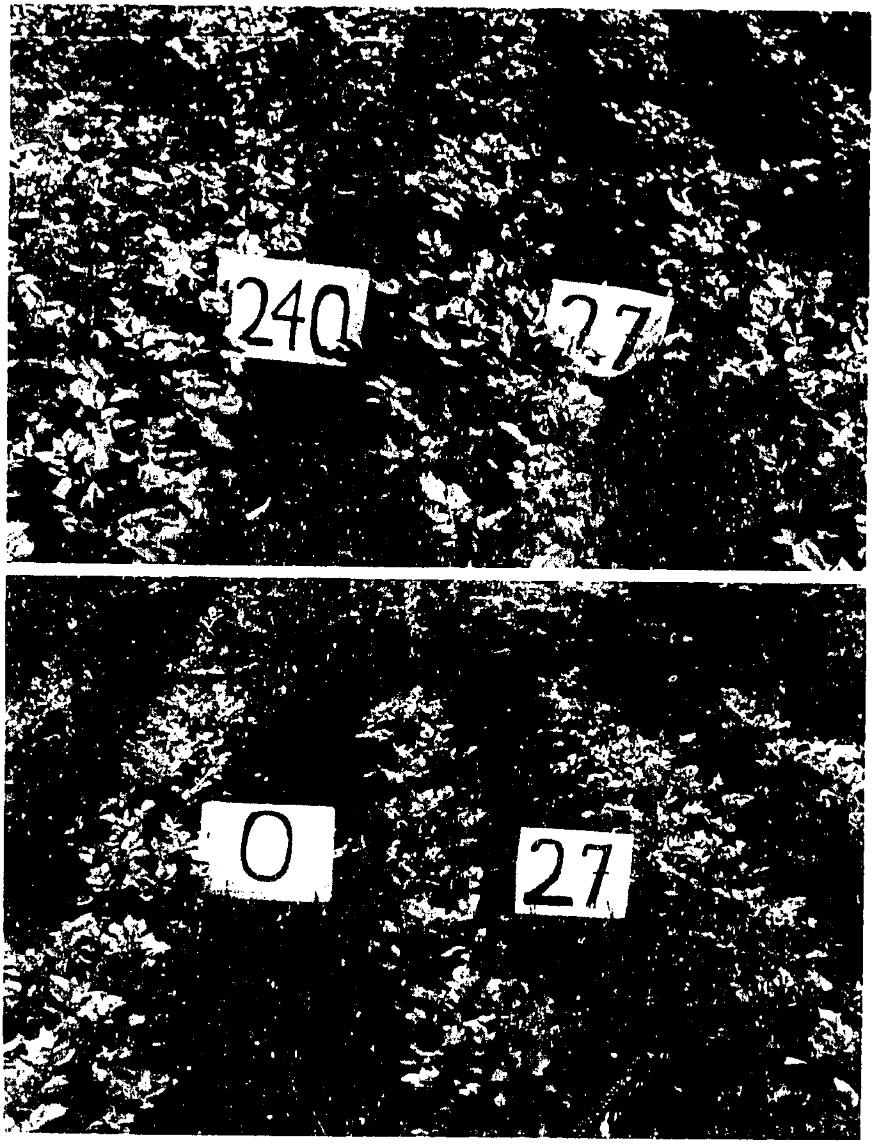


Figure 1. Tuber dry weight in clone LT-7 and cvs. Desiree and Katahdin as a function of nitrogen (N) fertilizer. San Ramon, dry season.



The effect of nitrogen fertilizer on the growth of cv. Desiree 27 days after planting in the San Ramon dry season. Top: *240 kg N/ha;* bottom: *0 kg N/ha.*

significantly increase past 60 days after planting (DAP), while Desiree and LT-7 accumulated tuber dry matter up to final harvest. Canopy dry matter production increased with increasing N fertilizer for each cultivar. High N fertilizer rates increased the production and duration of canopy dry matter for Katahdin, but this effect did not significantly increase tuber yield late in the season.

Differences in dry tuber yield between LT-7 and the other cultivars may be attributed to high plant dry matter production and high percent tuber dry matter of

LT-7 compared to these characteristics in Desiree and Katahdin. Nitrogen fertilizer tended to decrease dry matter content of tubers of LT-7 and Katahdin (Fig. 2). The tuber dry matter partitioning coefficient, K (the amount of dry matter partitioned to the tubers), was also affected by N; Desiree and LT-7 were affected more than Katahdin (Fig. 3).

In the San Ramon wet season, LT-7 had higher canopy and tuber dry matter production than Desiree. Overall yields in the experiment were reduced because of excessive rainfall early in the season.

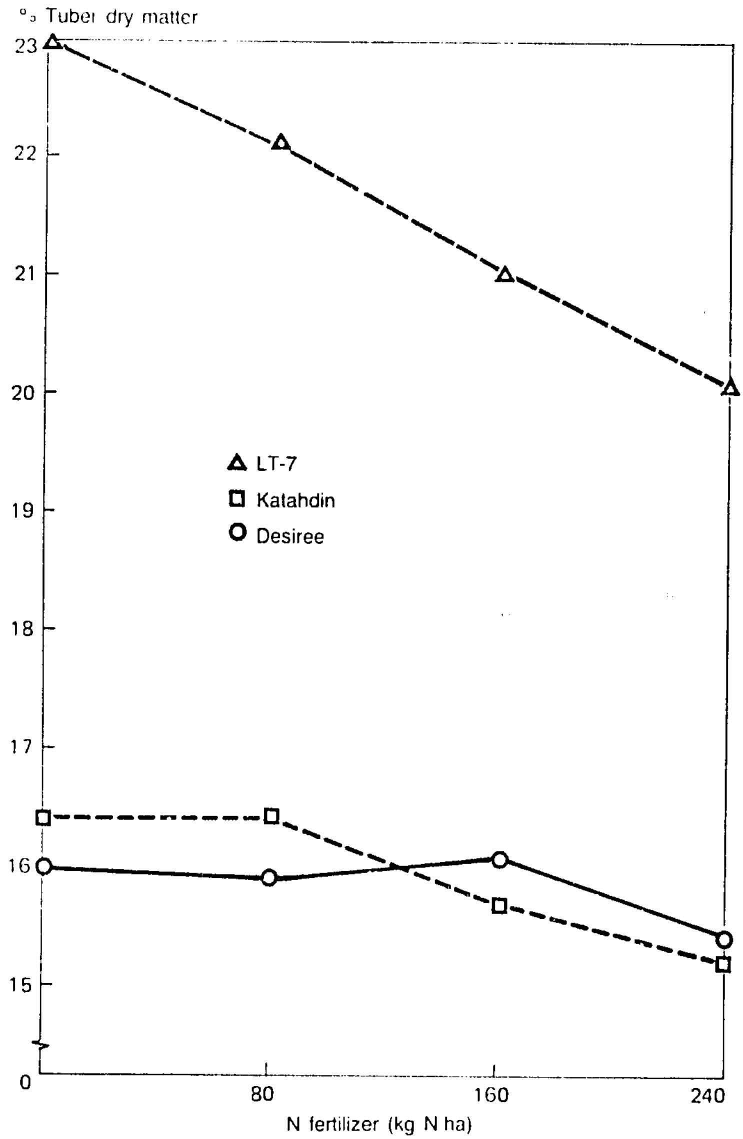


Figure 2. Percent tuber dry matter as a function of nitrogen (N) fertilizer in clone LT-7 and cvs. Desiree and Katahdin. San Ramon, dry season.

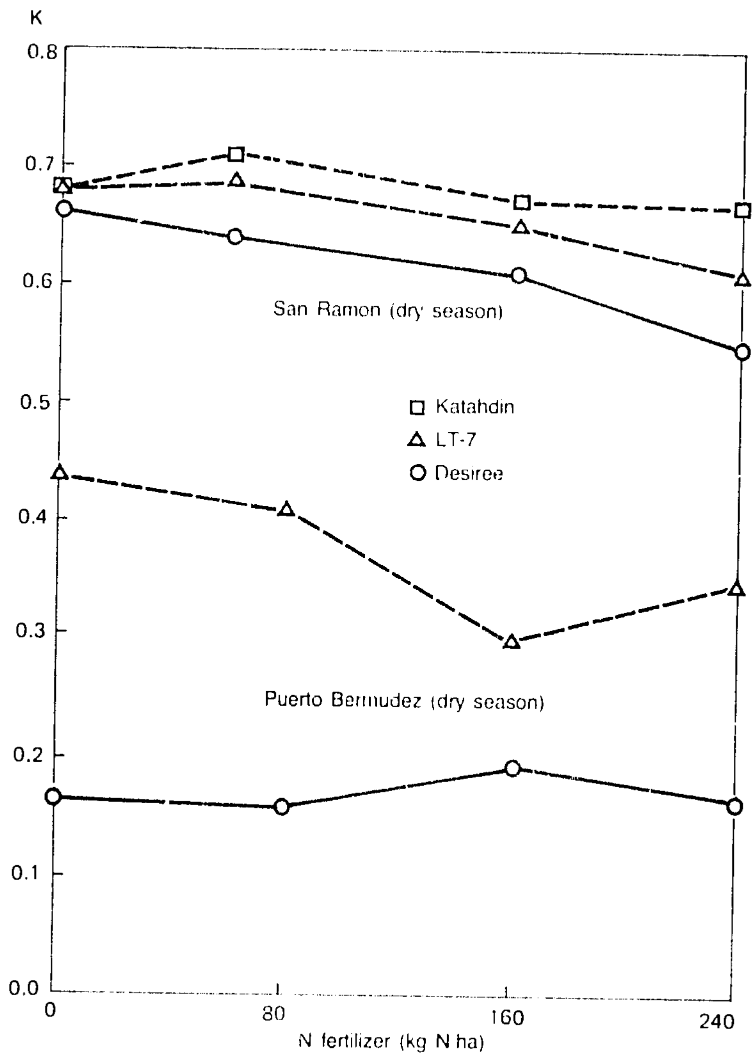


Figure 3. Percent plant dry matter partitioned to tubers (K) as a function of nitrogen (N) fertilizer at 60 days after planting in clone LT-7 and cvs. Desiree and Katahdin. San Ramon and Puerto Bermudez, dry seasons.

High soil moisture appeared to inhibit tuber formation. Canopy dry matter production was comparable to that of the dry season crop; however, K values were much lower in the wet season than in the dry season. As in the dry season, an increase in N fertilizer tended to decrease the percent dry matter partitioned to the tubers. When 240 kg N/ha was applied, canopy dry matter accumulation for both cultivars increased up to 63 DAP, while maximum canopy dry matter accumulation occurred at 50 DAP for the lower N fertilizer rates. High N fertilizer increased tuber yield by providing more assimilates for tuber bulking. Tubers of LT-7 had higher dry matter content than those of Desiree (20.2% vs. 13.1%). Nitrogen fertilizer did not affect tuber dry matter content.

A third N fertilizer experiment, using Desiree and LT-7, was carried out in Puerto Bermudez during the dry season when daily maximum air temperatures averaged 33°C and minimum air temperatures averaged 21°C. Despite this high level of heat stress, LT-7 produced an average of 15.2 t/ha while Desiree produced only an average of 3.5 t/ha. There was little yield response of either LT-7 or Desiree to N fertilizer. Canopy dry matter production in Puerto Bermudez was comparable to values measured in the San Ramon dry season; however, K values for LT-7 and Desiree were much lower in Puerto Bermudez than in San Ramon (Fig. 3). Tuber dry matter content for LT-7 averaged 19.3% while Desiree averaged only 10.1%. As in the San Ramon dry season, high N applications tended to decrease dry matter content of LT-7 tubers.

Drought stress. The response of potato clones to drought was assessed in the San Ramon dry season. The effect of drought duration on the clone DTO-28 was measured at San Ramon at 50% of the normal water application rates. The stress period ranged from 14 to 77 days. The stress index (SI), defined as [1-(value of stressed plant/value of control plant)], was measured for fresh and dry tuber

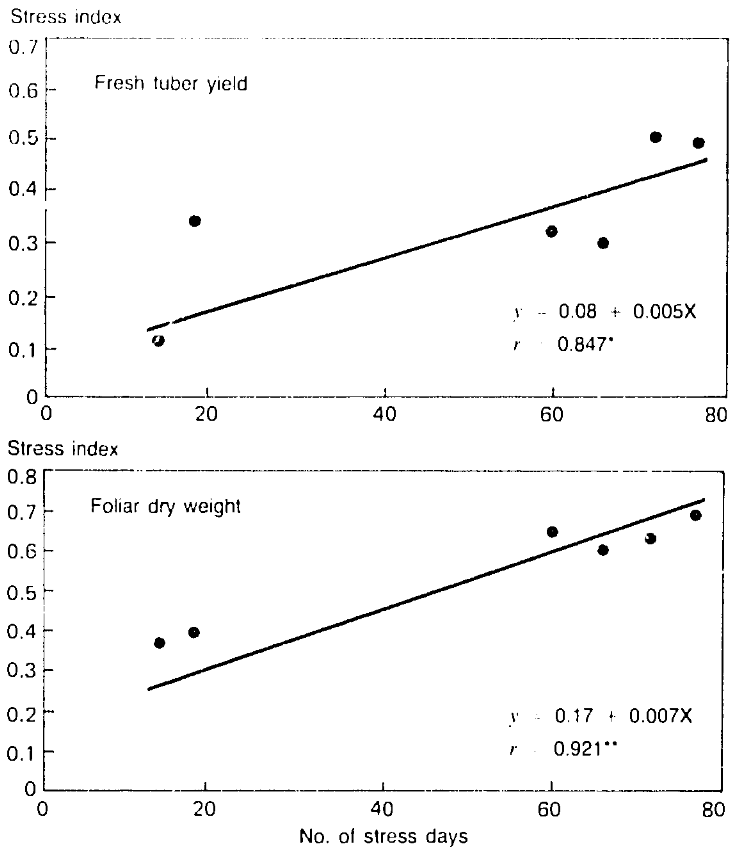


Figure 4. Stress indices for fresh tuber yield (*top*) and foliar dry weight (*bottom*).

Table 3. Clonal response to heat and drought stress at two sites, based on apparent water use efficiency in warm and warm-dry environments (Lima and San Ramon).

Clone	Warm		Warm-dry	
	Lima	San Ramon	Lima	San Ramon
LT-7	1[a]	1	4	2
Pentland Crown	2	6	3	4
LT-5	3	5	1	3
B-71-240.2	4	2	1	4
Desiree	5	3	6	1
CI-4343	6	4	5	5

[a] Scale: 1 = most resistant to stress; 6 = most susceptible.

yields and foliar dry weights. The relationship between the number of stress days and the SI was significant for all growth parameters (Fig. 4). Yield reduction of plants exposed to long drought periods may be partially attributed to reduced canopy growth.

To assess the effect of drought on potato growth and production among a group of clones, a line-source sprinkler irrigation system was established in Lima and San Ramon. This system allowed us to monitor clonal response to a series of irrigation regimes: those rows closer to the central irrigation line received more water than those further away. Plants were subjected to water stress from four weeks after planting to harvest. Minimum soil temperatures at 10-cm depth during the cropping season ranged from 20 to 25 °C in San Ramon and from 21 to 25 °C in Lima. The apparent water use is defined as grams of tuber yield per square meter land area per millimeter of yield per millimeter of irrigation water applied. The total water added in the warm optimum environment (adjacent to the central line) was 692 mm in Lima and 454 mm in San Ramon. In the warm drier environment (5.25 m away from the central line), total water use was 408 mm in Lima and 370 mm in San Ramon. Apparent water use efficiency in clones that are heat tolerant and early maturing (less than 90 days) ranked lower in the dry environments (Table 3). A location specificity was also observed among this material.

Heat stress. Effect of heat stress on potato leaves taken from two types of planting material (cuttings and TPS seedlings) was measured using a membrane

Table 4. Membrane thermostability and visual heat stress scores used to evaluate heat stress in potato leaves from cuttings and true potato seed (TPS) progenies. San Ramon, 1987.

Clone	Relative membrane conductivity (%)	Mean visual score[a]
Cuttings		
DTO-33	0.7	5.0
Desiree (control)	5.0	3.8
LT-5	8.3	7.3
C-85041	11.2	5.1
DTO-28	17.3	5.4
TPS		
C-85009 OP	5.4	3.7
Desiree (control)	3.5	3.3
C-85051 OP	4.6	2.8
C-85141 OP	5.3	3.0
DTO-28	6.1	3.3
379420.1 R128.6	18.9	7.3

[a] Mean visual score: 1 = no cutting; 9 = severe wilting

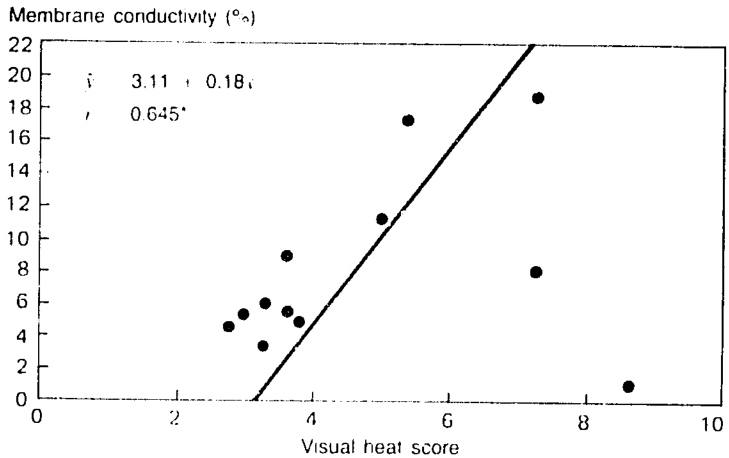


Figure 5. Potato leaf membrane thermostability at 53°C and visual heat stress scores.

thermostability test and a visual score. Excised leaves were exposed to 53°C (± 1°C) for 20 minutes and the wilting was scored visually (1 = no wilting and 9 = severe wilting). In the same samples, leakage due to membrane disruption was measured by conductivity. Severe heat-induced membrane damage was noted among the leaves of the clones being tested compared to damage in the non-stressed leaves (Table 4). Relative membrane damage and the visual score were significantly correlated ($r = 0.645$) (Fig. 5). These two tests can thus be used to evaluate clonal ability to tolerate heat-induced membrane damage and canopy survival, but not the dry matter partitioning for which yield tests are necessary.

Use of cut seed. Seed is a costly input in potato production in the warm tropics. To reduce this cost, experiments were carried out in Vietnam and the Philippines using cut seed. Suberization of the cut tuber surfaces occurred within five days. The yields from plants coming from cut seed were as high as those of plants coming from whole seed. The cut seeds produced more stems per unit of seed, particularly with varieties having a long dormancy. This technique is feasible providing that farmers use large seed tubers and disinfected knives for cutting. The results were consistent in Ho Chi Minh City in Vietnam, and Canlubang in the Philippines.

TRAINING

Training researchers to investigate improved agronomic methods for producing potatoes in warm climates was undertaken in a course held in El Salvador for the Central American and Caribbean countries. Staff members from the Center for Agricultural Technology provided the instruction—one member had been trained earlier in the year especially to undertake this work. The course covered such topics as the potential of potato as a food crop in warm climates and production problems, the scientific basis of potato production, research projects, and agricultural communication.

THRUST VII

Cool Climate Potato and Sweet Potato Production

During 1987, a total of 34,287 potato seedlings were screened for frost tolerance in the central Andes of Peru. Of these, 23,774 seedlings were from an Andean population, and 10,513 from a non-Andean population. An average of 17.5%, or 6138, seedlings survived the screening test, which involved two hours at -4.5 °C for the Andean population and two hours at -3 °C for the non-Andean material. The survivors were transplanted to the field for multiplication, selection, and further frost resistance testing under natural growing conditions. Some 1480 clones were tested for frost tolerance under the natural growing conditions at Usibamba (3800 m) and 520 clones were selected. Because of severe frost 85 days after planting, the relatively high yields recorded were undoubtedly the result of early tuberization, fast tuber bulking, and frost tolerance—a clear indication of the improvements achieved in developing earliness of the new frost-tolerant material.

A project was started to breed a potato population with horizontal resistance to late blight using sources of resistance free of R-genes. A hybrid population consisting of 30,369 seedlings from 36 families was screened against race 0 of *Phytophthora infestans*, and 6715 seedlings survived the test. Approximately 600 genotypes were selected from the surviving population for further evaluation. A second seedling population was generated by intercrossing andigena clones with tuberosum varieties without R-genes. This crossing program produced 35,000 seedlings that are presently being screened against race 0. Preliminary results indicated that the frequency of minor genes conferring resistance to late blight is about the same in both populations.

A survey of foliar blight distribution in the cool climates of Peru was concluded. This survey revealed that *Alternaria* is distributed in mid and low elevations (below 3000 m), that *Phoma* is predominantly found in the Andean valleys at mid elevations (3200 to 3300 m), and that *Septoria* is distributed mainly at the higher altitudes (above 3500 m). Field tests with 30 varieties and cultivars in a field with natural *Phoma* infestation indicated that four varieties exhibited relatively high levels of resistance to this pathogen.

Harvest of CIP frost-resistant experimental material in the Andes (3800 m), where it was exposed to temperatures as low as -4 °C.

BREEDING FOR FROST TOLERANCE

Seedling screening. During 1987, a total of 34,287 seedlings from 200 families (Table 1) were screened for frost tolerance. From this total, 23,774 seedlings representing 90 families were from an Andean population, and 10,513 seedlings from 110 families corresponded to a non-Andean population.

An overall average of 17.5%, or 6,138 seedlings survived the screening test, which involved two hours at −4.5 C for the Andean population, and two hours at −3 C for the non-Andean material. The survivors were transplanted to the field in Huancayo for multiplication, selection, and further frost-resistant testing under natural growing conditions. A total of 1350 clones were selected from single-plant hills for appearance, shape, color, and eye depth of their tubers, as well as for the number of tubers per plant.

Field testing. *Testing in replicated trials.* Four replicated trials were carried out in both Usibamba (3800 m) and in Huancayo (3200 m), in the central Andes of Peru, to assess the yield potential of advanced clones under frost as well as nonfrost conditions. Plant density was 44,444 plants/ha in Huancayo and 37,037 plants/ha at Usibamba. Tuber yields in Huancayo were high (Table 2) and the specific gravity of this material ranged from 1.055 and 1.104, with an average of 1.082. The majority of the clones had a high specific gravity of more than 1.075.

In an additional trial, a sample of these advanced clones was evaluated in

Table 2. Yield performance of the best 18 advanced frost-tolerant clones under nonfrost conditions at Huancayo (3200 m).

Clone no.	Specific gravity	Tuber yield (kg/plant)
82PY19.2	1.069	1.81
380024.14	1.074	1.74
380011.12	1.093	1.71
HFP49.5	1.070	1.67
Revolucion (control)	1.079	1.61
380493.1	1.104	1.60
376180.3	1.098	1.57
380493.18	1.078	1.55
Tomasa Condemayta (control)	1.080	1.50
82PY19.1	1.079	1.48
Yungay (control)	1.079	1.48
380075.1	1.071	1.42
380474.6	1.090	1.40
82PY1.3	1.086	1.37
PY11.5	1.077	1.31
380493.7	1.077	1.31
380075.11	1.083	1.30
380426.1	1.076	1.29
380493.19	1.097	1.29
377924.1	1.087	1.29
377427.1	1.089	1.26
Avg of all clones	1.082	1.18
CV (%)		19.2

Table 1. Seedling screening for frost tolerance in a growth chamber, Lima.

No. of families	Population type	No. of seedlings	Frost screening[a] (−4.5 C −3 C)	Survival rate (%)
90	Andean	23,774	4,421	18.6
110	Non-Andean	10,513	1,717	16.3
Total		34,287	6,138	Avg 17.5

[a] Andean population, 2 h at −4.5 C; non-Andean population, 2 h at −3 C.

Table 3. Yield performance of the best 18 frost-tolerant clones under nonfrost conditions at Huancayo (11 x 11 lattice)

Clone no.	Specific gravity	Tuber yield (kg plant)
381135.64	1.080	1.77
381135.103	1.075	1.73
Revolucion (control)	1.079	1.65
380271.14	1.093	1.61
381104.39	1.086	1.58
381111.22	1.081	1.57
SFY15.7	1.091	1.55
380437.2	1.079	1.48
381126.22	1.086	1.46
380413.13	1.063	1.46
381128.33	1.091	1.46
381097.8	1.086	1.45
Tomasa Condemayta (control)	1.089	1.45
380474.18	1.077	1.43
UFF14.3	1.098	1.41
381403.7	1.084	1.40
UPP82.3	1.100	1.39
381128.151	1.079	1.39
381090.152	1.088	1.39
380278.17	1.078	1.38
Avg of all clones	1.11	
SD	0.249	
CV (%)	22.5	

Table 4. Yield performance of the best 18 advanced frost-tolerant clones under frost conditions at Usibamba (3800 m).

Clone no.	Tuber yield (g plant)	Frost score[a] (-5 C and lower)
UFF14.1	728	6
375057.9	713	4
Mariva (control)	641	6
375070.53	593	3
HFF18.3	593	5
HFF14.4	587	4
377924.1	563	5
379048.18	559	8
HF18.1	552	6
UFF14.3	548	5
375596.6	529	4
Huancayo (control)	525	5
377744.3	518	5
380076.1	514	4
377427.1	510	5
375597.15	495	6
375004.4	478	6
375078.1	466	6
376180.3	456	7
376724.1	448	6
Avg of all clones	494	
CV (%)	29.5	

[a] 1 = foliage unaffected; 9 = plant killed completely.

an 11 x 11 lattice design, and the high yield as well as the variable but high specific gravity of this material were confirmed (Table 3).

Tuber yields in Usibamba were rather low because of the severe frost that struck and damaged the crop 85 days after planting. Normally, highly frost-resistant controls such as the triploid cultivated species, *Solanum juzepczukii*, and the pentaploid cultivated species, *S. curtilobum*, were severely damaged, and some potato fields in the area were killed completely. The yields that were recorded in the replicated trials were the result of early tuberization, fast tuber bulking, and frost tolerance. Yields recorded in the complete randomized block with four replications (Table 4) were lower than those recorded in the simple lattice of 10 x 10 (Table 5). This is a clear indication of the improvement made in developing earliness (early tuberization and fast bulking) of the new material selected for frost tolerance. Foliar frost damage was rather high, which would normally suggest that most clones were susceptible to frost. The severity and frequency of the frost was such, however, that the controls were completely destroyed in the first frost. Consequently, the materials may be more valuable with

Table 5. Yield performance of the best 18 frost-tolerant clones under heavy frost at Usibamba (10 x 10 lattice).

Clone no.	Tuber yield (g plant)	Frost score[a] (-5 C and lower)
FF22.7	1,190	7
HPF68.3	1,152	5
375558.9	1,073	3
82FY15.4	1,067	7
82FY14.6	1,031	6
HFF18.2	1,012	5
UFP27.4	996	3
HFP40.3	959	5
FP43.2	942	6
FP26.2	891	7
HFF2.2	827	4
82FF36.3	814	5
HFF20.3	791	4
380011.12	784	7
82FY14.4	784	5
Huancayo (control)	777	5
Yungay (control)	731	5
T. Condemayta (control)	668	7
Mariva (control)	547	7
Avg of all clones	632	
SD	187	
CV (%)	29.7	

[a] 1 = foliage unaffected; 9 = plant killed completely.

respect to frost tolerance than they appeared to be (Fig. 1).

Testing in nonreplicated trials. During the 1987 season, 1480 clones were tested for frost tolerance under the natural growing conditions at Usibamba. From this total, 1021 clones were planted simultaneously at CIP's Huancayo station for maintenance and the selection of simply inherited traits.

As mentioned above, frost at Usibamba was very severe and frequent this year, particularly 85 days after planting. Harvest took place 120 days after planting, and selection concentrated on frost tolerance and early tuberization, with a total of 520 clones being selected. In Huancayo only 187 clones of the same material were selected at harvest.

AGRONOMIC AND PHYSIOLOGICAL STUDIES

Studies on efficient use of nitrogen in traditional potato-growing areas. In order to identify potato genotypes efficient in their use of nitrogen, a sample of CIP clones and Peruvian varieties was tested in the field at Huancayo. Thirty-one advanced clones and five cultivars were tested in an experiment with two replicates for their response to nitrogen applied at 0 and 180 kg ha. Eleven of the genotypes tested in this set of experiments were also tested in 1985 and 1986. Unexpectedly, the effect of N was statistically insignificant (ANOVA p .10) under the environmental conditions of the central Andes of Peru and in the soil of CIP's experiment station. The unusual lack of response to N, in the presence of other nutrients, is unexplained at present.

CONTROL OF FUNGAL DISEASES IN COOL CLIMATES

Foliar blight distribution in the central Andes. A survey of the distribution of foliar blights in the cool climates of Peru was concluded. More than 50 fields were visited over a three-year period in the cool climate of the central Andes (-2 to 24.9 C). A total of 829 diseased leaf samples were collected. Leaves affected by *Botrytis* or leaf blight or the combination of both were not included in this survey.

The survey revealed the following: *Alternaria* is generally distributed in mid and low elevations below 3000 m; *Phoma* is found predominantly in the Andean valleys at altitudes between 3200 to 3300 m;

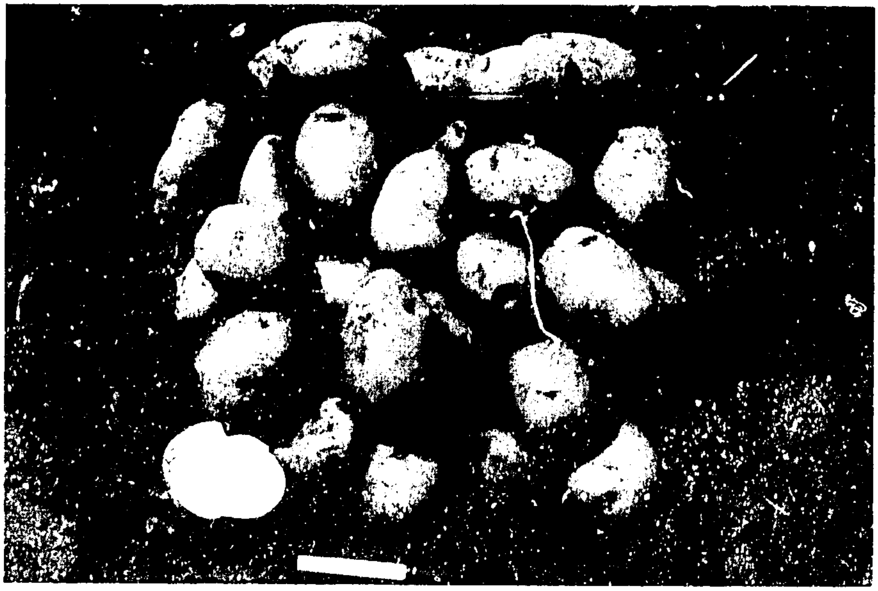


Figure 1. CIP clone F8, with excellent agronomic characters, high yield, and frost resistance, which enable it to resist temperatures of -4 C

and *Septoria* is distributed mainly at altitudes above 3500 m. The three species, *Alternaria solani*, *Phoma andina*, and *Septoria lycopersici*, were the predominant species that caused leaf spot symptoms of rather similar appearance. Although most samples obtained in the Mantaro Valley (3200 m) were infested with *P. andina*, some were also infested with *Alternaria*. Apart from *A. solani*, the two species *A. porri* and *A. brassicae* were also found.

Field tests with 30 varieties and cultivars in a field with natural *Phoma* infestation indicated that the varieties Esperanza, Monserrate, Ollanta, and Capiro exhibited good levels of resistance to this pathogen.

Powdery scab. In collaboration with the Peruvian Ministry of Agriculture and the University of Cuzco, two field trials were carried out in fields naturally infested with the powdery scab fungus (*Spongospora subterranea*). The potato germplasm tested was from CIP's pathogen-tested list. Fifty clones and varieties were planted in one trial and 75 in the other, each with three replications of five tubers each. Heavy infection occurred only in the field where the 75 clones and varieties had been planted. Based on the percentage of tubers infected and on the severity of the powdery scab, which was measured on a scale of 1 (no infection) to 9 (more than 75% of the tuber surface infected), only the two varieties Gabriela and Esperanza were rated as resistant and seven more clones as moderately susceptible. The 66 remaining clones and varieties had to be rated as susceptible. Additional research covering aspects of etiology, pathogenicity, and resistance to powdery scab is underway.

THRUST VIII

Postharvest Technology

The thrust base was relocated to Thailand to provide greater support to postharvest research in Asia. Research focused on low-cost storage of consumer potatoes in warm areas, storability of genetic material, and low-cost potato processing. Storage research on consumer potatoes was conducted in warm climates in Peru, Thailand, and Pakistan. Experiments on integrated control of postharvest losses caused by storage pests, storage diseases, water loss, and early sprouting showed several interactions between treatments. Evaporative cooling of potato stores reduced tuber weight losses during storage and deterred natural infestation by potato tuber moth (PTM). Tuber rotting was reduced when PTM was controlled by dried insect-repellent foliage or by evaporative cooling. The application of the sprout inhibitor CIPC effectively inhibited sprouting of tubers stored in cool highland areas and reduced tuber weight losses. In warmer areas, however, CIPC did not inhibit sprouting and caused tuber rotting.

Research on storability of genetic material concentrated on methods to evaluate clones for storability of seed and consumer potatoes during prolonged storage at ambient temperatures. Among 51 clones, tuber weight losses after storage ranged from 18.0% to 57.5%. For storability of seed tubers, the storability index and the incubation period were determined for each clone. Considerable differences in storability between clones were observed.

In processing, emphasis continued on technology transfer to produce dehydrated potato products that have shown to be acceptable to consumers. Commercial units applying low-cost processing techniques are now operational in Peru and India. One of the main products is potato flour produced from both sun- and solar-dried potato slices. Research on methods to produce dehydrated French fries has resulted in satisfactory processing techniques and excellent product quality. Consumer tests have shown good acceptability of this product. Research on solar drying systems for different potato products and different quantities has continued in Peru. In Thailand, clones and varieties were evaluated for processing and cooking quality. Socio-economic research was carried out on marketing, and consumption and demand for potatoes and potato products in Colombia, Peru, and Thailand.

Naturally ventilated stores for consumer potatoes in Thailand are placed on raised, slatted platforms to permit convective ventilation.

RELOCATION OF THRUST

The thrust base was moved in 1987 from CIP headquarters in Peru to Thailand to provide greater support to postharvest research programs in Asia. Postharvest problems in Asia are of increasing importance due to frequent high temperatures during the postharvest period and significant increases in potato production. The Thrust Leader is now based in Thailand, which is the lead country for postharvest technology within the Southeast Asian country network of SAPPRAD. The thrust, however, continues to support postharvest programs in other CIP regions.

STORAGE OF CONSUMER POTATOES

Research continues to concentrate on storage of consumer potatoes in warm-dry and warm-humid conditions. Experiments were designed to study methods for controlling postharvest losses caused by storage pests, storage diseases, water loss, and early sprouting of tubers.

Peru. The experiments in San Ramon on evaporative cooling using different store wall structures, as described in the 1986-87 Annual Report, were repeated. No effect of the type of wall structure, white stones versus charcoal, on tuber weight loss was found. Evaporative cooling was achieved by humidifying the store walls. At an average ambient relative humidity of 68% during the storage period, humidification of walls increased the humidity in the stores to 84%. Evaporative cooling reduced the mean daily maximum temperature in the stores from 26.3 to 23.7 C. Total tuber weight losses over a three-month storage period were reduced from 19.1% to 14.6%. Evaporative cooling had no significant effect on the number of rotten tubers.

The effect of the sprout inhibitor CIPC (isopropyl-N-(3-chlorophenyl)-carbamate or chlorpropham) was studied in separate experiments in Huancayo and San Ramon, using ten different clones and cultivars. Mean daily minimum and maximum temperatures in the store during a six-month storage period were 12.9 and 15.8 C in Huancayo, and 20.9 and 25.5 C in San Ramon. In Huancayo, CIPC inhibited sprouting and reduced tuber weight loss (Table 1). In San Ramon, however, CIPC did not control sprouting, and it appeared to be phytotoxic, resulting in increased rotting due to pathogen invasion of necrotic tissue

Table 1. Effect of CIPC treatments on total tuber weight loss (% of initial weight) during storage in Huancayo (HYO) and San Ramon (SR) (mean of 10 clones).

Treatment	Storage period: 60 days HYO	60 days SR	120 days HYO	120 days SR	180 days HYO	180 days SR
Control	4.6	3.1	8.7	10.4	21.7	38.2
CIPC-2 DAH[a]	5.9	7.2	9.4	51.4	12.5	92.9
CIPC-5 DAH	5.6	6.8	9.0	46.5	11.9	86.9
CIPC-10 DAH	5.6	4.6	9.2	41.2	11.7	81.7
Mean of CIPC treatments	5.7	6.2	9.2	46.4	12.0	87.2
LSD (0.05)	0.4	1.9	NS	4.9	0.7	4.2

[a] CIPC applied two days after harvest.

beneath the periderm. Rotting of tubers at San Ramon was reduced when CIPC was applied at a later interval after harvest, probably because of better periderm development at the time of CIPC application.

Experiments on integrated control of postharvest losses in San Ramon confirmed earlier findings that evaporative cooling of storage structures reduces storage weight losses. Averaged over five clones, tuber weight losses were reduced by evaporative cooling from 15.7% to 11.0% over a storage period of four months.

Various interactions were observed when postharvest treatments were applied in combination (Table 2). Natural infestation by potato tuber moth (PTM) did not occur in the store equipped with evaporative cooling; while in the absence of evaporative cooling, 51% of the tubers were infested by PTM. PTM damage was reduced significantly by the repellent weeds, *Lantana camara*, *Minthostachys* sp., and *Eucalyptus* sp., but not by insecticide application. Sprouting was delayed by two to three weeks when tubers were covered with *L. camara* or *Minthostachys*. CIPC, however, failed to inhibit sprouting and resulted in increased *Fusarium* dry rot and secondary bacterial soft rot. Damage by PTM appeared low in CIPC-treated tubers after six months of storage since the damage stimulated the rotting of the tubers, which were eliminated earlier during the storage period. Application of thiabendazole reduced rotting slightly, especially when tubers were pretreated by dipping in a sodium hypochlorite solution. Rotting was also reduced when PTM was controlled with *Minthostachys* or *Eucalyptus* or by using evaporative cooling.

Application of calcium sulphate to the soil before planting the crop in San Ramon had no effect on tuber susceptibility to *Fusarium* dry rot during storage. All experiments showed that storage weight losses were considerably higher with San Ramon-produced tubers compared with weight losses in the Huancayo-grown tubers.

Table 2. Effect of storage treatments on the incidence of *Fusarium* dry rot and potato tuber moth (PTM) damage (% tubers affected by weight[a]), after six months of storage in San Ramon.

Treatment	Dry rot	PTM damage
Sodium hypochlorite + thiabendazole dips[b]	1.3	71
Repellent dried weeds[c]	2.3	17
CIPC[d]	33.7	22
Control	4.3	76
LSD (0.05)	1.6	3.1

[a] Mean of five clones with 5 x 10 kg per clone.
[b] Tubers dipped for ten minutes in solutions of sodium hypochlorite (0.5% active chlorine) and thiabendazole (0.2% active ingredient), respectively.
[c] Means of results for *Minthostachys* and *Eucalyptus*, applied as a 5-cm cover of crushed dried leaves.
[d] Isopropyl-N-(3 chlorophenyl)-carbamate applied as a dust at 1.5 g/kg potatoes, two weeks after harvest.

In Huancayo, a total of 51 clones were evaluated for storability of consumer potatoes. After a six-month storage period, tuber weight losses ranged from 18.0% to 57.5%. Clones with good storability or keeping quality were characterized, in general, by a relatively long dormant period, a slow rate of sprout growth, and low total sprout weight after storage. Some clones, however, showed low weight loss in tubers after storage, despite a rather short dormant period and considerable sprout growth—possibly due to favorable periderm characteristics resulting in reduced water loss.

East Africa. Studies continue on the storage of consumer potatoes in warm lowland climates in collaboration with Kenya's

Ministry of Agriculture at the Mtwapa coastal station. In the most recent trials, using recently harvested and properly cured potatoes, losses after ten weeks of storage in rustic thatched stores were between 19% and 17%. The use of CIPC did little to reduce losses, as the tubers were mostly dormant throughout the storage period. Naturally ventilated stores were the best, but insecticide control of PTM was necessary in the open stores.

Pakistan. The storage period is characterized by initially low ambient temperatures, followed by a rapid increase in temperature while the relative humidity is low. These conditions offer potential for evaporative cooling of potato stores and for successful use of sprout inhibitors.

In cooperation with the Pakistan Swiss Potato Development Project, different designs of evaporative cooling systems were evaluated in the Punjab. Two stores of 20-ton capacity each were constructed and equipped with a forced draught ventilation system and a cooling unit (Fig. 1). One cooling unit was equipped with a locally made humidifier using rashig rings (plastic rings that increase the evaporative surface). In the other unit, a highly efficient air humidifier (water atomizer) was installed. Tubers in both stores were treated with the sprout inhibitor CIPC. Total tuber weight losses after 2.5 months of storage were 14.3% in the store equipped with the locally made humidifier, and 7.0% in the store equipped with the water atomizer. In comparison, tubers stored in the cold store during this period showed a total weight loss of 5.3%.

Thailand. The main potato harvest is at low elevations in northern Thailand during March and April. Prices are usually low at that time and increase gradually during May and June. Wholesale potato prices suggest that in five out of the last nine years, storage of consumer

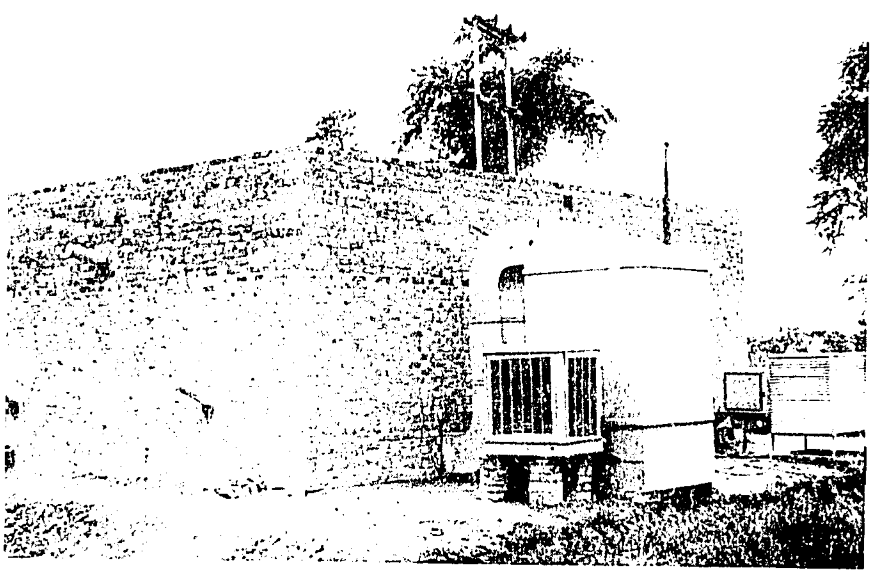


Figure 1. Two store compartments for consumer potato storage in Pakistan, each equipped with a different evaporative cooling system. *Left side:* with locally made humidifier. *Right side:* with water atomizer system

Figure 2. *Top:* the double-walled structure of a naturally ventilated store in Thailand, in which the space in between the walls is filled with rice husks for increased insulation. *Bottom:* the store, equipped with a removable thatched roof, is being filled with potatoes from the top (: 0.5-ton capacity).

potatoes for periods up to three months had been profitable, provided that storage losses could be adequately controlled. Storage experiments were carried out in cooperation with the Horticulture Research Institute of the Department of Agriculture. Naturally ventilated stores were constructed with a raised, slatted floor and detatchable thatched roof (*see* Fig. 2 and Thrust photo). Total tuber weight losses after a two-month storage period were 9.1% for cultivar Spunta and 8.5% for cultivar Kennebec. The number of tubers lost due to rotting was 3.2% for Spunta and 2.2% for Kennebec. No sprout inhibitor was applied, but sprout length generally did not exceed one centimeter and this did not affect the market price.

STORAGE OF SEED TUBERS

Peru. Research has continued to focus on methods to evaluate seed storability of genetic material under warm conditions during prolonged storage periods. Over 50 advanced clones, most of which appear on the CIP pathogen-tested list, were planted in Huancayo and subsequently stored in a cool (Huancayo) or a warm site (San Ramon) in different light stores. Seed tubers of each clone stored in both sites were then planted in one location (Huancayo) for comparison of field performance. For each clone, a storability index was calculated, defined as the yield obtained after storage under warm conditions divided by the yield after cool storage conditions. The storability index in the clones evaluated ranged from 0.39 to 0.94. The former figure would mean that the clone has poor seed storability, while the latter figure indicates excellent storability.

In another evaluation, the incubation period was determined in the same range of clones. The incubation period is the period between the onset of sprouting and tuber formation on the sprouts when tubers are kept in the dark at 18°-20° C at high relative humidity. Clones with a short incubation period usually have poor seed storability. A comparison of both evaluation methods showed that the incubation period was particularly useful for comparing a large number of clones, resulting in a relative figure for each clone. The storability index would be a practical method to characterize the seed storability of a limited number of clones for specific growing and storage environments. An increasing number of national programs are now considering seed storability as an important factor in their evaluation of genetic material.

POTATO PROCESSING

Transfer of technology. *Peru*. Emphasis continued on technology transfer to produce dehydrated food mixes based on potato. As in previous years, the CIP pilot plant in Huancayo was used frequently by national scientists to become familiar with processing methods and to work on specific processing problems they had encountered when applying these technologies. An increasing number of national institutions have shown interest in producing potato-based food mixes.

Centro IDEAS, a Peruvian development group, has now completed the construction of their processing plant in the Mantaro Valley of the Andean region of Peru. This project is financed by Appropriate Technology International (ATI), a private, nonprofit development assistance organization based in Washington, D.C. CIP has assisted Centro IDEAS and ATI in the preparation and development of this project in which potatoes and other Andean roots and tubers will be processed.

Raw material will be available throughout the year and the plant will operate continuously. CIP's original technology was modified to suit the specific needs of the project. The modified, simple procedures to produce potato-based mixes involve producing potato flour followed by specific mixtures with legume and cereal flours. In order to comply with national health regulations, the processing area of the plant was made from washable bricks. The plant also provides ample storage space for raw materials and for the finished products.

Two drying systems have been installed. One system is a solar dryer, similar to the modified CIP design, equipped with a preheating chamber, which has greatly increased the drying efficiency (*see* Ann. Rep. 1986-87). The second drying system is based on artificial drying, using kerosene-fueled heaters, and can be used throughout the year as a backup system for the solar dryer, which has limited efficiency during cloudy days. Consultations between Centro IDEAS staff and CIP-Lima social scientists have focused on the economics of producing and marketing processed products in Huancayo and Lima.

The National Program for Andean Crops (PNCA) has also started the construction of a low-cost pilot processing plant at their experimental station in Huancayo. CIP and PNCA continue to cooperate in the design of this processing plant. Another development group, Servicios Educativos Promocion y Apoyo Rural (SEPAR), continues to receive support from CIP in the use of this processing technology in various Andean communities.

During follow-up visits to families in communities in the central sierra area where processing procedures had been demonstrated a few years ago, it was found that about 50% of the women who had participated in earlier processing demonstrations continued to make potato-based food mixes. The main problems mentioned by the interviewed households were non-availability of some of the ingredients for the mix and lack of time for manufacturing the mixes. Potato processing has been particularly successful in villages where households cooperate in communal farming and processing activities.

India. The Society for Development of Appropriate Technology Inc. (SOTEC) of Bareilly has set up a pilot plant for village-level potato processing in India (as reported in Ann. Rep. 1986-87). This year, the potato processing equipment was modified further to suit local needs (Fig. 3). Several small-scale processing units have been set up with assistance from SOTEC. In these units, potato slices are dehydrated on racks in the open air before being ground into potato flour (Fig. 4). New potato recipes continue to be developed and evaluated for eventual use by potato consumers in the surrounding areas. SOTEC is also involved in helping to market the potato products. Different types of packaging have been developed for the various products being processed and products continue to be market-tested.

CIP-Lima social scientists provided on-site support to SOTEC to develop existing marketing arrangements. Furthermore, calculations done in Lima on the costs and returns to simple processing served to assist SOTEC staff in identifying potential constraints to the future transfer of this technology.

Research on potato-based products. *Peru*. Research on new potato products has continued to receive attention at CIP's pilot plant in Huancayo. A thesis report on the technology to produce dehydrated

Figure 3. A pedal-powered potato slicer, developed by SOTEC Inc. at its pilot plant in Bareilly, India.

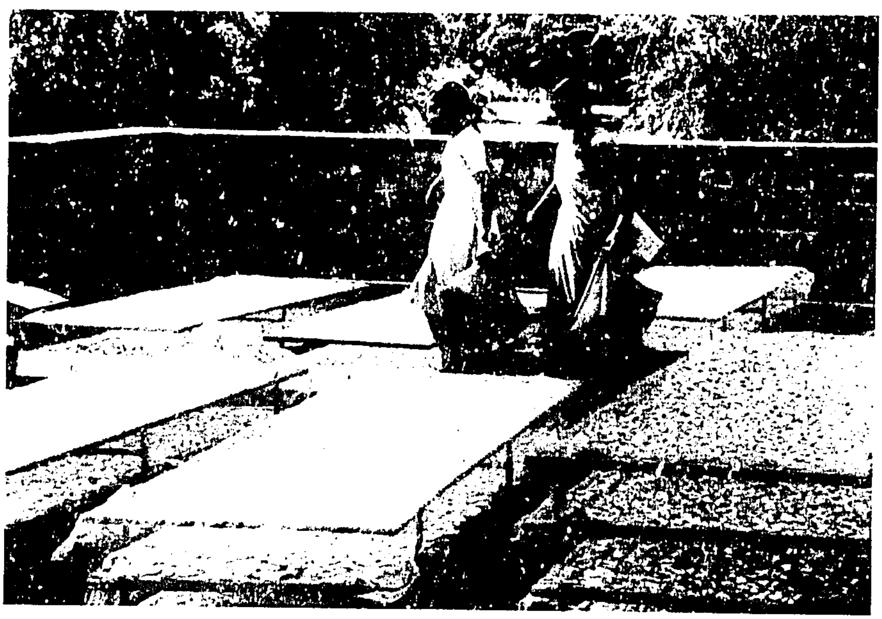


Figure 4. Sliced potatoes are sun-dried on stacked racks in the open air for one to two days before being processed into flour.

Table 3. Processing efficiency of manufacturing dehydrated French fries from potato.[a]

Variety	Raw material (kg)	Dehydrated product (kg)	Processing efficiency (%)
Revolucion	30.0	6.22	20.7
Yungay	30.0	6.35	21.2
Perricholi	30.0	5.67	19.6
Mariva	30.0	6.16	20.5
Desiree	30.0	6.05	20.2
Mean	30.0	6.13	20.4

[a] Mean of four replications per variety.

French fries has been completed. Experimental results showed that freshly cut pieces could be dried typically in 12-15 hours using a solar dryer equipped with an additional preheating chamber. After drying, the final product contained about 10% moisture. The average processing efficiency was about 20% (Table 3)—about 200 g dehydrated French fries could be produced from 1 kg fresh, unpeeled potatoes. The quality of the product did not change during a one-year storage period at ambient temperatures. The rehydration time of the product was reduced considerably by increasing the water temperature. At a water temperature of 40 C, adequate rehydration occurred after five hours, compared with nine hours at a water temperature of 15 C.

A market survey conducted in Huancayo (pop. 250,000) showed excellent consumer acceptability of dehydrated French fries. A further survey of 20 eating establishments in Huancayo showed that restaurant owners were very interested in this product; however, several respondents indicated a concern about the price and terms of supply. The long shelf life of the product makes it particularly attractive in places where the supply of fresh potatoes is irregular or seasonal.

A cooperative project on solar drying has been initiated with the Italian Institute of Atomic Energy (ENEA), Italy. Solar dryers of different designs, capable of drying different potato products and various quantities of material, are being tested in Huancayo. Designs will also be tested in the more humid conditions of San Ramon where drying is more difficult.

A baseline study of the market for processed potato products in Lima was carried out by researchers at the Universidad del Pacifico with technical support from CIP's marketing specialist. The

Table 4 Estimated annual consumption of processed potato products and the raw material requirements, Lima, 1987.[a]

Processed product	Consumption (t)	Raw material (t)
Potato starch	1,756	14,048
Papa seca	1,358	7,192
Instant mashed potatoes	91	455
Potato chips	874	2,622
Papa chuño	77	500
Pre-cut French fries and peeled potatoes	9,600	12,000
Total		36,800

[a] Source: R. Gomez and D. Wong. 1988. El mercado de productos procesados de papa en Lima metropolitana [The market for processed potato products in metropolitan Lima]. Report of the Centro de Investigacion de la Universidad del Pacifico, Lima, Peru. 163 p.

final report emphasized the diversity of products available (Table 4), the variety of consumers, and the difficulties in expanding the market given the relatively high price of such items and the limited food budgets of most consumers. Interviews with 109 consumers identified potato starch for use in cooking as a product with unrealized potential because of its versatility and demand by various users such as housewives and restaurants. Several other countries have requested and received the methodology used in this study.

Colombia. In northeast Colombia, policymakers concerned with rural development and national potato program researches have considered simple potato processing as one potential means of bringing about greater price stability for the potato and an improvement in growers' incomes. They consider Pamplona as an ideal location for establishing such facilities because it is an area where potatoes are the principal crop and it is noted for its small-farm population and geographic isolation from the rest of the country. In 1986, the Colombian Institute for Agricultural Research (ICA) set up a small pilot plant. After having established that with local varieties and infrastructure, processed potato products using simple technology could be produced, ICA personnel then began in May 1987 to assess the socioeconomic feasibility of such technology (PRACIPA-Comercialización). A key component of this assessment is an attempt to determine the needs and interests of local potato producers with respect to simple potato processing. Consequently, a gathering of producers and potato technicians was organized to show the types of dishes that could be prepared with processed potato products (e.g., crisps, cakes, and soups). Then, a formal survey was administered with 81 growers, selected from five different farming localities in the region.

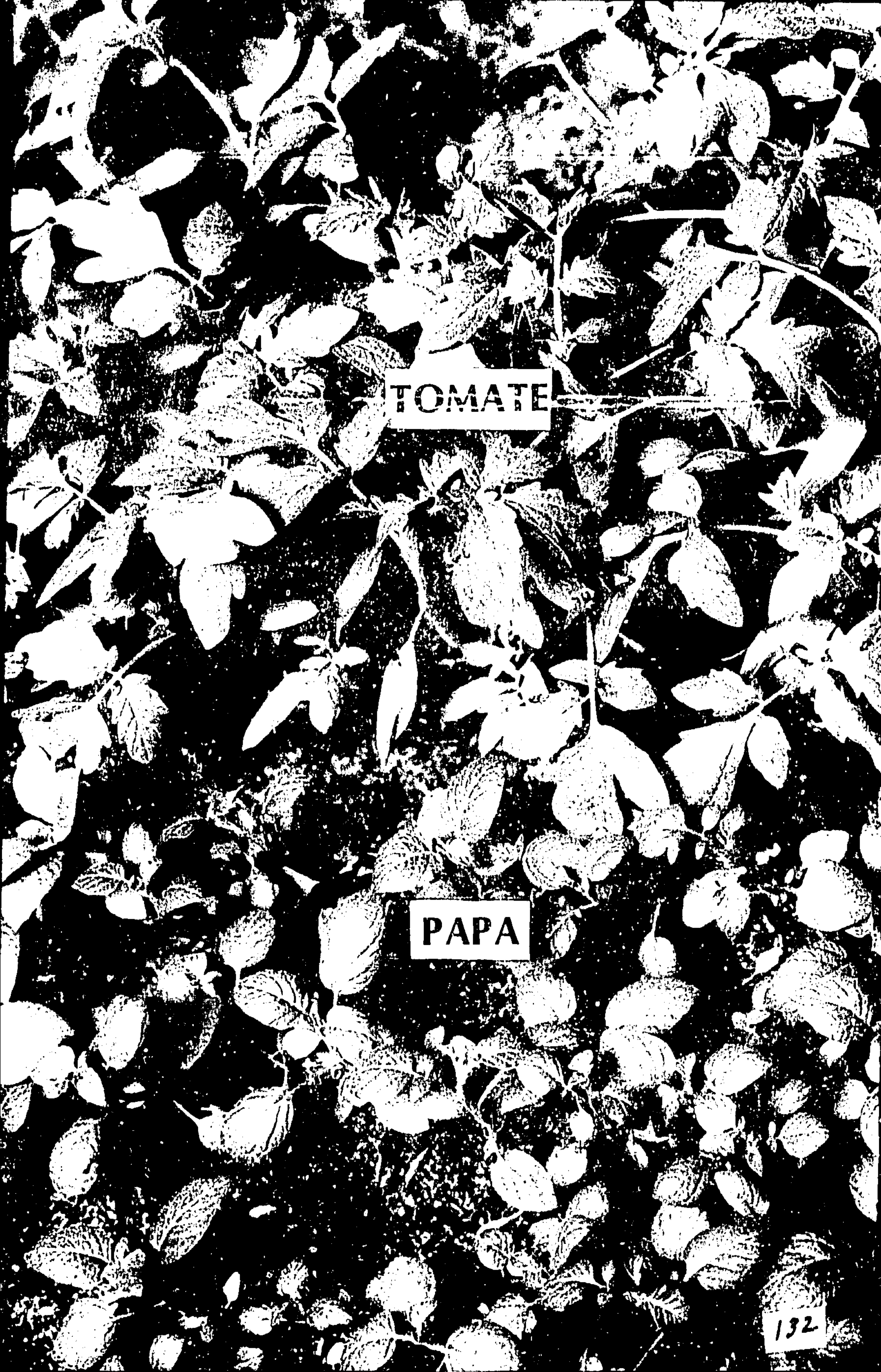
Highlights of the survey are as follows: 1) 52% of the growers interviewed reported selling potatoes at very low prices in 1984, and 9% in 1985 and 1986; 2) 73% of farmers indicated that family labor is employed year-round, and 68% have difficulty in hiring labor at harvest time; 3) 72% are familiar with potato crisps, but 28% reported being unfamiliar with any processed potato product; 4) 80 of the 81 growers interviewed are interested in processing part of their production; reasons mentioned include: improve prices, diversify the family diet, provide employment for household members; 5) products the growers are interested in producing include potato chips, potato flour, and French fries.

Thailand. Changing consumption patterns and an increasing number of fast food restaurants have resulted in an increasing demand for processed potato products in many Southeast Asian countries. In Thailand, in cooperation with the Agricultural Chemistry Division of the Department of Agriculture, a total of 25 clones and cultivars grown at low elevation (500 m) were evaluated for processing and cooking quality. Tubers were evaluated shortly after harvest and again after two months of storage at ambient temperatures. Each evaluation included a frying test to determine chip and French fry quality as well as cooking tests. Color cards were used to characterize the color of the fried product. Nine clones and cultivars were selected for further evaluation. Only four out of the nine selected clones had a specific gravity of at least 1.080—a requirement commonly considered by the chip industry.

Kasetsart University in Bangkok, in collaboration with the Horticultural Research Institute and CIP, conducted a study on the demand for potato products in Bangkok. The study showed that a large proportion of potato production per year is used for industrial processing into snack foods. Moreover, according to survey results, as household incomes increase in Bangkok, potato consumption appears to increase both in processed and fresh forms.

TRAINING

Eleven Tunisian scientists were instructors at the storage course held at the training center at Saida. Different methods of storage—traditional, diffused light, and refrigerated—as well as associated topics such as tuber physiology, storage diseases, and virus disease spread in stores were included in the program, and excursions were made to storage and processing facilities. In India, practical processing was taught at a two-day, in-country course on simple, village-level technology at the plant of the Society for Development of Appropriate Technology at Bareilly. Participants also learned about production costs and marketing of processed products. Two Bangladeshis also visited the plant to gain practical experience with the low-cost techniques that have been developed.


TOMATE
PAPA

THRUST IX

Seed Technology

Breeding work on true potato seed (TPS) progenies concentrated on testing advanced selections for tuber yields under a wide variety of locations. Three clones were good combiners for wide adaptation in TPS crosses, and most crosses had a higher degree of adaptation to short-day conditions. Out of 286 crosses screened for seedling resistance to early and late blight diseases, 26 crosses showed acceptable tolerance to both pathogens. Based on the performance of a vigorous cross, Atlantic x I 1-7, an index criteria for acceptable TPS vigor was developed. The most effective presowing treatment for optimizing seedling vigor in nondormant TPS was priming the TPS in solutions of low water potential.

Enhancement of progeny uniformity characteristics using pollen selection and seed size separation techniques was found promising in certain crosses. The yield advantages of the raised bed system for seedling transplanting were confirmed. In seedling tuber production in bed, a layer of gypsum applied to the soil surface increased tuber yields and acted as an effective control against potato tuber moth. Potato flowering was increased with a four-hour light interruption of the night period under short-day environments. In Chile, a collaborative project with CIP on TPS production determined that the average costs of non-emasculated TPS were US$246 per kilogram. The highest share of the total cost of TPS production was related to pollination work; for example, labor and technical management costs were the two most expensive inputs. The collaborative effort between CIP and INIA of Chile to produce TPS on a commercial scale will continue for a fourth season. It was shown that seeds (tubers, cuttings, and TPS seedlings) produced in warm climates yielded lower than those produced in cooler areas. In Burundi, the basic seed production program has redesigned its strategy to eliminate latent bacterial wilt disease. This new system is based on in-vitro micropropagation methods with subsequent transplanting of plantlets to plastic bags for small tuber production.

In sweet potato research, considerable variations in developmental responses of 15 clones to six different Peruvian environments were observed. Several techniques were shown to improve the effectiveness of grafting in flower promotion: graft scion compatibility, stock and scion conditioning under short days, and obtaining scions at onset of flowering.

Early potato seedling growth showing vigor comparable to that in tomato seedlings as a result of proper TPS handling methods.

International TPS progeny evaluation trials. The international trials to evaluate TPS progenies have permitted identification of a number of new high-performing progenies. Of 27 progenies tested in San Ramon and Lima, Peru, and in Brazil, Bangladesh, and Chile, the best progeny was 377881.16 x 377250.7. Also good were the progenies C83.119 x 575049 and Maine-28 x C83.119. In a collaborative effort between CIP and two other countries, another set of trials for long-day adaptation, comprising a sample of 30 progenies, was carried out in Peru, (San Ramon), Italy (Milan), and Japan (Iwate and Kanagawa). The progeny CH 103609 x AVRDC 1287.19 was the best overall performer. Progeny CH 103209 x AVRDC 1287.19 was also a good performer, particularly in Japan. The progenies LT-8 x AVRDC 1287.19 and LT-8 x 377964.5 were high yielders in Japan. Progenies Serrana x 377964.5 and LT-5 x 377964.5 were particularly well suited for Italian conditions. All of these selected progenies will be produced on a large scale for further testing in bigger-sized experiments.

A group of 286 progenies with potential for regional utilization were screened independently at the seedling stage in Huancayo for late blight resistance and in San Ramon for early blight resistance. Of the total tested, 26 progenies were identified as having good levels of resistance to both diseases.

Africa. In Ethiopia, a trial of TPS progenies was made for the first time to familiarize national potato scientists with this technology. Among the eight hybrid and OP progenies used, the best yield was given by CIP 981005 (Atzimba x DTO-33). Two OP progenies, 700466 and 676008, gave acceptable yields, but tuber uniformity of 700466 was poor. In the next season a study of nursery seedbed substrates will be implemented.

In TPS progeny trials in Senegal, the Sengalese Institute for Agricultural Research and the Center for Horticultural Development obtained good yield results by using seedling tubers as planting material. Yields from 22 to 30 t/ha were produced by selected TPS progenies such as Atzimba x R-126.6, Atzimba x DTO-33, and CEX-69.1 x DTO-28.

Asia. Intensive evaluation of TPS progenies continues in India in more than twenty agroclimatic conditions. The results obtained from multilocational trials in India over the last four years have shown that the field performance given by these TPS hybrid progenies, HPS-2 III, HPS-I 13, and HPS-II III, under the different agroclimatic conditions, indicated that they were the best yielders irrespective of the planting materials used. These hybrids also produced uniform tubers in shape, size, and color. On the basis of their performance, seed of these hybrids will be produced on a large scale for use in farmers' field trials.

TPS PHYSIOLOGY

Seedling vigor. A number of methods were tested for their effectiveness to predict early seedling growth of plants from TPS. The coefficient of velocity ($CoV = 100[\Sigma N_i / \Sigma N_i T_i]$, where N = number of seedlings on day i and T = days after sowing) calculated from daily emergence counts one to ten days after sowing was found to be a practical and reliable quantitative index for characterizing seedling vigor. By standardizing soil media during testing and recording the temperature, the CoV could be a usable parameter for comparisons among locations. Based on the performances of the more than 30 crosses investigated, criteria for selection of high seedling vigor at a supraoptimal temperature (>25° C) were proposed, using the performance of the most vigorous cross, Atlantic x LT-7 as a role model. Acceptable seedling vigor in TPS may be quantitatively defined as the initial emergence rate or CoV levels >20, final emergence 17 days after sowing >90%, and top dry weight of seedlings >10 mg plant.

Dormancy and presowing treatments. Various experiments were conducted to understand and characterize the effects of seed dormancy on seedling emergence in selected TPS crosses. In most crosses the TPS could be described as deeply dormant at 0-2 months after harvest, partially dormant at 3-6 months, and nondormant at greater than 6-12 months. The data from numerous experiments strongly indicate that the use of nondormant seed is a requirement for optimizing the expression of seedling vigor in TPS during early stages of plant development. This was clearly demonstrated in the results from five different TPS lots of Atzimba x R-128.6 tested after increasing periods of storage. The after-ripening requirement in storage before sowing TPS was not circumvented by the use of presowing treatments, even though gibberellic acid (GA) did increase final emergence in the deeply dormant 1987 TPS lot (Fig. 1). These seedlings had a lower dry weight per plant than the seedlings which developed from nondormant seed, irrespective of presowing treatments.

Osmoconditioning (priming) or soaking nondormant TPS in solutions of low water potential was found to be the most effective presowing treatment for increasing seedling vigor in TPS. Partially dormant (3 mo) TPS was effectively primed in approximately 8 out of 12 crosses and in all crosses when nondormant. For all crosses, the effectiveness of priming increased as dormancy was lost in storage. Nondormant TPS in more than 30 crosses, when primed in KNO_3 + K_3PO_4 at −1.0 MPa, had higher CoV seedling vigor levels than seed treated with gibberellic acid (GA) and controls.

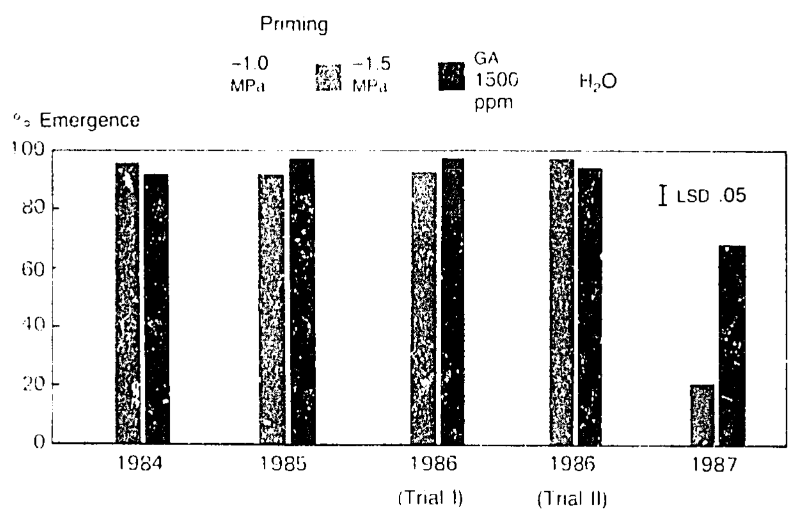


Figure 1. Effect of four presowing treatments in five TPS lots on final percent of seedling emergence 17 days after sowing. MPa = −10 bars (water potential).

TPS maturity. A proper stage of berry development at harvest was shown to be an important factor influencing seedling vigor in TPS. The effectiveness of the standard GA treatment for increasing emergence and seedling development in partially dormant TPS of Atzimba x DTO-28 decreased as seed maturity increased.

In TPS of two crosses (Atzimba x R-128.6 and Serrana x R-128.6) tested at three and six months after harvest, the rate (CoV) and final percent of emergence and dry weight per seedling increased linearly with seed maturity, particularly when the TPS was primed. The optimum stage of TPS maturity required for maximizing seedling performance in these two crosses was similar (approx. 10-12 weeks). It was observed, however, that even under optimum conditions for delaying plant senescence, on-plant berry development periods could not be prolonged beyond eight to nine weeks for earlier maturing female plant genotypes such as Atlantic or DTOs. Nevertheless, seedlings from Atlantic x LT-7 harvested after nine weeks of berry maturity showed superior seedling vigor to all the other selected crosses at CIP. Moreover, these seedlings were as developed or more developed than tomato seedlings grown side by side after sowing.

Storage conditions. The effect of proper storage conditions on seedling performance is well documented in small-seeded sexually propagated crops. However, the need to preserve vigor when considering that the seed is dormant at harvest—as is the case for TPS—has not been investigated previously. Several experiments were started at CIP to determine the storage conditions that could best reduce seed dormancy while also avoiding unacceptable reduction in seed vigor. Preliminary results suggest that these two conflicting objectives can be achieved using variable storage techniques. Until more information is obtained, the TPS should be disinfected immediately following extraction from the berries, followed by drying (approx. 2 days) at 25 C and then stored at 20 C with a desiccant to 3-6% moisture for six months, and thereafter at 5 C or lower. However, since seed vigor reductions are not considered to occur in dormant seed, TPS destined for storage periods longer than 24 months may require different initial conditions to preserve dormancy, such as low temperatures.

TPS characteristics and progeny performance. The tuber characteristics resulting from certain TPS crosses were improved in uniformity by separating lots into specific size fractions of seed width or terminal velocity (density). Further improvements in progeny characteristics were found in one cross when the pollen used to produce the TPS had been either screened for a specific diameter or harvested from flowers previously treated with the insecticide Metasystox.

For both seed and pollen screening methods, however, neither the large nor small size separations were necessarily the most effective for enhancing progeny performance. Moreover, the effects of pollen pretreatments were dependent on the pollen donor genotype and its interaction with the mother plant. For example, progeny uniformity of the resulting tubers decreased in one TPS cross produced with Metasystox-treated pollen as compared to progenies generated by a control of untreated pollen. This was expected from the random nature of the treatment, which may adversely affect progeny uniformity due to possible shifts in segregation ratios favoring the least frequent characters as expressed in TPS produced with untreated pollen. Nevertheless, in all crosses evaluated, the berry set and TPS number per berry, and thus TPS yields, decreased linearly with pollen size.

Other experiments aimed to clarify the environmental effects on true potato seed germination were conducted using 21 different crosses. It was found that 30% of these did not respond to light 43% responded positively, and 27% responded negatively. The latter group was the least vigorous during germination. Using TPS from open-pollinated berries, 794 accessions of *Solanum tuberosum* spp. *andigena* were also screened for high temperature germination at 30 to 25°C without presowing treatment. Germination of four lots was 30-60% and approximately 57% of these accessions did not germinate at all. The eight most vigorous genotypes were also identified.

TPS AGRONOMY

South America. In Peru, activities concentrated on evaluating progenies for producing potatoes for consumption or further propagation as well as on several characteristics to improve possibilities for successful adoption of TPS technology in warm tropical areas. In two series of experiments, the performance of a selected group of progenies, tested as transplanted seedlings or as seedling tubers, was assessed in the contrasting environments of Huancayo (cool) and San Ramon (warm).

In the first series of experiments, seedling tubers of 2.8- to 3.5-cm diameter were tested against seven hybrid and seven OP progenies grown in the field from transplanted TPS seedlings in each location. After storage in diffused light at the production sites, the tubers were field-planted and their performance compared to that of seedlings of the same progenies transplanted on the same date. A split plot design with four replicates was used at each location. Field practices were similar to those normally used in potato cultivation. The interaction progeny type x propagation method x environment was highly significant. Results indicated that the yield differences between hybrid and OP progenies were minimal when seedling tubers were used for propagation. This suggests that in areas where seedling tubers can be used advantageously, OP seed of selected progenies could be used instead of more expensive hybrid seed.

In the second series of experiments, seedling tubers of 15 selected hybrid progenies were produced in Huancayo by direct sowing of TPS in nursery beds. After harvest, seedling tubers of 5 to 10 g were stored in Huancayo until planting time. Tubers and seedlings of the same progenies were then planted at San Ramon and Huancayo using an experimental design and practices similar to those in the first experiments. Yield ranking of progenies (Table 1) following both propagation methods was similar in the cool, but not in the warm location. This suggests that in more favorable cool environments the genetic potential for yield in progenies is less affected by traits such as survival and improved early growth of transplants. In warm environments progenies that perform well as transplants would not necessarily have the same relative performance as seedling tubers, and vice versa.

Several management practices for improved performance of the crop from transplanted seedlings (for producing potatoes directly for consumption) continued to be evaluated to refine agronomic methodologies. In Huancayo and San Ramon, field arrangements for seedling transplanting that had shown promising results in previous experiments (e.g., transplanting in raised beds) were

Table 1. Yields (t/ha) from TPS used as seedling tubers or transplants in two locations (plots of 12.2 m²).

Material	Cool location (Huancayo)				Warm location (San Ramon)			
	Seedling tubers		Transplants		Seedling tubers		Transplants	
	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank
CFK-69.1 x 380701.12	68.6	1	45.8	1	34.3	2	26.2	4
Atzimba x 380701.12	64.2	2	41.7	2	26.4	8	31.6	1
80JA5.8.12 x R-128.6	62.5	3	36.0	5	25.6	9	14.3	11
I-931 x R-128.6	60.3	4	36.9	4	14.5	15	16.8	9
79D10.9 x 380701.12	60.0	5	41.4	3	25.1	10	10.3	14
Atzimba x R-128.6	59.4	6	36.6	6	19.7	12	30.4	2
Atzimba x DTO-28	58.1	7	28.8	12	30.8	4	18.3	8
377887.74 x 377877.9	57.9	8	33.5	8	18.2	13	21.7	5
Atzimba x LT-1	54.9	9	27.9	13	22.1	11	19.4	7
79G8.7 x R-128.6	52.4	10	31.8	9	36.4	1	11.1	13
Atzimba x 380700.79	52.0	11	34.7	7	30.0	6	28.3	3
Atzimba x XY14.7	49.1	12	31.4	10	33.5	3	16.5	10
377877.9 x 378017.2	42.3	13	14.6	15	16.4	14	19.5	6
LT-1 x DTO-33	30.3	14	30.6	11	28.1	7	12.3	12
TS-1 x R-128.6	35.2	15	19.8	14	30.3	[illegible]	9.7	15
Means	53.8		32.7		26.1		19.1	

compared with other transplanting methods at different plant densities. Yield advantages of the raised bed systems were confirmed, especially in San Ramon at high plant populations.

The use of TPS for producing potatoes in beds for consumption could offer an interesting alternative in subsistence farming areas if production costs are minimized. Use of chemicals for controlling the usually high insect activity in warm areas such as San Ramon has been shown to increase production costs, thus limiting potential for adoption. During the dry season, when potato tuber moth is a major problem, several treatments that could significantly reduce pest control costs were evaluated with respect to pest control and yield. The application of a layer of gypsum to the soil surface improved yields significantly, especially when a 5-cm straw mulch was added.

Improved materials were evaluated with respect to their ability to withstand transplanting shock. A group of 44 progenies from CIP's TPS breeding program were evaluated for root regeneration, a characteristic that has been found highly correlated to seedling ability to recover growth after transplanting.

Studies were carried out in Peru on the distribution of Anastomosis groups (AG) of *Rhizoctonia solani* (a major cause of damping-off in seedbeds). Data indicate that AG-3 is present only in the highlands (cool environment) and AG-4 is present in the lowlands (warm environment). These results were confirmed in laboratory studies indicating that optimum development of AG-3 is at 20-25°C and of AG-4 at 25-28°C. Pathogenicity studies have indicated that, independent of temperature, AG-4 isolates of *R. solani* produce higher damping-off than

AG-3 isolates. Healthy looking berries were collected from CIP's experimental stations at Huancayo and San Ramon to determine the pathogen and saprophyte flora present inside the seedballs. Results from this study indicated that only two microorganisms were present and both were fermentative yeasts.

As a technology, the direct use of TPS for producing potatoes for consumption may have limited application in areas where potatoes are traditionally grown from seed tubers. In Brazil, however, experiments with farmers near Brasilia have shown that seedling tubers replanted in the following season can give acceptable yields of between 22 and 33 t/ha. This technology is now considered suitable for trials in northeastearn Brazil (Pernambuco State), which theoretically offers the best possibility of success. Difficulties to be resolved are the possibility of bacterial wilt infection and lack of knowledge of adequate agronomic practices by extensionists and farmers.

Paraguay is another country where TPS may play a useful role. Initial trials were started in 1986 and continued in 1987. The size of the farms and the lack of any strong traditional methods of planting indicate that the use of seedling tubers may be a possible alternative for planting materials. At least one more season of trials on substrates for nursery beds, fertilization, pest control, and storage will be required before starting the transfer to farmers. It is also important to explore the possibility of producing TPS locally.

In Chile, a collaborative project between CIP and the National Agricultural Research Institute (INIA) for producing TPS on a semi-commercial scale has been in effect for three seasons. It will continue for one more season (1987-88) for an estimated production of 10 to 15 kilograms of seed. Since there is little demand in Chile for TPS, the seed is mainly for export to other countries.

Asia. Several farmers in two locations in West Bengal, India, have started using TPS and have adapted the technology to their own conditions. They are using selected TPS hybrids and OP progenies and are producing seedling tubers. Yields of seedling tubers have ranged from 2.3 to 4.4 kg/m^2 and yields of consumer potato ranged from 15 to 25 t/ha.

A pilot scheme to transfer TPS technology to farmers is being promoted in Negros, Philippines. From a total of 200 potato growers, 28 are using TPS transplants on an average field size of 250 m^2, with tuber yields ranging from 10 to 15 t/ha. Farmers sell the large tubers and keep the small ones for replanting. Farmers also produce tubers from high-density nursery beds with 100 plants/m^2; for example, the hybrid progeny, Greta x AVRDC 1287.9, is used in this way. Eleven farmers are growing third generation seed tubers from TPS. The scheme is still in the learning phase as several farmers have failed to manage the nursery beds properly but are willing to try again.

Several research institutes in northern China have extended the use of TPS. Farmers are experimenting with transplanted seedlings and seedling tubers. The major objective is to produce potatoes for starch processing. The yields have ranged from 25 to 32 t/ha with transplants, and from 37 to 39 t/ha with seedling tubers. In southwest China, awareness among farmers of the possibilities of using TPS is growing. This year there was a 130% increase in the area planted to TPS over last year, and more than 2,600 farmers used TPS on a total of 77 ha.

Studies on TPS production practices continued in various environments of Peru. In general, inflorescences developed at the end of the flowering period had a lower berry set and produced smaller and less seeds per berry than the earlier developed ones. The effects of berry load per inflorescence and stem density on seed production were similar to previously reported effects on berry production (Ann. Rep. 1986-87). In an experiment conducted with six clones, an increased number of berries per inflorescence decreased average seed weight and size, but increased total seed production, mainly through a larger production of medium and small size seeds (Fig. 2). For the two varieties, Serrana and Renacimiento, it was found that the number of berries per inflorescence did not affect the seed size and weight.

In an experiment testing several stem densities of the varieties Atzimba, Yungay, and Renacimiento, the high densities resulted in a decreased number of flowers and a decreased number of berries and seeds produced per plant. The total seed production per unit area increased for Yungay and Renacimiento while Atzimba produced the same number of seeds per m^2 at low and high stem densities (Fig. 3). Stem density also affected the flowering behavior of the plants. At low stem density, relatively more lower order inflorescences were formed than at high stem density. The lower order inflorescences produced smaller and lighter seeds than the primary inflorescences. This compensated for the reduction of seed size and weight by increasing stem density. As a result, the average seed size and 100-seed-weight of the total production was not affected by the stem density.

When seed of the same size from different treatments and experiments were compared with respect to germination and early seedling growth, no significant effect was found for the position of the inflorescence on the mother plant, the number of berries per inflorescence, or the stem density of the mother plants.

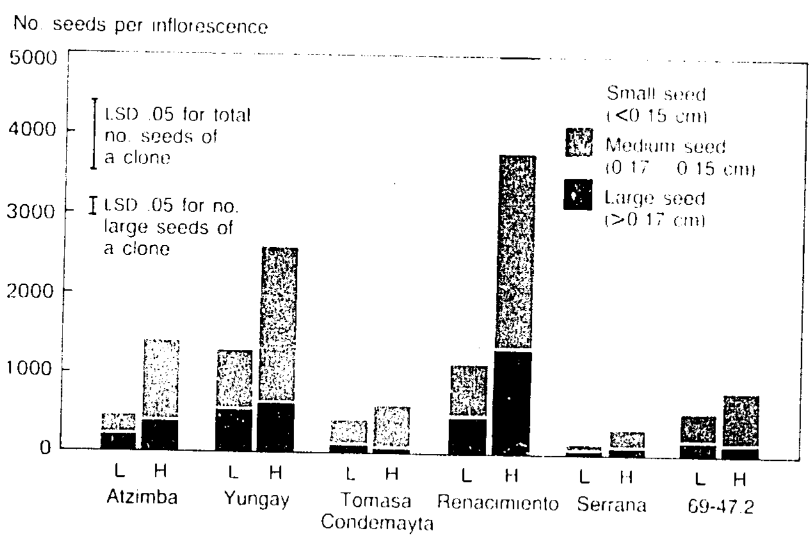


Figure 2. Effect of low and high berry set on seed production per inflorescence in five potato varieties and one clone, Huancayo. L = 25% berry set; H = 80% berry set.

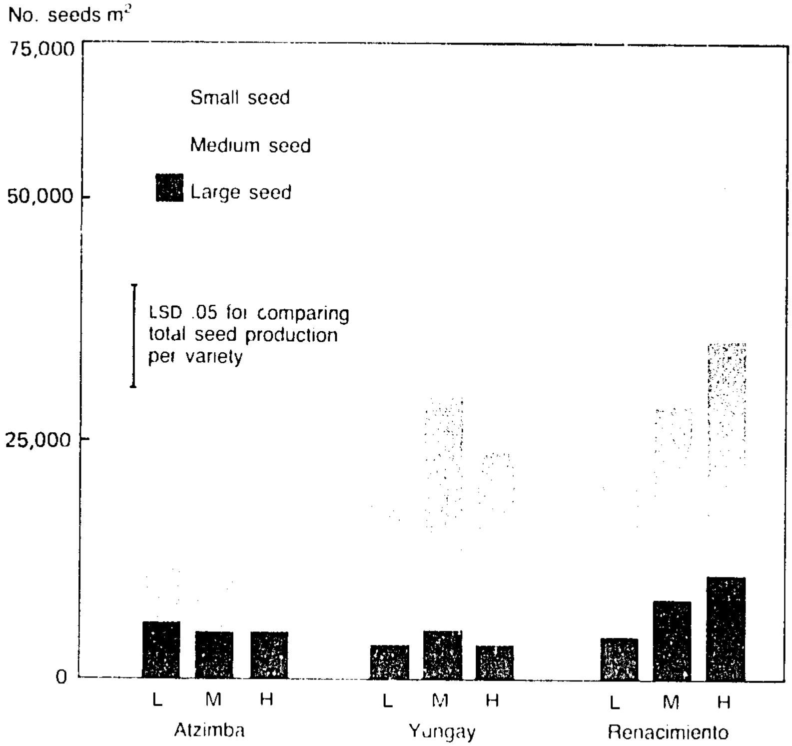


Figure 3. Effect of stem density on the number of large, medium, and small size seeds produced per m^2 from three potato varieties (expt. 2). L = low stem density (8-9 stems m^2); M = intermediate stem density (15-18 stems m^2; and H = high stem density (24-30 stems m^2).

Studies were conducted to evaluate the effect of night-breaks for inducing flowering in potatoes. In an experiment comparing the effect of additional hours of artificial light and night-breaks practiced every one hour during the dark period on flowering, it was found that a three-hour night-break was as effective as additional hours of light in promoting flowering in potato plants. A three-hour night-break was found effective for flower formation of clones that normally produce few flowers under short days such as DTO-28 and DTO-33. According to results obtained with plants grown under nine hours of controlled daylength, a three-hour night-break timed from midnight to 3:00 A.M. appeared to be the best treatment.

TPS PRODUCTION COSTS

A cooperative project between CIP and the National Institute of Agricultural Research of Chile (INIA) has continued for the third consecutive year to produce large quantities of TPS for distribution. The project was carried out at INIA's Remehue Experimental Station in Osorno. Production costs were calculated for six TPS progenies: Atzimba x LT-7, Atzimba x 7XY.1, Atzimba x R-128.6, Serrana x LT-7, Tollocan x 7XY.1, and CFK-69.1 x LT-7.

This year, the average production cost per kilogram of TPS produced with emasculation was US$246. Costs varied from US$128 for Tollocan x 7XY.1—the most efficient combination in fruit setting—to

US$307 for Atzimba x 7XY.1. In general, flower collection and pollen extraction accounted for 40% of the total costs; growth and management of parental clones for 34%; and emasculation for 12%. Since the latter activity was performed by INIA personnel trained last year, labor efficiency was improved, the need for close supervision was reduced, and costs therefore diminished significantly compared to costs in previous years. Labor and technical management were the two most important inputs, accounting for 69% of the costs per unit of output.

PROPAGATION IN WARM CLIMATES

South America. In Peru, CIP is studying the suitability of various potato propagation methods that could be employed in self-sustained production systems under warm climatic conditions. In two field experiments carried out during the Lima summer, the performances of highland-produced seed tubers of LT-5, Rosita, and Desiree were compared to performances of rooted stem-cuttings of the same three clones. Highland-produced seedling tubers of the progenies Atzimba x R-128.6 and Atzimba x DTO-28 were also compared to transplants of the same progenies.

One experiment involved a relay cropping system in which potatoes were planted into an existing maize crop, which was removed 20 days after planting potatoes; in the second experiment potato was used as the sole crop. Considering both experiments together, the plant stand of cuttings was 90% or more and comparable to that of seed tubers. Plant stand from TPS transplants was significantly less than from seedling tubers of the same progenies (Table 2). The transplant survival of TPS seedlings was improved in the relay crop system (82.3%) compared with seedling survival in the potato sole crop system (68.2%); whereas the survival of cuttings was similar in both systems. The best yield from cuttings was obtained with LT-5 (21.8 t/ha), comparable to the best yield obtained with seed tubers of Desiree (22.5 t/ha). The number of tubers produced by plants from cuttings was significantly lower than that from seed tubers, but the proportion of large size tubers (>3.5 cm) was greater. TPS

Table 2 Field performance of seed tubers and rooted cuttings of three clones, and seedling tubers and transplants of two TPS progenies. Lima summer, 1987.

Planting material		Plant stand at 30 days (%)	Yield (t/ha)
LT-5	Seed tubers	97.7[a]	22.0
	Cuttings	93.4	21.8
Rosita	Seed tubers	88.4	16.9
	Cuttings	96.0[b]	15.5
Desiree	Seed tubers	99.6[b]	22.5[a]
	Cuttings	90.0	17.2
Atzimba x R-128.6	Seedling tubers	91.8[b]	13.5
	Transplants	71.7	11.2
Atzimba x DTO-28	Seedling tubers	94.5[b]	21.5
	Transplants	78.8	21.3

[a] Single DF contrast significant at 5%.
[b] Single DF contrast significant at 1%.

Table 3. Total yield, yield of large size tubers, tuber number, and plant stand 36 days after planting (DAP) of different types and origins of planting materials. San Ramon dry season, 1987

Planting material			Yield	Tubers 3.5 cm	Tuber number	Plant stand 36 DAP
Clone progeny	Type	Origin[a]	(g m⁻²)	(g m⁻²)	(no. m⁻²)	(%)
Atzimba	Seed tubers	Field (HYO)	2280	1887	55	100
		Field (SR)	1910	1478	50	89.2
	Tubers from cuttings	Nursery bed (HYO)	2154	1858	41	93.8
		Nursery bed (SR)	1243	1077	23	68.3
		Field bed (SR)	1812	1551	36	72.5
	Rooted cuttings	-	1915	1658	34	91.7
Desiree	Seed tubers	Field (HYO)	2270	1879	57	100
		Field (SR)	1451	1200	31	80.8
	Tubers from cuttings	Nursery bed (HYO)	1478	1250	32	93.8
		Nursery bed (SR)	1061	926	19	73.3
		Field bed (HYO)	1279	1014	33	82.6
	Rooted cuttings	-	1357	1019	35	79.2
Atzimba x DTO-28	Seedling tubers	Nursery bed (HYO)	1435	1077	44	93.3
		Nursery bed (SR)	900	715	21	76.3
		Field bed (SR)	865	651	23	89.6
	Transplants	-	893	271	61	77.1
SED			277	248	7	5.9
CV (%)			25.9	28.9	26.2	9.3

[a] HYO = Huancayo, SR = San Ramon

transplants produced higher tuber numbers than seedling tubers of the same progeny, but with a smaller proportion of large size tubers.

During the San Ramon dry season, rooted cuttings were transplanted to the field for comparing their productivity with seed tuber materials produced in cool (Huancayo) and warm climates (San Ramon). These materials included field multiplied tubers (mean tuber weight 60 g) and tubers from cuttings produced in high density nursery beds (mean tuber weight 25 g). The yield performance of transplants was compared with that of seedling tubers produced in nursery beds, under both cool and warm conditions.

The yield of cool highland tuber material was consistently superior to the yield from the warm lowland tuber material (Table 3). Cuttings and TPS transplants yielded less than cool-produced tuber material. However, LT-5 cuttings produced greater total yield and yield of large size tubers than warm-produced tuber materials of the same clone. Yields from Desiree cuttings and Atzimba x DTO-28 transplants were comparable to those from tuber material of the same clone or progeny produced under warm conditions. TPS transplants had greater tuber numbers but a lower yield of large size tubers than seedling tubers. In general, large size, field-produced seed tubers yielded more and had greater tuber numbers than small size, bed-produced tubers from cuttings. Yield differences reflected mainly the differences in the plant stand observed during the crop establishment period in the field.

Results have indicated the following: 1) warm climate tuber material whether produced in the field or in nursery beds, is likely to yield less than seed tubers imported from cool zones, and 2) the best use for TPS appears to be related to production of seedling tubers for planting the following season since high tuber numbers are obtained. Seed production from stem cuttings would lack efficiency because of low tuber numbers. The great proportion of consumer size potatoes makes stem cuttings more suitable for direct consumer production.

There continues to be considerable emphasis in South America on exploring innovative ways to improve traditional seed production methods. In Argentina, there have been studies on the use of very small tubers of the most common variety, Spunta, for seed production, as this variety has a tendency to produce an excess of large tubers unsuitable for seed. Various sizes of mini-tubers from 2 to 12 g, produced in greenhouses, were planted at several densities. The proportion of large tubers increased with seed size and increasing distance between hills. At a distance of 30 cm, a seed size of 20 g appears to be optimum. The principal drawback of the very small tubers is their lower survival rate, which results in wider spacing and hence the production of large tubers.

To further support the Argentinian seed industry, CIP has continued to assist development of locally produced antisera for virus identification. The laboratories of the National Institute of Agricultural Technology (INTA), in Cordoba, are now producing ELISA and latex kits and have presented samples to ten selected seed companies and associations. Preliminary use of these kits demonstrated their effectiveness in identifying potato diseases. CIP support will continue until Argentina is self-sufficient in antisera production.

Africa. The basic seed production program in Burundi has redesigned its strategy to flush out latent infection by bacterial wilt. The new system is based on in-vitro micropropagation methods and subsequent transplanting of plantlets to large plastic bags for small tuber production. The tubers are planted in the lower of the two seed farms (Muramira, 2140 m) since it is easier to identify wilt symptoms and there is less likelihood of selecting plants with latent infection. Final multiplication takes place at Mwokora (2300 m), where seed is never retained.

The initial results in this season indicated that under the new system, seed harvested from Mwokora had only 2.3% wilt compared to an average of 26.3% in seed originating from Mwokora and maintained by positive selection. Thus it appears that the new system is more effective. Even so, proper rotations and phytosanitary procedures must still be maintained at Mwokora to reduce the level of soil infestation by the pathogen. The technique of positive selection has been introduced to farmers in two areas of the country. Within designated plots, up to 30% of healthy plants were selected. The yield from selected hills was compared with the average yield of 300 plants selected at random in a farmer-managed plot. A yield of 0.71 kg/plant was obtained for the selected material versus 0.52 kg/plant for the unselected plants.

Asia. Studies continue on using various types of cuttings for seed and consumer potato production. At CIP's research station at Sta. Lucia, Philippines, it was confirmed that mother plants should be established from the most juvenile cuttings to obtain prolific production of cuttings and to delay senescence. In cooler conditions, such as the highlands at Baguio City, an extended photoperiod improved the growth of cuttings.

In Vietnam, the technique of using sprout cuttings for planting material is now well advanced. An average of only 200 kg of seed is used to produce sufficient cuttings for one ha; for example, during 1985-86, 30 ha were planted in this manner, and in 1986-87, 97 ha were grown. A total of 1200 t of clean tubers were produced of which 600 t were distributed as seed. The amount of seed planned for the next season is 1300 t.

At the Kunming Institute of Botany in China, strong emphasis is placed on improving the efficiency of in vitro multiplication techniques. Results from collaborative research showed that a shoot with 3 to 4 nodes cut from an in vitro plantlet could be multiplied to 3 or 4 shoots in two to three weeks even if cultured in static, shallow liquid Murashige-Skoog medium to which growth agents had been added. The shoots tuberized within another three to four weeks and could be sprouted with appropriate treatments. This method lowers the cost of material and labor and can be used to increase quickly the quantity of virus-free prebasic seed. At the University of Yunnan, a tissue culture laboratory and screenhouses were installed and virus-free plantlets and seedling tubers were produced and supplied to farmers for evaluation. Similar developments also took place at the South China University.

CASE STUDIES ON SEED TUBER SYSTEMS

During the year a case study was completed on the seed potato system in the Philippines. Seeds and seed systems, whether formal or informal, are the link between cropping seasons and their smooth functioning is vital to ensure production. A project based on case studies of seed systems in developing countries was designed to answer questions about strengths and weaknesses in organized seed potato schemes. A systems approach was adopted to facilitate complete analysis of the many activities and institutions typically involved in such programs.

In the Philippines, a recently completed ten-year cooperative project between the German Agency for Technical Assistance (GTZ) and the Philippine Bureau of Plant Industry (BPI) established a complete seed potato scheme where there had never been one before. Thus the case offered the opportunity to examine the rate of development of the different technical and institutional activities necessary to maintain a functioning seed program.

A principal conclusion of the case study is that institutional and not technical problems are the current limiting factors that prevent the program from reaching planned objectives. By appropriate training and infrastructure construction, the project has put into place an admirable capacity to maintain germplasm and to produce basic seed from an in vitro-based rapid multiplication scheme supported by quality control testing. The limiting institutional factors include problems with management and coordination. Management problems were highlighted by the serious depletion of seed stocks in the seed program's control, a problem in part due to the absence of an effective management accounting system, which made it difficult to coordinate the production activities of the various components of the program.

Potato production for Philippine farmers is a high cost, rapid cash flow enterprise. However, those farmers that lack the capital for self-financing are forced to seek outside funds for their crops. Crop financing limits what a typical farmer can do with his crop. Usually there is very little farm production remaining for the farmer to sell to the seed market. Thus the credit and capital constraints on potato farmers make it difficult for them to become seed production specialists—a basic assumption of the cooperative project. The study illustrates the necessity of understanding the informal seed system with which the formal seed system must interact. This entails accepting the premise that in addition to creating institutions such as virus laboratories, existing institutions such as the informal seed market must be accounted for. Any plans for modifying such institutions require much more time.

SWEET POTATO

Propagation practices. Because of the lack of information regarding field cultivation methods of in vitro-propagated sweet potatoes, a series of experiments were designed to: 1) determine the developmental responses of sweet potatoes grown from in vitro propagation methods compared with those grown from standard cuttings; and 2) test transplanting, transportation, and cultivation methods of in vitro-propagated plant material. The experiments are being carried out with 15 clones at six locations throughout Peru, representing a wide range of responses to various environments.

A series of propagation handling and cultivation methods were evaluated, which resulted in the development of techniques for 1) seed germination 2) obtaining and rooting cuttings and 3) transplanting and post-planting maintenance of sweet potatoes and other *Ipomoea* species. The use of these techniques has resulted in almost 100% survival and healthy growth of plant material in all six locations.

Environmental effects on seed formation in sweet potatoes. Seed setting in sweet potatoes is usually poor, which can affect the efficiency of breeding programs. Preliminary experiments were conducted with 15 sweet potato clones and 13 other species of *Ipomoea* at Lima, San Ramon, Huancayo, and Yurimaguas for determining the optimal environmental requirements for maximum flowering and seed production of sweet potatoes and other *Ipomoea* species.

Observations were made of the developmental responses to decreasing daylength and temperature (December-June) at the four locations. Concurrently, a system was created to record and eventually analyze the responses. Based on the results of these, and for the purpose of expanding the range of latitudes and environmental conditions, continuing experiments using 150 sweet potato clones and 30 other *Ipomoea* species were established at the original four locations as well as at Tumbes, Piura, Cañete, Chincha, and Tacna.

These experiments are being conducted on a year-round basis to evaluate the developmental responses to increasing and decreasing daylengths and temperatures. Considerable variation of flowering responses and seed production, as well as overall vegetative growth and/or storage root production of sweet potato and other *Ipomoea* species was observed. Additional investigations are in progress to determine the extent of the range of environmental conditions to which the developmental stages of sweet potatoes respond.

Experiments on grafting for flower induction, using varying daylength treatments (short day, 9 hrs; natural daylengths, 11.5-13 hr; and long day, 15 hr) given to both scions and root stocks, have shown the importance of the inducing capacity of the root stock, the physiological conditions of the scion, and the photoperiod of the site where the grafted plant is grown.

Complementary experiments, aimed to evaluate and improve the flower induction capacity of stocks from three species (*I. nil*, *I. purpurea*, and *I. setosa*), identified varietal differences in flower induction capacity of the stocks, the positive effect of short-day treatments on the stock, and effect of stock age on flower induction of the grafted plant.

In general, the techniques that have shown improved flower induction capacity in sweet potato are 1) the selection of a stock of high compatibility, 2) stock conditioning by a short-day treatment, 3) obtaining the scion from mother plants close to flowering stage, and 4) growing grafted plants under short daylength conditions.

TRAINING

Nine group activities dealing with seed production were attended by approximately 200 people. There was the annual seed production course in Peru for Latin American countries, seed production courses combined with certification in Argentina and India, and a conference on prebasic seed production for South American countries in Brazil. Rapid multiplication techniques was the subject of a course in China. These techniques were also taught in a course in Cuba, which was concerned mainly with in-vitro propagation methods. Eight visiting scientists at CIP headquarters studied rapid multiplication techniques, in-vitro propagation methods, and serological detection of viruses--three major components of prebasic seed technology. At CIP's Sta. Lucia facility in the Philippines, six Vietnamese were trained in rapid multiplication methods and the handling of TPS for crop production.

In Bangladesh, where considerable research on TPS has been carried out at the farm level, a workshop was held to promote the technology and to show policymakers its potential value under local conditions. Subsequently, two days of training to help with the transfer of adapted technology to the farm level were held for scientists, extensionists, and collaborating farmers.

Potato and Sweet Potato in Food Systems

Research has continued on trends in root crop production and utilization. Since 1960, total root crop production has declined in developed countries and expanded in developing countries. A comprehensive review of available literature on sweet potato has been initiated, focusing on chemical, technological, and nutritional aspects. A questionnaire survey on constraints to sweet potato production in selected countries pinpointed insect damage and marketing problems to be of major importance.

Agroecological potato maps have been developed and computerized for 121 countries. Overlays of climate, altitude, and population were made where data were available. In developing countries, the potato is produced in ten distinct climates. Of the total production in these zones, 44% occurs in lowland tropics with a cool to humid winter; over 11% occurs in the hot, dry, lowland climates, while only 5% comes from the hot, humid climates; and the highland regions and temperate zones account for approximately 20% each.

Case studies of nine national potato programs revealed the necessity for strong national commitment and clear priorities if production goals are to be met. A China study has been completed which contains the most complete collection of national and provincial historical and current statistical materials on potato and sweet potato available in any language. Seed programs received continued attention through questionnaires and case studies of developed and developing countries. A comparative study of seed sectors in the Netherlands, Canada, and the United Kingdom was undertaken.

Baseline studies of potato marketing in Bangladesh, Bhutan, Burundi, Madagascar, Rwanda, Peru, Thailand, and Zaire have been completed. Local institutions, with assistance from CIP, have carried out subsequent site-specific marketing research in Bangkok, Kinshasa, and Lima. A collaborative study of potato marketing in Indonesia has been initiated. A network approach has been developed among Andean countries to facilitate greater regional cooperation in mutually beneficial marketing research. Studies in Peru on potato seed sources and on traditional seed flows illustrated the importance of up-to-date socioeconomic data in promoting use of improved seed and varieties.

Chinese farmers begin processing sweet potatoes by hand-slicing them in the field prior to sun drying.

PATTERNS AND TRENDS IN ROOT CROP PRODUCTION AND USE

Since the 1960s, total root crop production has been declining in developed countries and expanding in developing countries (Fig. 1). In developing countries, the potato stands out from other root crops with a significantly more rapid growth rate (Fig. 2). The average world per capita consumption of root crops was reported to be about 70 kg in 1984. This total is made up of 32 kg of potatoes, 19 kg of sweet potatoes, 16 kg of cassava, and 4 kg of other root and tuber crops.

When the yields in developed and developing countries were compared, the yield gap for both potatoes and sweet potatoes was about 100% of the developing country yield in the early 1960s (6-8 t/ha). Gradually, this has been reduced over time, and at present, potato and sweet potato yields are about 12-14 t/ha in developing countries and 17-18 t/ha in developed countries (Fig. 3).

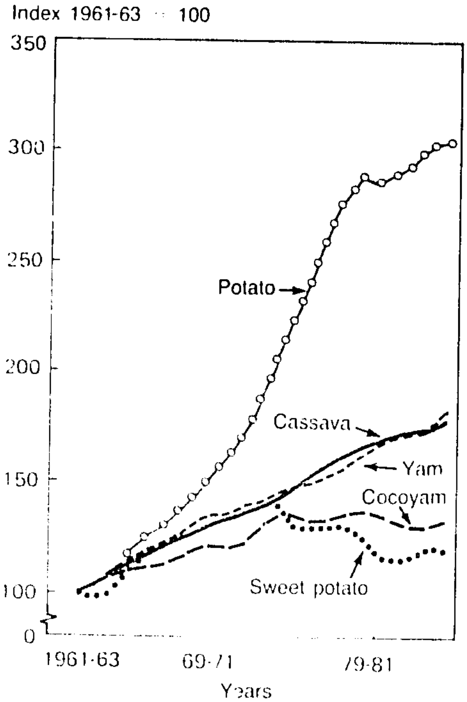


Figure 2. Root crop production trends in developing countries, 1961-85 (three-year moving averages).

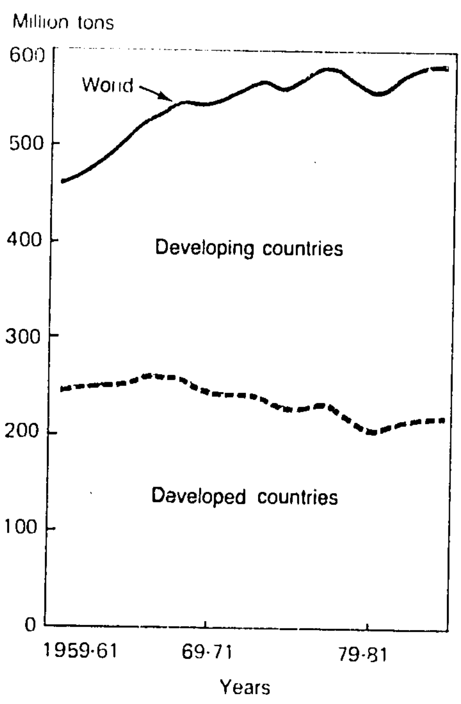


Figure 1. Total root crop production in developing and developed countries, 1961-85 (three-year moving averages).

Constraints to production and use of potatoes and sweet potatoes. A comprehensive review of available literature on nutritional composition and use of the sweet potato and its contributions to both human and animal diets has been initiated and will be co-published in the future with Cambridge University Press. Included in this work will be a bibliography of over 800 sweet potato titles, including material on chemical, technological, and nutritional aspects (*see* Tables 1 and 2).

Questionnaires on constraints to production and use of potato and sweet potato were prepared. To date, 73 questionnaires on potato and 35 on sweet potato have been sent to CIP regional staff and

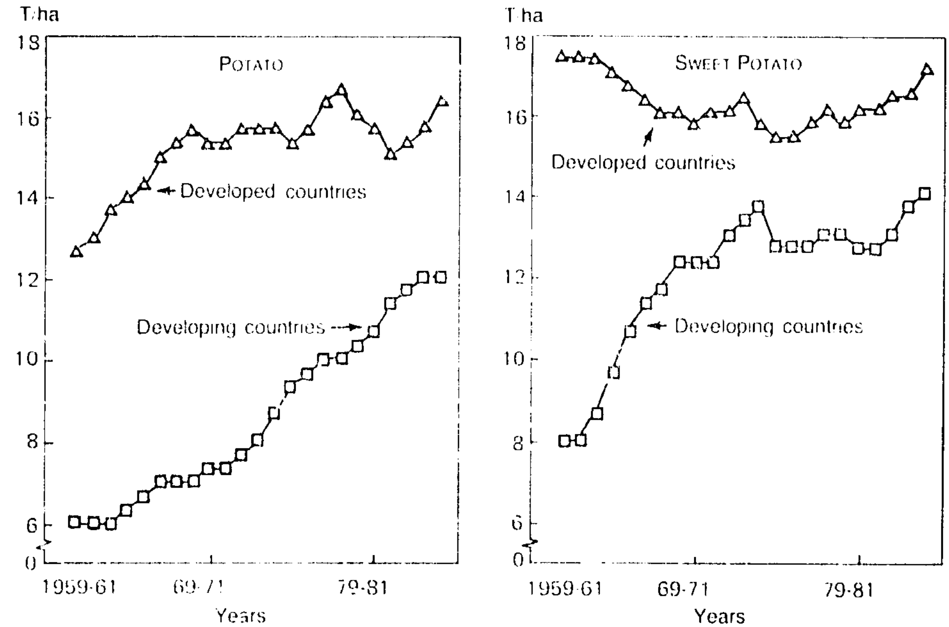


Figure 3. Potato and sweet potato yields in developing and developed countries, 1961-85 (three-year moving averages).

national program leaders. Responses have been received for 19 potato and 14 sweet potato questionnaires. Supplemental data were obtained from CIP regional staff during CIP's 1987 Annual Review in Lima. A major problem area for sweet potato has already emerged from the responses received: limited market demand.

Table 1. Comparative energy yields of sweet potato and other major crops[a]

Crop	Average tropical yield (t/ha)	Edible energy value (MJ/kg)	Proportion of edible energy (%)	Edible energy per ha (MJ x 10³)	Avg crop growth period (days)	Edible energy per ha/day (MJ)
Non-cereals[b]						
Sweet potato	6.45	4.8	88	27.2	140	194
Cassava	8.72	6.3	83	45.6	330	138
Yam	7.00	4.4	85	26.2	280	94
Banana	13.00	5.4	59	41.4	365	113
Cereals[b]						
Rice[c]	2.01	14.8	70	20.8	140	149
Maize	1.24	15.2	100	18.8	130	145
Sorghum	0.83	14.9	90	11.1	110	101
Millet	0.55	15.0	100	8.2	100	82

[a] Table from J. Woolfe, *Sweet Potato: An Untapped Food Resource* (in preparation).
[b] Cereals, air-dry; non-cereals, fresh.
[c] Paddy rice.

Table 2. Chemical composition of sweet potato roots and leaves, and carotene content of raw sweet potato roots.

Source	Root color	Carotene (mg 100 g fresh root)	Retinol equivalent[a] (vit. A mg 100 g fresh root)
Food composition	White	70	12
Tables	Purple	90	15
	Yellow	250	40
	Orange	4 000	667
Philippines (1970)	White to deep orange	Trace - 11,450	Trace - 1,908
USA (1986)	White to orange	30-3,308	5-551
New Zealand (1983)	Creamy yellow	76	13
South Pacific (1987)	Whitish	33-128	5-21

[a] WHO adult recommended daily allowance is 750 g.

Marketing is receiving little research attention in the countries surveyed and respondents have requested CIP's assistance to conduct field-level studies on constraints to production and use of sweet potato, with special emphasis on marketing. In contrast, demand does not appear to be a limiting factor for potato; the principal constraints, such as the scarcity of quality seed at reasonable prices, limit production by keeping costs and prices high.

China study on potato and sweet potato. China produces 80% of the world's sweet potato and is second among nations, after the U.S.S.R., in potato production. A research contract with the International Food Policy Research Institute (IFPRI) reviewed available materials on Chinese sweet potato and potato development during the period 1947-1987, supplemented with some data from the 1930s. The study contains the most complete collection of national and provincial current and historical statistical materials on production of these crops available to date in any language. It provides detailed discussions on cropping systems, agro-climatic characteristics, pests, diseases, and varietal information by region as collected primarily from Chinese materials. Regional information on processing and other forms of utilization, institutional development, pricing, and marketing is referenced in the study, but the coverage of these categories is relatively sparse.

These materials were supplemented with information gathered during a joint mission of CIP, IFPRI, and the Asian Vegetable Research and Development Center (AVRDC) to China on sweet potato production and technology development. The team visited institutions in the Beijing Municipal Area, and the provinces of Shandong, Jiangsu, Sichuan, and Guangdong.

AGROECOLOGICAL ZONING OF POTATOES

A major effort was undertaken in 1987 to determine and map potato agroecological zones in developing countries. National thematic maps for 121 countries were digitized using a special computer mapping program. The maps, which are organized by latitude and longitude coordinates, can be conglomerated on the continental or international level to allow construction of different geographical projections. For countries where data are available, overlays of climate, altitude, density of production, and other factors were added to the base maps. In addition, geography thesis research was conducted in Peru to determine precise agroecological zones of potato production. Eleven distinct Peruvian zones were determined, ranging from very humid, hilly conditions to lowland arid conditions with irrigated production, illustrating further the diverse climates where potatoes are grown even within a single country.

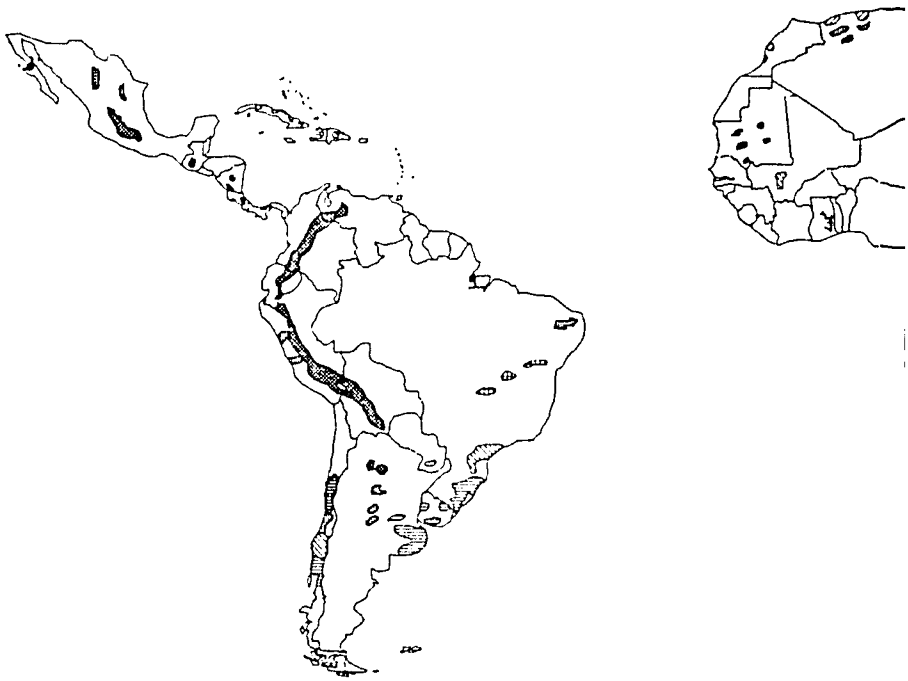
The potato is produced in at least ten distinct developing country climates of the widely used Koppen classification (see Map 1 and Table 3 for a more detailed description). When production data are imposed on these zones, an estimated 44% of developing country production occurs in lowland areas with cool winters (Table 3). Although such regions have been labeled "subtropical," these same climates are seen by some geographers as "tropical rainy" or "tropical humid-summer climates with a humid winter."

As researchers and farmers have developed and put into practice new potato varieties and production systems that flourish in subtropical areas, the Indo-Gangetic plain has quickly become one of the world's leading potato-producing zones.

Table 3. Potato production zones by climate: developing countries.

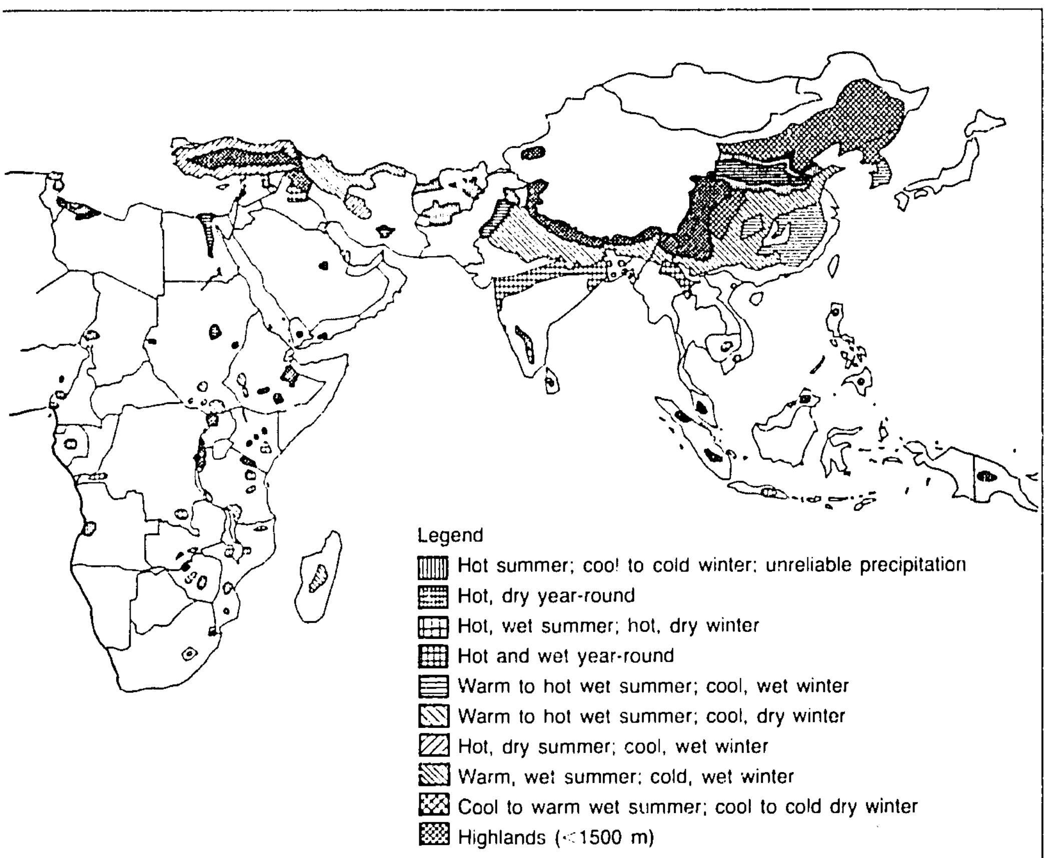
Climate	Estimate of total production (%)	Probable-growing season	Observations
Hot summer, cool to cold winter, unreliable precipitation	5	Cooler months	Irrigation
Hot dry year-round	6	Cooler months	Irrigation
Hot wet summer, hot dry winter	2	Dry season, if found	Irrigation
Tropical rain forest	1-2		Frequent short dry periods
Warm to hot wet summer, cool wet winter	7	Winter	Humid subtropical spring or fall crop
Warm to hot wet summer, cool dry winter	35	Dry winter	Lowland Asia, dry "winter"
Hot dry summer, cool wet winter	2	Various	Irrigation
Warm wet summer, cold wet winter	10	Summer	Temperate
Cool to warm wet summer, cool to cold dry winter	12	Summer	Temperate
Highlands (1500 m)	21	Various	Complex production

Map 1. Potato production zones by climate in developing countries.



Much of this production is found in the Asian potato-cereal food system, which stretches from the Punjab of India throughout Southeast Asia into China. This is the main potato production zone in developing countries, both in terms of number of people affected and land area covered. Rapid expansion of the potato in this Asian belt is due not only to better adapted varieties but to the ecological, rotational, and climatic complementarity that cereals, especially rice and wheat, have with potatoes.

Over 11% of potato production in developing countries comes from the hot, dry lowland climates where the average daily mean temperatures may reach up to 30° C, but where night temperatures fall below 20° C permitting tuberization. Irrigation or high groundwater is a necessity in such regions. Presently, only about 5% of total production occurs in the hot, humid mid-elevation zones (500-100 m) of the tropical rainy or rain forest environments. Taken together, however, this means that in developing countries more than 50% of potato production today occurs in lowland tropical zones with climates varying from hot-dry summer to warm spring or fall to cool-dry winters. The remainder of production is found in the highlands and temperate zones, especially in northern China and Turkey.



Map 1 also shows that new pockets of potato production are emerging in other warm, lowland climates (e.g., West Africa and the Caribbean). Although some of the pockets shown on the map are modified by elevation (< 1000 m), most are areas where farmers themselves are using agronomic techniques such as microniche manipulation and selection of appropriate seasons for potato production. This mapping exercise shows that the range of possibilities for the spread of the potato is quite great. Climates, such as those found in tropical rain forests with short dry seasons are difficult for potatoes; although Yurimaguas, Peru, where potatoes have been successfully grown by CIP, falls into this kind of climate. All other climates, however, are potentially suitable growing zones for the potato, making it perhaps the most adaptive of the major food crops. This is evidenced by the fact that potatoes are grown in more countries of the world than any other food crop except for maize.

ASSESSMENT OF POTATO PROGRAMS

Several lessons for designing and managing potato programs can be derived from the nine case studies of technological change and impact that have been conducted to date in Rwanda, Sri Lanka, Tunisia, Vietnam, India, Korea, Philippines, and the country networks (: PRECODEPA (Central America-Caribbean) and SAPPRAD (Southeast Asia). Programs that became established and were sustainable after special funding was terminated were based, from the outset, on strong national commitment, integration into existing local institutions, and clear priorities. Initially, most programs paid close attention to seed production and distribution. As seed problems were solved, other priorities emerged. Some

Throughout the developing world, women play important roles in potato and sweet potato production; here women in a community are sorting potatoes before storage.

small programs, like the Tunisian seed program, were found to generate exceptionally high economic returns. The case studies illustrate that technology has seldom been transferred directly among countries. Thus, successful programs need to test and adapt foreign technology to local conditions. CIP's role has varied dramatically among the cases, depending upon local needs, resources, and institutional capacities.

SURVEY OF NATIONAL
SEED PROGRAMS

Two questionnaire surveys were prepared, covering the topics of seed potato systems and seed potato projects. Questionnaires were mailed to 78 informed individuals or officials in developing countries.

The Netherlands, Canada, and United Kingdom. Potato seed programs in three developed countries were analyzed under a CIP contract to review the factors shaping seed potato systems in the more developed countries as a contribution to a wider global study on seed potato programs. The study defines seed potato systems and the various essential components in the Netherlands, Canada, and United Kingdom in the context of the potato markets which they service. The institutional arrangements for implementing each of the essential functions and the interrelationships required were also identified. The organization of seed sectors varied sharply among the three countries. The Dutch sector, for example, is less influenced by the state and is more market-oriented. Dutch success arises from a combination of factors: the industry-imposed disciplines to ensure standards, a breeding policy aimed at supporting private breeding (with a long history of breeders' incentives), and a close integration of breeding, seed multiplication, and marketing. In Canada and the United Kingdom, state involvement has been more pervasive, and the challenge has been to intervene without constraining international competitiveness. Institutional difficulties are numerous, and many are common to seed systems in developing countries. Common issues concentrate on the appropriate role of the state and financing of activities for the common good.

Korea. Korea offers an example of a highly successful program for producing and distributing quality seed potatoes (Ann. Rep. 1986-87). Nevertheless, a Korea-CIP study conducted in 1986 and 1987 indicated that the seed program is still providing only 15% of farmers' total seed requirements. The Alpine and Horticultural Experiment Stations have excess capacity for producing basic seed; however, limited public sector resources constrain the multiplication and distribution of larger amounts of foundation, registered, and certified seed. The Korean study indicates that greater involvement of the private sector could help expand the flow of quality seed to farmers.

As Korea's basic seed problem was being overcome, new priorities emerged for the potato program. These included breeding and testing foreign varieties, and on-farm and postharvest research. A strong demand for French fries and potato chips exists, but expansion of potato processing is currently limited by the lack of certified seed of varieties suitable for processing. For this reason, the Korean national potato program is now working to quickly identify and diffuse appropriate varieties through expanded breeding, on-farm research, and seed production.

Due to the country's complex agricultural calendar and the difficult storage conditions, postharvest research is also needed to improve storage systems and ensure a reasonably constant year-round supply of potatoes, both for consumption and processing.

MARKETING AND DEMAND FOR POTATOES

Baseline studies. Reports on potato marketing surveys carried out in Bangladesh, Bhutan, Burundi, Madagascar, Peru, Rwanda, Thailand, and Zaire have been completed and a synthesis of this work has begun. The highlights of a comparison of the country findings include: 1) the growing importance of marketing problems; 2) the multitude of markets (e.g., seed, fresh potatoes, exports) to be examined; 3) distinct marketing patterns for large versus small growers (e.g., Table 4) implying the need for appropriate marketing initiatives by type of farmer; 4) a tendency rising for incomes to generate greater demand for potatoes; and 5) a need for lower potato prices to induce ever greater consumption.

Indonesia. A study to assess conditions for, and implications of, expanding potato production in the medium-altitude areas of Java, Indonesia, was carried out by the Agency for Agricultural Research and Development (AARD) and the ESCAP-CGPRT Center under a research contract with CIP. Indonesia envisions that potato production could double in the next seven years, mainly in medium altitude areas (400-800 m). Research has focused on those conditions, such as price behavior, demand, marketing and production technology, under which expansion would be possible. Tentative conclusions indicate that returns from potato growing are highly sensitive to output and input prices as well as fluctuations in yields under present technological conditions.

Consumer demand for potato appears to be growing relatively fast in the urban areas, partly because of the emerging processing industry and an increasing demand for snacks. High-yielding varieties and disease-free planting material are vital to the expansion of potato production in medium-altitude areas.

Table 4. Potato marketing in the Mantaro Valley of Central Peru

Procedure	Type of producer: Small	Medium and large
Orientation of production	Subsistence	Profit
Marketing period	Begins April-May	Begins during or before March
Place of sale	Fairs or markets in the valley	In farmer's field or in Lima markets
Type of buyer	Various; many are strangers	Few and well known
Negotiation practices	Negotiate in the marketplace	Negotiate prior to hauling potatoes to market
Quantity and quality of sales	Less than 500 kg; less than half # 1 and # 2 grade	From 500 to 15,000 kg; more than half are # 1 and # 2 grade
Form of sales	Ungraded; without the sack	By type and grade of potatoes; with the sack

Source: Scott, G. and Gutierrez, C. 1987. La comercialización de alimentos campesinos: el caso de la papa en la sierra nevada del Peru. *In* Cuadernos de Agroindustria y Economia Rural, No. 18. Lima, Peru

In Bangladesh, potatoes are now among the most important bari, *or winter crops; they are found in many local markets and are consumed by families of all income brackets.*

Peru. Marketing of processed potato products in Lima was also examined in the study carried out by the Universidad del Pacifico's Research Center (*see* Thrust VIII). Processed potato products sold in the capital include: potato starch, papa seca, potato chips (of various categories), papa chuño, instant mashed potatoes, potato flour, and peeled and sliced potatoes (for restaurant use). During 1987, instant mashed potatoes and potato starch were imported; the other products were produced domestically. Retailers typically received the highest margin (40% of the retail price) of all participants in the market chain, although the study considers these margins reasonable. Future marketing developments will be influenced by the availability, price, and processing characteristics of locally produced potatoes as well as government policy, particularly with regard to imports.

Thailand. An initial study of potato marketing in Thailand, based on field work in 1984 by a CIP-Lima social scientist in collaboration with the national potato program, identified marketing margins and the demand characteristics for potatoes sold in Bangkok as a priority area for future study. During 1987, a team of agricultural economists at the Department of Agricultural Economics, Kasetsart University—with support from Thailand's Horticultural Research Institute and CIP—undertook a study to address these issues. Preliminary findings of that study indicate that potatoes are considered a crop of unrealized potential in Thailand in terms of both possible expanded production and increased demand. Aggregate consumption of both fresh and processed potatoes appears to be increasing, although consumption of fresh potatoes still predominates. For high income consumers in Bangkok, consumption is increasing for both fresh and processed potatoes; however, processed potatoes have increased in scope as the processing industry continues to expand and market opportunity as well as product acceptance has improved. Domestic consumption for fresh and processed potatoes in Thailand has already reached a reported 16,000 tons per year. In Bangkok alone, demand for potatoes is estimated to increase at the rate of 9% or more per year.

Principal constraints to increased consumption include inadequate knowledge of recipes calling for potatoes and of the potato's nutritional value, and a nonstandardized potato grading system. Also, poor storage and handling technology causes high postharvest losses, and an unstable supply results in unstable consumer prices.

The following recommendations are a result of the Thailand study:

- An improvement in transportation and handling. Transportation as well as packaging of potatoes should be improved through better packaging materials and designs, and a better way of loading and unloading to minimize damage and weight loss.
- An improvement of marketing facilities at Pak Klong Talad Market Terminal (Bangkok) should be planned to facilitate better buying and selling processes and improving product quality.
- An improvement in statistical report services on potatoes should be made in the public sector to improve the accuracy of reported statistics.
- The future socioeconomic research on potatoes in Thailand should emphasize the production and marketing study at the farm or local level to identify marketing problems facing potato farmers at the local level.

Zaire. Previous CIP research on potato marketing in Zaire pointed out the importance of the Kinshasa market as an outlet for domestically grown potatoes. In 1987, Zaire's Institute for Agronomic Research and Studies (INERA) carried out a study in Zaire's capital to better understand factors that influence prevailing potato marketing and demand patterns. Findings of this study emphasize the high price of potatoes, which is largely attributable to air freight charges from North Kivu some 2000 km away. The study recommends exploring the feasibility of single potato processing to reduce shipping costs, as well as losses in handling and transport, and thereby expanding the market for potatoes in Kinshasa.

Marketing research network. PRACIPA-Comercialización (Programa Andino Cooperativo de Investigación en Papa), a cooperative program of potato marketing research for the Andean region, was begun in May 1985 with support from the International Development Research Centre of Canada. Each country identified a principal research topic for study: 1) Bolivia, institutional seed marketing; 2) Colombia, marketing prospects for simple processed products; 3) Ecuador, marketing and demand for improved quality seed; 4) Peru, a market information system for potatoes; 5) Venezuela, marketing patterns for potatoes in the highland region. CIP's marketing specialist provides technical support and assists in the coordination among these projects.

The initial findings of the research carried out by national potato program staff in Bolivia point to the complexity of seed distribution through institutional channels (Table 5) and the utility of having basic marketing information of this type for planning future production. Similarly, a farm survey in Ecuador found that contrary to widely held beliefs, seed multipliers use the tubers harvested largely on their own farms for seed and do not distribute them. Several other countries have expressed interest in the network concept as a means of institutionalizing research capacity in marketing.

FARMER USE OF HIGH QUALITY POTATO SEED

Socioeconomic aspects of farmers' use of seed of modern and indigenous varieties were studied in the central highlands of Peru. The research, carried out as part of the Peruvian National Potato Program Basic Seed Project, indicated the importance of neighbors and more distant farmers in the renovation of seed by small farmers. Over 50% of seed sources were of this type. Markets were also shown to be an important seed source, especially for low-zone farmers. Commercial seed growers accounted for only 9% of sources.

The importance of inter-regional seed flows and variety preferences was shown in a follow-up survey conducted on the central coast in 1987. This region is the

Table 5. Amount (tons) of potato seed distributed to producers by eight agricultural institutions in the Cochabamba region of Bolivia.

Type	Institution 1	2	3	4	5	6	7	8	Total (t)
Improved seed									
Andigena	67	20	3	23	–	10	24	8	155
Tuberosum	1	760	–	1	224	20	–	–	1,006
Farmer's seed	–	–	59	46	–	70	–	–	175
Total	68	780	62	70	22	100	24	8	[illegible]

Source: Bustamante, J. Annual Report 1987-88 PRACIPA-Comercialización Project: Bolivia. Instituto Boliviano de Tecnología Agropecuaria (IBTA).

major purchaser of seed from commercial growers in the central highlands, and the survey indicated a major decline in the varieties Revolucion and Mariva in favor of the leafminer resistant variety, Tomasa Condemayta, between 1982 and 1987. These shifts are of relevance not only to the commercial highland growers, but also for determining how the Seed Project addresses the seed needs of the commercial system.

Regarding small-farm seed usage and need, the Seed Project has been developing strategies to link the informal Andean system with the formal seed program. One method is to establish basic seed multiplication and distribution units within existing seed networks. A second approach has been the direct sale of small quantities of high quality seed to farmers for individual multiplication. In the 1986-87 season, 160 20-kg bags of seed were sold to farmers through the extension service, at prices much higher than the cost of common seed. A follow-up survey of 80 of the farmers, carried out two months after the harvests, revealed that 43% had stored the whole of their healthy production and a further 43% had stored the seed size tubers for use as seed the following season. The overwhelming majority were willing and able to multiply the high quality seed.

Perhaps even more significant was that nearly 70% of the farmers bought a further 20-kg bag of seed offered for sale during the survey, again at a higher price than common seed. Most decided to buy a different variety than that purchased the previous year to initiate a new multiplication process.

These survey results indicate quite clearly that multiplication practices already in use by farmers can be harnessed to multiply and diffuse high quality seed throughout the small farmer population.

TRAINING

A commercialization workshop was held at headquarters for the PRACIPA network of national programs in the Andean countries of South America. The accomplishments made by the country projects during the year were discussed. The meeting also provided an opportunity to transfer methods and relevant results and to plan future research.

Human Resource Development Through Training

Human resource development is a much broader field than just training, but, along with training, it also includes learning experiences provided by a wider range of education and development activities. As such, whereas much of the training provided by CIP is intended to improve the capacity of national programs to perform job skills needed now, many of its activities are of a developmental nature whose objective is to prepare collaborators to respond to problems that may be encountered in the future.

While many of CIP's collaborative events with national programs fall within the larger framework of human resource development, this section will address a few initiatives designed to increase abilities of national counterparts to generate and exchange information with potential users of improved technologies. Furthermore, this mode of operation used so successfully with potato improvement will now be used with sweet potato.

The initiatives highlighted here complement CIP's overall training program and respond to national demands and recommendations made by reviews and studies of the work of international agricultural research centers. Specifically, some of the studies indicate that, in addition to training in technology generation and use, national programs request training on improving abilities to make new knowledge and planting materials available to their constituents, particularly farmers and their families.

Individual technical training is being given at CIP headquarters in Lima

TRAINING PROGRAM

Activities of the training program support CIP's research thrusts. Details on this training are given in the various thrust reports. Training is supplemented by regional or country-wide activities that take place in collaboration with national programs through CIP's regional research network. While the objective of most of these events is to enable participants to respond to farm-level problems, many are of a specialized nature intended to enable participants to conduct adaptive research. A complete listing of all activities conducted by CIP and collaborative research networks during 1987 is presented in Table 1.

In summary:

- 79 visiting scientists from 31 countries spent 405 working weeks with CIP scientists at headquarters and at regional sites.
- 25 specialized group training activities were conducted in which 483 national research and education collaborators from 58 countries participated.
- 19 production group training activities were conducted in which 1233 national researchers, extension and education collaborators, and farmers participated.
- 109 students and national collaborators from 19 countries conducted theses research at headquarters, regional sites, or universities overseas.

TRAINING ON COMMUNICATION SKILLS

The inclusion of training on communication skills in CIP's training program was prompted by the idea that communication

Production-oriented training is designed to enable course participants to respond to farm-level problems.

is a process that links the ability to understand problems faced by farmers and the generation and transfer of technology to provide solutions to those problems. To date, efforts have been made to improve communication skills between scientists and to enable participants in group training events to share knowledge with their primary clients and with farm families.

Technical writing workshops have been held in English at CIP headquarters in Lima, and in Indonesia in 1984, and in Spanish in Uruguay and Colombia in 1987. While the workshops in Peru and Indonesia were focused mainly on teaching scientists how to write and publish scientific papers, the workshops in Uruguay and Colombia covered these aspects but also were designed to develop teamwork between national editors and researchers.

A team composed of a writer-editor and a researcher from each of 14 countries participated in the workshops in Latin America, a total of 35 participants. Prior to the workshops, each team submitted a draft of an article for publication in a refereed journal. During the workshops, the teams developed the drafts according to guidelines of a known journal. One of the writer-editors has already adapted the workshop methodology and materials for use in a national course taught in Peru. Twenty-one articles were written or edited by the participants and several have been submitted for possible publication in a journal of the Latin American Potato Association.

Efforts to include improvement of communication skills in group training events, primarily production courses, where most of the participants perform extension-type work, began in 1985 in in-country courses

To enhance scientist-to-scientist exchange of information, technical writing workshops have been conducted in Spanish for Latin America.

Table 1. Training activities of CIP and the collaborative research networks, 1987.

Region	Activity	No. of participants	No. of countries
Headquarters-Peru			
	Seminar on cassava and sweet potato improvement (CIAT CIP)[a]	26	11
	Workshop on marketing	7	5
	Visiting scientists[b]	79	31
	Scholarships	33	15
	Student assistantships	21	1
	Preprofessional practice[c]	55	5
Region I			
Colombia	Workshop on technical and scientific writing[a]	21	9
Ecuador	Integrated pest management	13	2
Peru	Production with special emphasis on seed production[a]	17	11
Venezuela	In-vitro introduction and maintenance of sweet potato germplasm	18	11
Region II			
Argentina	Production and certification of seed potatoes[a]	23	4
Brazil	Conference on prebasic seed production	33	6
Uruguay	Workshop on technical and scientific writing[a]	14	6
PRECODEPA			
Cuba	Tissue culture and rapid multiplication techniques	9	5
El Salvador	Tropical agronomy	9	5
Region III			
Ethiopia	Production	45	1
Kenya	Workshop on germplasm utilization and distribution in Tropical Africa	24	15
Kenya	Integrated pest management	14	10
Kenya	Workshop on sweet potato improvement in Africa (CIAT CIP IITA)[a]	17	7
PRAPAC			
Burundi	Workshop on seed production under bacterial wilt conditions	26	3
Burundi	Production	40	1
Zaire	Production	14	1
Region IV			
Egypt	Production	20	1
Region V			
Cameroon	Production	14	1
Cape Verde	Production	23	1
Morocco	Production	19	1
Nigeria	Workshop on integrated pest management (CIAT CIP IITA)[a]	19	9
Tunisia	Storage	21	2

[a] United Nations Development Program (UNDP).

[b] 55 trained at headquarters in Peru and 24 in the regions

[c] 44 from Peru; 11 from developed countries

Table 1 (cont.). Training activities of CIP and the collaborative research networks, 1987.

Region	Activity	No. of participants	No. of countries
Region VI			
Bangladesh	Storage	47	1
Bangladesh	Workshop on true potato seed	30	1
Bangladesh	True potato seed technology	23	1
India	Village-level processing	10	1
India	Modern methods in potato production	13	3
India	Integrated control of potato tuber moth	6	4
India	Seed production and certification	12	3
Pakistan	On-farm research	19	1
Region VII			
Philippines	Germplasm management	33	14
SAPPRAD[a]			
Indonesia	On-farm trials	20	1
Papua New Guinea	Production	23	1
Philippines	Production	300	1
Sri Lanka	True potato seed	185	1
Thailand	Seed storage	286	1
Thailand	Potato tuber moth control	120	1
Region VIII			
China	Tissue culture of potato and sweet potato	28	1
China	Bacterial wilt	17	1
China	Virology	19	1
China	Germplasm management	16	1
China	Rapid multiplication techniques	23	1

[a] All courses for farmers and technicians

in Bolivia and a regional course in Peru. This has since expanded to other regional activities in Colombia, Ecuador, and El Salvador. In these events, lectures and practical work on communication skills complement production or specialized training throughout the entire event. Practicals concentrate on preparation of clean drafts of the messages each participant considers to be of highest priority in the home countries. With these drafts, messages can be prepared by professional communicators for the media considered to be most appropriate in the country. For example, in a course on integrated pest management in Colombia in 1986, participants prepared drafts for posters, flipcharts, radio scripts, and newsletters.

In a course on potato production in warm climates conducted in El Salvador in 1987, practicals on planning and executing a field day were carried out. At the end of the course the participants actually held a field day for researchers, extensionists, and farmers. The final course evaluation pointed out that the participants felt this exercise had contributed immensely to achieving the objectives of the course.

Up to now, most communication training efforts have been intentionally focused in Latin America. The strategy is

#3

Course participants who receive training in communication skills learn to prepare simple drafts of their messages that can later be refined for use by the media.

Experience in organizing and conducting field days is included in some production and specialized courses.

to identify and develop, if necessary, national capacities to continue these activities, allowing CIP to undertake similar approaches in other parts of the world. Plans for this process are already in the making.

TRAINING ON COURSE DESIGN AND COORDINATION

Of the 44 group training activities listed in Table 1, 40 were conducted away from Peru with national programs. This would not have been possible without their strong collaboration and support. They not only provide classrooms, laboratories, greenhouses, field facilities, and logistical support, but also—and of paramount importance—they collaborate in setting objectives, developing programs, teaching, and evaluating the events.

National course coordinators play important roles in the overall process of human resource development. Often, training events are conducted in coordination with small national research teams who work in places far from central offices and support. To facilitate their work and enhance their capabilities in this process, CIP has initiated an approach for supporting individualized technical training with training on topics related to the management and conduct of training.

To date, course coordinators from Ecuador, El Salvador, Honduras, and Peru have undergone a period of training at CIP headquarters in Lima a few months prior to the time a course was conducted in their countries. During this time, the topics covered in discussions and directed individual study were the setting of behavioral objectives, developing curricula, preparing training materials, creating appropriate learning environments, and carrying out evaluations. These experiences have been very positive, and in

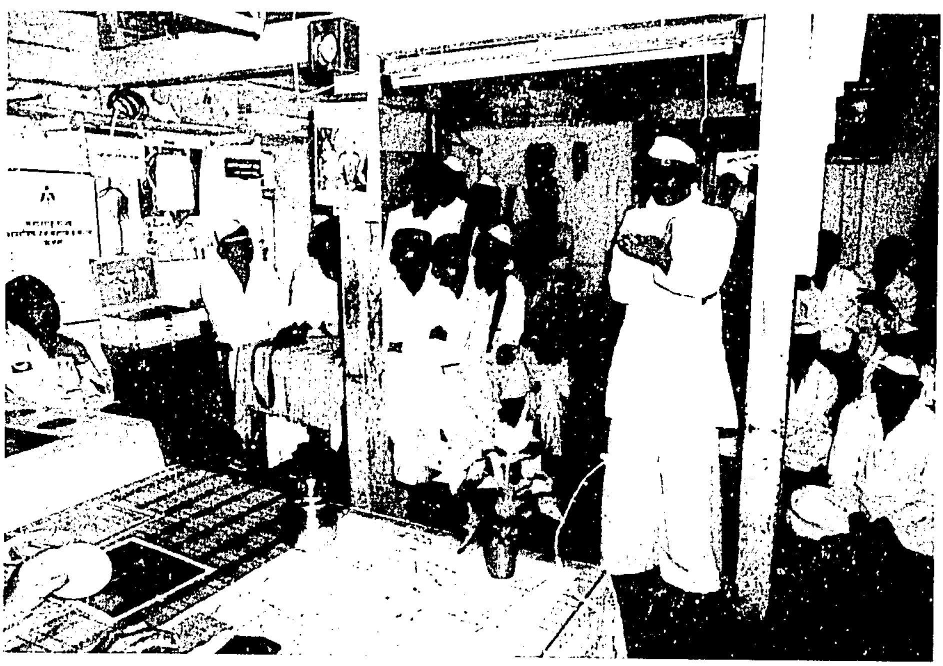
Course coordinators from national programs are important to the success of in-country and regional courses and, in some cases, training is provided for coordinators on how to organize and conduct training activities.

the future this approach will be expanded in Latin America and elsewhere.

TRAINING ON IDENTIFYING FARM-LEVEL PROBLEMS

The objective of providing training on farm-level problems is to enable national program workers to identify, analyze, and describe production problems as farmers perceive them, and to take these problems into account in generating and transferring technology.

As with training on communication, how to conduct farm surveys is taught as an integral part of production and specialized courses. For example, during a 1987 course on integrated control of potato tuber moth in India, a national social scientist conducted a practical session on informal interviews with farmers. Prior to this activity, the course participants attended a lecture and discussed the process. This meeting was then followed by interviews with farmers for half a day. During the following two days, in-depth discussions about the interviews were interspersed among sessions on specific techniques. Experiences with this approach have been positive, and in course evaluations, such as for the course in India, training on this aspect has been judged as important. Since so much information was gained from the farmers on how they perceive and deal with the tuber moth problem, participants felt more time should have been allowed for this exercise. In the future, additional emphasis will be placed on developing national capacity to assume greater responsibility for this in CIP's training events worldwide.



Research should begin and end with the farmer. Exercises and discussions on identifying problems faced by farmers are included in some of the production and specialized courses.

TRAINING ON MANAGING AND ACCESSING INFORMATION

The most up-to-date information on a problem is essential to carrying out good research. Interaction with national programs through CIP's regional research program and a follow-up study of former training program participants pointed out that much potato research is being conducted without the support of adequate information on related research. Furthermore, in many cases, completed research is not published and valuable findings are not shared with neighboring countries who may be facing similar problems. The net result is that limited national financial resources allocated for research are being spent on duplicate research, or on research based on incomplete or outdated information.

To address this situation, CIP, with special funding from IDRC, took steps in 1985 to develop an Information Service Unit that encompassed the services previously offered by the library. Since then, two databases have been developed—one on potato and the other on sweet potato—which already include all reprints in the CIP library and will soon include all publications and documents in the library. CIP and national researchers can also obtain computerized reference lists on potato and sweet potato from the AGRIS, CABI, and DIALOG databases. Searches and selective dissemination of information on specific topics can be made readily available on request; to date, more than 200 users have already received these services.

This project has created a source of information that can make a significant contribution to national abilities to conduct good research. It also facilitates the exchange of information between scientists by supporting the publishing of a journal, an item already mentioned in the section on training on communications skills. The services this project provides have been explained in various specialized training activities and in regional research and training planning conferences. At CIP headquarters, orientation and hands-on experience have been given to nearly all visiting scientists and to many other guests. In the future, a more concerted effort will be made to ensure that all potential users, wherever they may be, are aware of this source of information and how they may make effective use of it.

Indicative of the importance given to information science by the international agricultural research centers was the CGIAR Documentation and Information Services meeting, which was held in 1987 at CIP headquarters in Peru. The objectives of this meeting were to review advances in information technology, explore alternatives for cooperation among the centers, and identify mechanisms for strengthening links with national programs. Represented in this meeting were 15 international centers, the CGIAR Secretariat, national and regional institutions, and major international and private information agencies. Recommendations emerging from this meeting centered around three major points: 1) support the development of national and regional capacities for managing and delivering agricultural information; 2) support major center programs as they move into areas of strategic and basic research; and 3) cooperate more effectively to ensure the fullest utilization of the work of each center and eliminate duplication of work.

HUMAN RESOURCE DEVELOPMENT PROJECT

It is generally accepted that international agricultural research centers do not have

The importance given to dissemination of research information by the international agricultural research centers was demonstrated in a meeting held at CIP-Lima of information specialists at the CGIAR Centers and national and regional groups.

comparative advantages to undertake adaptive research and extension-type activities, these being the domain and responsibility of national agencies. Therefore, through a three-year project funded by the United Nations Development Programme (UNDP) on "Human Resource Development for National-Level Generation and Transfer of Root and Tuber Crop Technology," three CGIAR centers—CIAT, CIP, and IITA—have joined efforts to enhance the movement of appropriate technology to potential users. This project is guided by an advisory committee composed of members from countries that will benefit from the training and includes systematic monitoring and final evaluation by an outside consultant.

Each center will undertake individual training activities on topics related to their mandated crops and will also collaborate in specialized areas critical to developing leadership, strategic planning, problem solving, decision-making, and training and communication skills. These are the major topics felt to be central to the development of human resources and will be included in the following joint training activities: organization and management of vegetative seed production programs, methods of integrated pest management, farm-level diagnostic skills, methodologies for developing and promoting new and traditional food uses for root and tuber crops, development and support of training and communication abilities at the national level, and improved networking and communication among root and tuber crop workers.

List of Abbreviations and Acronyms

a.i.	active ingredient
AID	Agency for International Development
AMV	alfalfa mosaic virus
ANOVA	analysis of variance
APLV	Andean potato latent virus
APMV	Andean potato mottle virus
avg	average
AVRDC	Asian Vegetable Research & Development Center (Taiwan)
BARI	Bangladesh Agricultural Research Institute
BPI	Bureau of Plant Industries (Philippines)
BW	bacterial wilt
CDH	Centre pour le Developpement de l'Horticulture (Senegal)
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
cm	centimeter
CNPH	Centro Nacional de Pesquisa de Hortaliças (Brazil)
CPRA	Centre de Perfectionnement et de Recyclage de Pratiques Agricoles de Saïda (Tunisia)
CPRI	Central Potato Research Institute (India)
CV	coefficient of variation
cv.	cultivar
d	day
DLS	diffused-light stores
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)
ENEA	Comitato Nazionale per la ricerca e per lo sviluppo dell'Energia Nucleare e delle Energie Alternative (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

GCA	general combining ability
h	hour
ha	hectare
IBPGR	International Board for Plant Genetic Resources
ICA	Instituto Colombiano Agropecuario (Colombia)
ICAR	Indian Council for Agricultural Research
IDRC	International Development Research Centre (Canada)
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture (Nigeria)
INIA	Instituto de Investigaciones Agropecuarias (Chile)
INIAP	Instituto Nacional de Investigaciones Agropecuarias (Ecuador)
INIPA	Instituto Nacional de Investigacion y Promoción Agropecuaria (Peru)
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
L	liter
lat.	latitude
LB	late blight
LER	land equivalent ratio
long.	longitude
LSD	least significant difference
LUE	light use efficiency
m	meter
meq	milliequivalent
min	minute
MJ	megajoule
ml	milliliter
mm	millimeter
mo	month
NASH	nucleic acid spot hybridization test
ND	not determined
nm	nanometer
ns	not significant
NS	not studied
OP	open-pollinated
PCARRD	Philippine Council for Agriculture and Resources Research and Development
PLRV	potato leafroll virus
PNAP	Programme National de l'Amelioration de la Pomme de Terre (Rwanda)
ppm	parts per million
PRACIPA	Programa Andino Cooperativo de Investigacion en Papa (Andean region)
PRAPAC	Programme Regional d'Amelioration de la Culture de Pomme de Terre en Afrique Centrale (Central Africa)

PRECODEPA	Programa Regional Cooperativo de Papa (Central America-Caribbean)
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
PVY	potato virus V
PVX	potato virus X
PVY	potato virus Y
RH	relative humidity
RNA	ribonucleic acid
SAPPRAD	Southeast Asian Program for Potato Research and Development
SD	standard deviation
sec	second
SED	standard error of difference
SPFMV	sweet potato feathery mottle virus
t	ton
TPS	true potato seed
UNA	Universidad Nacional Agraria-La Molina (Peru)
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
var.	variety
vol	volume
vs.	versus
wk	week
wt	weight
yr	year

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Research and Consultancy Contracts and Special Projects

Research and consultancy contracts and special projects play a vital role in CIP's efforts to remove constraints on global production and utilization of potato and sweet potato. The contracts motivate research on priority problems and provide funds for carrying out needed work. CIP's flexibility to meet changing needs is greatly increased by the contracts, which have proved to be very effective and low cost. In budgetary terms, one of the major advantages of collaboration with other institutions through contract research is that facilities and personnel needed for a specific research activity are already in place. This represents a savings in terms of CIP's resources and may become an even bigger factor as CIP moves further into biotechnological research with its high-cost implications. Annually, between 35 and 40 contracts with institutions in developing and developed countries are core-funded, with approximately US$500,000 being committed per year. The returns on investments have been enormous, both in terms of research data and in building valuable relationships with the contractees who frequently play an important role in CIP's research planning conferences and other planning and assessment activities.

Thrust I — Collection, Maintenance, and Utilization of Unexploited Genetic Resources

1. Rothamsted Experimental Station, England —Stability/variability of potato in culture and storage. *M. G. K. Jones*

2. Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador — Maintenance of the potato germplasm in vitro collection. *F. Muñoz*

3. Ente Nazionale de Energie Alternative (ENEA), Italy — Development of potato varieties resistant to insects pest by means of conventional innovative breeding technologies. *A. Sonnino*

Thrust II — Production and Distribution of Advanced Breeding Material

4. Cornell University, United States — The utilization of *Solanum tuberosum* spp. *andigena* germplasm in potato improvement and adaptation. *R. L. Plaisted, H. D. Thurston, W. M. Tingey, B. B. Brodie, E. E. Ewing, and D. Ave*

5. North Carolina State University, United States — Breeding and adaptation of cultivated diploid potato species. *W. Collins*

6. I.V.P. Agricultural University, Netherlands — A breeding program to utilize the wild *Solanum* species, apomixis, and cytoplasmic male sterility. *J. G. Th. Hermsen*

7. University of Wisconsin, United States — Potato breeding methods with species, haploids, and 2n gametes. *S. J. Peloquin*

8. Instituto Nacional de Tecnologia Agropecuaria (INTA), Argentina — Program to use greater genetic variability in the potato breeding plan. *A. Mendiburu*

9. ·ricculture Canada — Nutritional and chipping evaluation of selected parental .iones in Peru, the Philippines, and Canada. *T. R. Tarn*

10. University of Tacna, Peru — Evaluation of sweet potato germplasm for tolerance to certain abiotic stresses under arid conditions. *N. Arevalo*

11. Instituto Nacional de Investigación y Promoción Agropecuaria (INIPA), Peru — Evaluation of advanced clones from CIP and the national potato program of Peru.

12. Centro Nacional de Pesquisas de Hortaliças (CNPH/EMBRAPA), Brazil — Evaluation of potato germplasm (*Solanum tuberosum* L.) in relation to resistance to *Alternaria solani*. *F. J. B. Reifschneider*

13. Co. ··o "Mario Neri" (ERSO), Italy — Selection of potato clones with high starc'i content. *A. Ferraresi and L. Concilio*

14. Centro Nacional de Pesquisas de Hortaliças (CNPH/EMBRAPA), Brazil — Selection of TPS progenies adapted to the northeast and central west of Brazil. *J. A. Buso*

Thrust III — Control of Bacterial and Fungal Diseases

15. Centro Nacional de Pesquisas de Hortaliças (CNPH/EMBRAPA), Brazil — Potato germplasm evaluation for resistance to bacterial wilt. *C. A. Lopez*

16. Instituto Colombiano Agropecuario (ICA), Colombia — Evaluating the resistance of potato genetic material to *Pseudomonas solanacearum* and *Phytophthora infestans*. *F. Montes and J. Llanos*

17. Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador — Study and control of potato diseases "lanosa" and rust in Ecuador. *H. Orellana*

18. University of Wisconsin, United States — Fundamental research to develop control measures for bacterial pathogens of the potato. *A. Kelman and L. Sequeira*

19. Universidad Nacional de Huánuco, Peru — Development of disease-resistant potato varieties with adaptation to the ecological zones of the Department of Huánuco. *E. Torres Vera*

20. National Agricultural Laboratories, Kenya — The reaction of selected potato clones to two races of *Pseudomonas solanacearum* in Kenya. *A. O. Michieka*

Thrust IV — Control of Virus and Virus-Like Diseases

21. Instituto Agronomico per l'Oltremare (I.A.O.), Italy — Production of antisera against major potato viruses. *M. Broggio*

22. Swiss Federal Agricultural Research Station, Switzerland — Development of monoclonal antibodies for potato virus identification. *P. Gugerli*

23. North Carolina State University, United States — The accumulation of sweet potato feathery mottle virus, dsRNA, and selected viral proteins in sweet potatoes. *J. Moyer*

24. Universidad Nacional Agraria-La Molina, Peru — Consultative contract on maintenance of monoclonal antibodies for potato viruses. *J. Castillo*

25. Universidad Nacional Agraria-La Molina, Peru — Maintenance of monoclonal antibodies for potato viruses. *J. Castillo*

26. Centro de Investigaciones Agricolas "A. Boerger" (CIAAB), Uruguay — Evaluation of genetic material for resistance to PVX and PLRV under field conditions. *C. Crisci and F. Vilaro*

27. Instytut Ziemniaka (Institute for Potato Research), Poland — Breeding potatoes resistant to the potato leafroll virus, PLRV. *K. M. Swiezynski*

Thrust V — Integrated Pest Management

28. University of the Philippines, Los Baños, Philippines — Integrated control of nematodes and weeds by the use of biological control agents and solarization. *R. Davide*

29. North Carolina State University, United States — Evaluation of potato lines for resistance to the major species and races of root-knot nematodes (*Meloidogyne* spp.). *J. N. Sasser*

30. Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador — Evaluation of clones resistant to potato cyst nematode (*Globodera* spp.) in Ecuador. *R. Eguiguren and J. Revelo*

31. Universidad Nacional Agraria-La Molina, Peru — Consultancy on *Pratylenchus* spp. as important nematode pests of potatoes. *M. Canto*

32. Universidad Nacional Agraria-La Molina, Peru — Consultancy on biological and selective chemical control of insect pests of potato and sweet potato. *J. Sarmiento and Colleagues*

Thrust VI — Warm Climate Potato and Sweet Potato Production

33. Universidad Nacional Agraria-La Molina, Peru — Management of soils, fertilizers, and mineral nutrition of the potato under adverse soil and climatic environments. *S. Villagarcia*

34. Scottish Crop Research Institute, Scotland — Drought tolerance in potatoes. *P. Waister*

Thrust VII — Cool Climate Potato and Sweet Potato Production

35. Instituto Colombiano Agropecuario (ICA), Colombia — Consultancy on potato breeding to obtain frost-tolerant clones adapted to Andean countries. *N. Estrada*

Thrust IX — Seed Technology

36. Victoria Department of Agriculture, Australia — Production of pathogen-tested potato germplasm for Southeast Asian and Pacific countries. *P. T. Jenkins*

37. Instituto di Agronomia, Universita de Napoli, Italy — Selection of TPS parental lines in high seed production. *L. Monti and L. Frusciante*

38. Instituto de Investigaciones Agropecuarias (INIA), Chile — Production of true potato seed in Chile. *A. Cubillos and J. Kalazich*

39. Louisiana State University, United States — The use of *Agrobacterium* plasmid vectors to insert anti-bacterial, anti insect, and frost resistance genes into potato plants. *J. M. Jaynes*

40. Universidad Nacional Agraria-La Molina, Peru — Training and consultancy research in effects of soil management and fertilization on flowering, fruit setting, and seed quality of the potato. *S. Villagarcia*

Thrust X — Potato and Sweet Potato in Food Systems

41. Society for Development of Appropriate Technology (SOTEC), India — Development of village level potato processing and utilization of potato in local foods. *R. W. Nave*

42. Centre for European Agricultural Studies, England — Potato seed programs in developing countries. *N. Young*

43. National Museum of Ethnology, Japan — Andean potato farming system. *N. Yamamoto*

44. University of Arizona, United States — Household gardens. *V. Niñez*

45. University of Georgia, United States — Potatoes in Rwanda. *A. Haugerud*

46. Cornell University, United States — Economics of integrated pest management. *P. Ewell*

47. Lima, Peru — Consumption of Andean food crops. *M. Benavides*

48. Pacific University, Peru — Marketing of processed potato production in Lima. *R. Gomez*

49. ESCAP CGPRT Centre, Indonesia — Demand and marketing of potatoes in Java, Indonesia. *T. Bottema*

50. England — Sweet potato: an untapped food resource potential. *J. Woolfe*

51. International Food Policy Research Institute (IFPRI), United States — White potato/sweet potato development in China. *B. Stone*

Support Department

52. International Potato Center, Peru — Consultancy on management of sweet potato germplasm. *R. del Carpio*

53. Consultancy Contract, Lima, Peru — Possible causes of damage to potato plants in CIP greenhouses. *U. Moreno*

Regional Research and Training

54. International Agricultural Center, Netherlands — Consultancy for regional research and training. *H. P. Beukema*

SPECIAL PROJECTS

1. Louisiana State University, United States — The use of *Agrobacterium* plasmid vectors. *J. Jaynes*

2. Louisiana State University, United States — Conferring resistance to potato viruses and viroid by molecular interference. *J. Jaynes*

3. University of Wisconsin, United States — Chemotheraphy and thermotherapy of in vitro potato and sweet potato plantlets. *S. Slack*

4. Ente Nazionale de Energie Alternative (ENEA), Italy — Use of solar energy for the dehydration of potato food products. *G. Scarano*

5. ENEA, Italy — Anther culture and protoplast fusion for potato improvement. *A. Sonnino*

6. Weizmann Institute of Science, Israel — Characterization of organelle genomes in the potato germplasm as an aid in breeding potatoes for developing countries. *E. Galun*

7. Weizmann Institute of Science, Israel — Gene and organelle transfer by electroporation—a prospective tool for potato improvement. *E. Galun and D. Aviv*

8. Weizmann Institute of Science, Israel — Utilization of plant protoplast biotechnologies for transfer of organelles. *E. Galun and D. Aviv*

9. University of Massachusetts, United States — Improvement of plant crops by means of a biotechnology suitable for developing countries. *D. Mulcahy*

10. North Carolina State University, United States — Development of serological and nucleic acid hybridization assays for recently described sweet potato viruses. *W. Moyer*

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RESEARCH THRUSTS
(Leaders and Co-Leaders)

I. Collection, Maintenance, and Utilization of Unexploited Genetic Resources
(P. Schmiediche—Z. Huaman)

II. Production and Distribution of Advanced Breeding Material
(H. Mendoza—M. Iwanaga)

III. Control of Bacterial and Fungal Diseases
(E. French—C. Martin)

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
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VIII. Postharvest Technology
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IX. Seed Technology
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Lucas Reaño, C.P.C., Administrative Supervisor
German Rossani, M.D., Medical Officer
Jacques Vandernotte, Chief Pilot

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Edgardo de los Rios, C.P.A., Accountant
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Staff as of December 31, 1987 are listed by Department or Region.
* Left during the year
† On sabbatical from other institution.
‡ 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 Resources
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, McDonalds Corporation
World Bank INIPA

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Moreno Patiño

REPORT OF INDEPENDENT ACCOUNTANTS

March 18, 1988

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, 1987 and 1986, 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 in the circumstances.

As described in Note 2-c), and in accordance with guidelines established by the Consultative Group for International Agricultural Research for the preparation of financial statements by International Agricultural Research Centers, firm orders for purchases of fixed assets and services are recorded in the year of their commitment rather than at the time when the actual liability arises.

In our opinion, except for effect of the matter described in the preceding paragraph, the financial statements examined by us present fairly the financial position of International Potato Center - CIP as of December 31, 1987 and 1986 and its revenues, expenditures and changes in its unexpended fund balances and changes in its financial position for the years then ended, in conformity with generally accepted accounting principles consistently applied.

Moreno Patiño

Countersigned by

---------------------------------(partner)
Francisco J. Moreno
Peruvian Public Accountant
Registration No. 155

INTERNATIONAL POTATO CENTER — CIP

BALANCE SHEET (Notes 1 and 2)
AS OF DECEMBER 31, 1987 AND 1986
(Expressed in U.S. dollars)

	1987	1986
ASSETS		
CURRENT ASSETS		
Cash and short-term deposits	2,716,847	3,215,983
Accounts receivable		
Donors	3,099,626	1,609,037
Advances to personnel	18,075	20,592
Loans to executives and employees – current portion (Note 3)	115,366	119,064
Other (Note 4)	352,219	229,280
Inventories of laboratory and other supplies	624,473	517,495
Prepaid expenses and other current assets	113,502	81,075
Total current assets	7,040,108	5,792,526
RESTRICTED FUNDS (Note 3)	275,000	300,000
LOANS TO EXECUTIVES AND EMPLOYEES – NON-CURRENT PORTION (Note 3)	176,545	357,034
FIXED ASSETS (Note 5)	11,355,942	10,487,260
	18,847,595	16,936,820

The accompanying notes are an integral part of the financial statements.

	1987	1986
LIABILITIES AND FUND BALANCES		
CURRENT LIABILITIES		
Bank overdrafts and current portion of long-term debt (Notes 3 and 6)	283,353	483,071
Accounts payable and other liabilities	1,040,334	1,871,373
Grants received in advance	2,182,245	–
Other payables and accrued expenses	229,026	197,253
Total current liabilities	3,734,958	2,551,697
LONG-TERM DEBT (Note 3)	167,509	283,760
PROVISION FOR SEVERANCE INDEMNITIES, net of advances of US$61,273 (US$78,372 in 1986)	425,029	457,411
FUND BALANCES		
Funds invested in fixed assets (Note 5)	11,355,942	10,487,260
Unexpended funds –		
Operating funds – Unrestricted	6,195	34,928
– Restricted	88,888	172,643
Capital	188,000	–
Working funds	1,317,000	1,300,000
Special projects	1,510,969	1,637,393
Cooperative activities	53,105	11,728
	3,164,157	3,156,692
GRANT PLEDGED (Note 7)		
	18,847,595	16,936,820

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, 1987 AND 1986
(Expressed in U.S. dollars)

	1987	1986
REVENUE		
Operating grants:		
Unrestricted	9,211,096	8,881,253
Restricted	2,194,525	2,631,441
Other restricted core grants	723,860	582,945
	12,129,481	12,095,639
Special project grants	1,840,181	2,530,864
Grants for fixed asset additions	806,547	837,054
Grants for cooperative activities	444,755	251,506
Working fund grants	17,000	350,000
Other income, net	665,991	433,729
	15,903,955	16,498,792
EXPENDITURES		
Operating costs:		
Potato research program	3,795,862	3,455,313
Research services	1,602,004	1,489,915
Regional research program and training	2,958,629	2,817,074
Conferences and seminars	103,593	34,500
Library and information services	642,913	702,299
Administration cost	1,434,283	1,280,125
Other operating costs	1,563,061	2,060,486
	12,100,345	11,839,712
Other restricted core expenditures	807,615	615,706
Special projects	1,963,173	1,636,624
Cooperative activities	403,378	293,466
Grants returned	3,432	19,275
	15,277,943	14,404,783
Additions to fixed assets	618,547	837,054
	15,896,490	15,241,837
Excess of revenue over expenditures	7,465	1,256,955
Unexpended fund balance, beginning of year	3,156,692	1,756,953
Unexpended SAPPRAD balances assumed by CIP	-	142,784
UNEXPENDED FUND BALANCE, END OF YEAR	3,164,157	3,156,692

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, 1987 AND 1986

(Expressed in U.S. dollars)

	1987	1986
SOURCE OF FUNDS		
Excess of revenue over expenditures	7,465	1,256,955
Decrease in other assets	–	21,340
Increase in accounts payable and other liabilities	–	1,360,796
Increase in grants received in advance	2,182,245	–
Decrease in restricted funds	25,000	100,000
Decrease in loans to executives and employees – non-current portion	180,489	54,758
Provision for severance indemnities	42,651	113,810
Assumption of SAPPRAD fund balance	–	142,784
Increase in funds invested in fixed assets	868,682	1,215,883
	3,306,532	4,266,326
APPLICATION OF FUNDS		
Purchase and replacement of fixed assets		
– Core acquisitions	618,547	837,054
– Special projects	207,098	98,733
– Net cost of replacement	43,037	280,096
Increase in accounts receivable	1,607,313	205,512
Increase in inventories	106,978	47,882
Increase in prepaid expenses and other current assets	32,427	–
Decrease in accounts payable and other liabilities	998,984	–
Decrease in grants received in advance	–	643,992
Decrease in long-term debt	116,251	119,816
Payment and advances of severance indemnities	75,033	41,911
	3,805,668	2,274,996
Increase (decrease) in cash and short-term deposits	(499,136)	1,991,330
Cash and short-term deposits, beginning of year	3,215,983	1,224,653
CASH AND SHORT-TERM DEPOSITS, END OF YEAR	2,716,847	3,215,983

The accompanying notes are an integral part of the financial statements.

INTERNATIONAL POTATO CENTER — CIP

NOTES TO FINANCIAL STATEMENTS
AS OF DECEMBER 31, 1987 AND 1986
(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, the Near and Middle East, Asia and Africa. The CIP's principal objective is to contribute to the development of the 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 on 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 projects grants are accounted for in the period stipulated by the donor. Other income, net, is recorded when earned and is comprised primarily of interest on investments, proceeds from sales of fixed assets and supplies, translation gains and losses, and of administrative costs of special projects.

c. Expenditures —
Firm orders for purchases of fixed assets and services are recorded in the year of their commitment. At December 31, 1987, the amount recorded under this practice totaled US$364,100 (US$1,209,500 in 1986).

Expenditures made by international programs are recorded on the basis of advices received. Expenses related to special projects are applied when incurred against the respective income.

d. Investments —
Short-term investments are principally comprised of certificates of deposit bearing interest at current bank rates and are valued at cost.

e. Inventories of laboratory and other supplies —
Inventories of laboratory, supplies and other materials are valued at estimated market value, which approximates cost.

f. Fixed assets —
Fixed assets are stated at cost. Additions to fixed assets are recorded as grant expenditures and cost of replacements are reported as operating expenses in the statement of revenue, expenditures and changes in fund balances and added to the related equity account. Upon the sale or retirement of fixed assets, their cost is removed from the fixed asset and related equity accounts. Fixed assets are not depreciated.

Maintenance and repairs are recorded as operating costs in the year incurred.

g. Vacations —
Employee vacation expenses are charged to operating expenses when they are taken.

h. Provision for severance indemnities —
Peruvian employees' severance indemnities are accounted for on an accrual basis and are calculated in accordance with current legal dispositions. The amount accrued represents the amount that would have to be paid to the employees if they were to terminate as of the date of the financial statements.

3. Loans to executives and employees and long-term debt

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 the CIP's own funds. At December 31, 1987, the balance of the loans obtained from Citibank N.A. amounts to US$265,753 (US$380,611 in 1986), which bears interest at the New York prime rate plus 1.5% and is repayable in monthly installments until June 1990.

Loan balances with executives and employees at December 31, are as follows (in U.S. dollars):

	1987	1986
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	265,753	380,611
Loans funded by CIP, repayable over a three- to five-year period, non-interest bearing, secured by employees' homes	26,158	95,487
	291,911	476,098
Less current portion	(115,366)	(119,064)
	176,545	357,034

In addition, at December 31, amounts outstanding under the term loan from Citibank N.A. are as follows (in U.S. dollars):

	1987	1986
Current portion (Note 6)	98,244	96,851
Non-curren portion (maturing 1988-1990)	167,509	283,760
	265,753	380,611

These amounts are guaranteed by a deposit of US$275,000 (US$300,000 in 1986) in the aforementioned financial institution, which earns interest at 6.3% per annum (5% in 1986).

4. Accounts receivable — Other

This balance is comprised of the following at December 31 (in U.S. dollars):

	1987	1986
Advances to organizations for research work	248,679	102,199
Travel advances	46,809	40,564
Advances to contractors and other	8,014	19,035
Other	48,717	67,482
	352,219	229,280

5. Fixed assets

Fixed assets at December 31, comprise the following (in U.S. dollars):

	1987	1986
Buildings and constructions	3,001,705	2,902,754
Research equipment	1,567,297	1,338,529
Vehicles and aircraft	2,313,207	2,219,541
Furniture, fixtures and office equipment	1,220,813	1,095,839
Operating farm equipment	456,782	402,481
Installations	1,373,237	1,302,915
Site development	776,706	667,215
Communications equipment and other	561,250	531,025
Construction in progress	84,945	26,961
	11,355,942	10,487,260

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 this memorandum account. The balance of this memorandum account at December 31, 1987, is US$699,891 (US$860,154 in 1986).

6. Bank overdrafts and current portion of long-term debt

At December 31, this balance is comprised of the following (in U.S. dollars):

	1987	1986
Bank overdrafts	185,109	386,220
Current portion of long-term debt (Note 3)	98,244	96,851
	283,353	483,071

The CIP has various credit lines and loan arrangements with Citibank N.A. totalling US$680,000 (US$459,000 in 1986), which bear interest at the New York prime rate plus 1.5%. As of December 31, 1987, unused amounts under these credit facilities totaled US$400,000 (US$65,657 in 1986).

7. Grants pledged

During 1987 the following donations were pledged to the CIP for special projects in 1988 through 1991 (in U.S. dollars):

	1988	1989	1990	1991
Australian Development Assistance Agency	80,985	-	-	-
International Development Research Centre - Canada	225,848	132,817	-	-
Swiss Development Cooperation and Humanitarian Aid	27,200	-	-	-
United States Agency for International Development	282,000	284,600	380,000	22,500
Netherlands Government	144,065	-	-	-
Pepsico Food International	25,000	25,000	-	-
McDonald's Corporation	25,000	25,000	-	-
Rockefeller Foundation	31,000	-	-	-
Union Carbide Agricultural Products	12,000	-	-	-
Belgian Government	476,100	476,100	413,300	182,850
	1,329,198	943,517	793,300	205,350

Such 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 that are not covered adequately by other institutions, but which are of global importance. 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 approximately 40 donor organizations who 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