INTERNATIONAL POTATO CENTER (CIP)

Commemorative stamp issued by the Government of Peru

ANNUAL REPORT

CIP 1982

THE COVER–

The Central Post Office of Peru put into circulation on 27 December 1982, a postage stamp commemorating CIP's Tenth Anniversary. The following article is taken from the post office brochure that describes the stamp and its history.

The Potato

The Postmaster General of the Ministry of Transportation and Communication of Peru has issued a new stamp to commemorate the Tenth Anniversary of the International Potato Center.

The Center, with its main headquarters in our capital city of Lima, applies itself to research and development of the potato tuber from the perspective of extending its cultivation, given its high nutritive value in terms of protein.

Currently, the Center has Regional Representatives in South America, Tropical, North, and West Africa, Near and Middle East, South and Southeast Asia. Funding is provided by countries, foundations, development agencies, the European Economic Community, the Interamerican Development Bank, the United Nations Development Program, and corporations to develop technologies for cultivation of the potato in the less-developed areas of the world.

In this way, the potato, originally from Peru and constituting a Peruvian gift to the world, could become the most important food resource in developing countries.

Lima, December 27, 1982

International Potato Center
Annual Report 1982

INTERNATIONAL POTATO CENTER
P.O. Box 5969, Lima, Peru

International Potato Center (CIP)

CIP is a nonprofit, autonomous scientific institution established by agreement with the Government of Peru for developing and disseminating knowledge for greater use of the potato as a basic food. International funding sources for technical assistance in agriculture finance the Center.

As one of the worldwide network of centers funded by the Consultative Group on International Agricultural Research (CGIAR), CIP has the following mandate:

"To develop, adapt, and expand the research necessary for the technology to solve priority problems that limit potato production in developing countries. This includes adapting the collective knowledge that has contributed to the stepwise increase in potato production in developed countries.

"The world potato collection, which has been accumulated by CIP, provides ample opportunity for research breakthroughs through the exploitation of this large quantity of previously unavailable genetic resources."

The 1982 **Annual Report** is published in English and Spanish by the International Potato Center, P.O. Box 5969, Lima, Peru. Printed for worldwide distribution, the report covers the period of 1 November 1981 to 31 October 1982.

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Contents

Director General's Message

This past year at CIP has been full of activities. Even though there was no growth in staff or real funding, the quality and the quantity of research and training both continued to increase; important trends for any institution that remains vital and critical of its programs and progress.

The Technical Advisory Committee (TAC) for the Consultative Group on International Agricultural Research (CGIAR) conducted the Second Quinquennial Review of CIP's program. The World Bank Secretariat for the CGIAR used CIP as the "guinea pig" to conduct the first Management Review of any CGIAR center. This was the first step in implementing reviews of all centers on a regular basis, as recommended in the Second Quinquennial Review report for the CGIAR system. We are pleased with the results and recommendations of these two reviews.

In the final chapter of the Second Quinquennial Review of CIP there is a section on "Lessons from CIP" that deserves mentioning. The Quinquennial panel felt that these lessons, which resulted from strategies at CIP, could have a possible system-wide application. They include the following points:

- A modest approach leading to relationships between CIP and national programs, which will increasingly prove an invaluable asset for the diffusion of technologies.
- An early development of a relatively large research and transfer network with national programs, and the extensive use of contract research.
- CIP's close collaboration with national programs and use of their site-specific knowledge.
- Results that confirm the effectiveness of the narrowly focused model for the generation of technologies of wide adaptability.
- The establishment of a zero growth policy for numbers of international staff.

We would like to acknowledge the continuing support of CIP's loyal donors, especially during the present economic stress on the world and the CGIAR system. We shall continue to maintain what we believe are the essential elements of our success: 1) modest, essential facilities, 2) high caliber international and host country staff, 3) global network for the production and transfer of technology, 4) pooling of research capabilities in Third World countries through research networks, and 5) strong association with scientists from the Third World in the process of CIP program evaluation, implementation, training, and transfer of technology.

We welcome several new members to the Board of Trustees: Dr. Flavio Couto from Brazil, Dr. Noboru Takase from Japan, Dr. Magnhild Umaerus from Sweden, and Dr. Klaus Raven and Dr. Raúl Figueroa from Peru. Dr. Joab L. Thomas terminated his second full term of office in April 1983. During his two terms (six years), he served CIP well and contributed annually over a month of his time to CIP activities either as secretary or chairman of the Board. Dr. Thomas will be replaced as chairman by Dr. Gelia Castillo, the first woman to hold this position in any of the CGIAR centers. She has been on the Board for the past five years and has attended six annual internal reviews, participating in a critical and constructive manner in evaluating CIP's programs. In 1982 she received an honorary doctorate degree from the University of Wageningen in the Netherlands in recognition of her outstanding international services as a sociologist. Dr. Castillo has been an active and constructive participant in Third World development programs for many years, and CIP is most fortunate to have her as chairwoman of its Board of Trustees.

During 1982 Dr. José Valle Riestra, originally from Peru, arrived at CIP to assume the position of Deputy Director General, which was left vacant by Dr. Roger Rowe who had joined another CGIAR center. Dr. Valle Riestra was a member of CIP's first Board of Trustees during the time that he was the director of research at the Universidad Nacional Agraria in La Molina. He has since held senior positions with a donor agency and another CGIAR center, both positions requiring considerable contact with Third World countries. Thus he comes to CIP with an international background in Third World country needs, CGIAR donor funding, and CIP's research activities. We feel fortunate that Dr. Valle Riestra has returned to CIP and to his home country, Peru, the host to CIP's headquarters facilities.

CIP staff have reacted very positively to the two external reviews held early in 1983 and to the recent reorganization of the Thrusts, which have been in existence since the research program was established. Such changes in program and staff indicate the vitality of the institution to consider and make changes for improving what is already an excellent program.

Richard L. Sawyer
Director General
June 1983

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** Left during the year.
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World Bank[1]

[1]Central core operating funds.
[2]Special project funds.

Survey of Research

This 11th Annual Report covers research during 1982. Research was organized within nine multidisciplinary Thrusts, each covering a major area of importance established by recommendations arising from CIP Planning Conferences. Within each Thrust, projects have been developed that change according to annual progress evaluations and analyses of priority problem areas. As research progresses and results are produced, technologies emerge that require development and evaluation.

In its early years CIP established a global network of scientists to evaluate the emerging technologies in various sociological and ecological environments of the world, and to adapt and transfer the knowledge to national research programs. The technology transfer program has been organized into seven regions, each staffed by a senior CIP scientist who develops collaborative projects with national scientists. The designations of *Thrusts* and *Regions* appear in other sections of the Annual Report.

CIP maintains the world potato collection of primitive cultivars and wild tuber-bearing species at its highland station in Huancayo, Peru. The size of the collection has been further reduced by eliminating genetic duplicates; it now stands at 5000 accessions of primitive cultivars and 1291 accessions of wild tuber-bearing species. CIP alone has contributed substantially to the development and use of this important genetic resource, but recognition is also given to other institutions in both developed and developing countries that have collaborated with CIP in this important endeavor. In 1982 there were approximately 120 research projects in progress between CIP headquarters, regional research programs, and other institutions worldwide.

Research contracted to other institutions is a strategy employed by CIP to augment its research base. Thirty-five contracts were financed from CIP core funds: ten were active in Peru; six in the United States; three each in Colombia and the Netherlands; two each in Chile, Sri Lanka and the United Kingdom; and one each in Argentina, Australia, Canada, Ecuador, Germany, Kenya, and Switzerland. In February CIP co-sponsored with the Potato Association of America and the European Association for Potato Research a congress entitled "Research for the Potato in the Year 2000," which took place in Lima and was attended by 226 scientists from 47 countries. After the congress, 43 visiting scientists were invited to assist in five CIP Planning Conferences on: Viruses, Viroids and Mycoplasmas; Late Blight Research for the 80s and 90s; Integrated Control of Insect Pests; True Potato Seed Program and the Future; Potatoes in the Hot, Humid Tropics. The recommendations from these conferences were included in the research program.

During the year, work continued on incorporating resistances to late blight and bacterial wilt into advanced clones. As a result, 14 countries have this material in advanced selection trials, and 16 countries are using the clones in variety trials. Nine countries are growing locally named varieties selected from CIP-introduced material, and another eight countries have released CIP introductions for general cultivation without naming. Two regional multiplication and distribution centers, managed by regional scientists in Kenya and the Philippines, facilitate the transfer of this improved material to national potato programs.

Viruses and virus-like organisms (viroids) are the most important factor contributing to degeneration of potato seed tubers. Our major activity in the control of virus diseases is the identification of high levels of resistance or tolerance and their incorporation into improved genetic material. Resistance to potato leafroll virus (PLRV) has been identified in the wild species *Solanum acaule*. A number of countries where PLRV and potato virus Y (PVY) are important are collaborating to evaluate improved clones. Turkey, Argentina, and Brazil conducted field tests on the new hybrid combinations and a high percentage of clones were selected. Further improvements of the cDNA detection test for the potato spindle tuber viroid (PSTV) have continued in collaboration with the United States Department of Agriculture laboratory in Maryland. As soon as the necessary laboratory facilities are installed at CIP, this will be used as a routine test.

Biological control of nematodes and insects is another major research activity that has met with considerable success. Results worldwide suggest that the fungal agent *Paecilomyces lilacinus*, first identified at CIP for control of the root-knot nematode on potatoes, is now controlling the pest on several other important vegetable and commodity crops. This work is coordinated through the International Meloidogyne Project of North Carolina State University (U.S.).

The potato tuber moth (PTM) is another important pest that attacks the potato in fields and stores. Biological control measures have proven very effective in stores, possibly due to their closed-in environment. A commercial formulation of the bacteria *Bacillus thuringiensis* sprayed in the stores, and aromatic plants such as *Lantana* sp. used to cover potato piles, have been effective in controlling PTM. In field trials, dry funnel traps with synthetic sex pheromones were used to capture large numbers of male moths before mating, thus significantly reducing fertile female moth populations. As a result, crop damage was decreased by 50 percent.

Production of potatoes from botanical or true potato seed (TPS), for both seed and consumption, is a major research priority. Through the Regional Research Program, this technology has been tested by agriculturalists in countries such as India, South Korea, and Sri Lanka and is now being evaluated in farmers' fields. In many other countries, it is presently being tested at research stations.

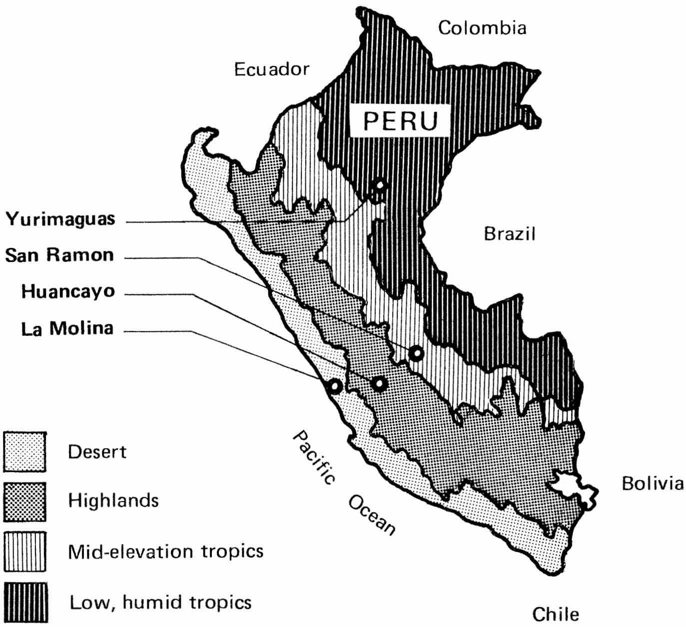
A more recent development for the use of TPS is the production of seedling tubers. At CIP, 700 to 1000 small tubers were produced per m^2 by close planting of seedlings. Although smaller tubers were produced than those by conventional methods, the tubers were similar in size to those traditionally planted by some farmers in many countries. Plans are now in progress to organize the first large-scale testing of this technology in cooperation with farmers.

The technology to control sprouting in storage by exposing tubers to diffused light has continued to spread in those countries where it was first introduced. Social scientists and physiologists at CIP have been working jointly to monitor the acceptance of this storage technology—data indicate that the number of stores built each year by farmers has increased rapidly. For example, the estimate for 1982 was that a minimum of 800 stores had been built in only five countries. The next big challenge is to develop relatively simple techniques for storing consumer potatoes in hot climates.

Social scientists at CIP link current biological projects to the actual needs relating to social and economic conditions prevailing in developing countries. In addition, they are actively involved in the development of TPS technology. Other studies conducted in 1982 focused on world trends in potato production, consumption, and demand, and on nutrition. The information accumulated by these studies is being used by CIP to define research priorities and to reorientate related projects. Case studies on potato consumption habits have produced details of consumer preferences not previously recognized. Contrary to generally accepted ideas on tuber size preference, the small tuber is preferred in several Asian countries because it complements traditional dishes, such as curry with its many side dishes. This finding casts a new light on the impact that TPS technology could have on a particular production system; i.e., a system can be designed to develop a preponderance of small tubers.

In 1983 CIP's research program will continue to focus on already established projects. Senior scientists from headquarters will be spending extended periods of time in the regions, collaborating with national scientists in order to assist in technology evaluation and transfer through the regional research network.

Research Sites



The potato originated on the high plains (*altiplano*) in what are now parts of Peru and Bolivia. This center of diversity is not only for potatoes but also for its major pests and diseases.

In Peru work is conducted at four main experimental sites where the environments are similar to those of most developing countries: **La Molina**, desert; **Huancayo**, highlands; **San Ramon**, mid-elevation tropics; and **Yurimaguas**, low, humid tropics. CIP research at these sites tests and identifies clones with resistance to a wide spectrum of biotic and abiotic pressures. These natural test environments are augmented by extensive screenhouse and growth chamber facilities.

CIP research sites and potato-growing seasons, with meteorological data for 1981-1982.

Site	Latitude Altitude	Growing season (mo)	Temperature Air max (°C)	Air min (°C)	Rainfall (total mm)
La Molina	12°05'S 240 m	Jan - Mar	27.0	18.9	2
		May - Nov	21.2	15.6	20
Huancayo	12°07'S 3280 m	Oct 81 - May 82	19.3	5.4	536
San Ramon	11°08'S 800 m	Nov 81 - Mar 82	29.6	19.2	1032
		May - Aug	29.4	17.8	433
Yurimaguas	5°41'S 180 m	May - Aug	31.3	19.7	442

Research Organization

Research at CIP is coordinated by six departments that serve as administrative units for grouping scientific personnel according to their particular field of research as well as for budget management. The departments are Taxonomy, Breeding and Genetics, Physiology, Pathology, Entomology and Nematology, and Social Science. The Training and Communications Department provides essential support services to these departments and to the technology transfer program of Regional Research and Training.

Thrust is a term used by CIP to denote a major research area in which all departments participate to create a multidisciplinary team of scientists. Individual projects are formulated to tackle the main issues within each Thrust. In addition, each Thrust has a coordinator who is responsible for integrating these various project activities. In 1982, research focused on nine Thrusts, reported in detail in the following sections.

Thrust I

COLLECTION AND CLASSIFICATION OF TUBER-BEARING SOLANUMS

COLLECTION AND CLASSIFICATION OF TUBER-BEARING SOLANUMS

During 1982, collection expeditions for wild tuber-bearing *Solanum* species were made to Brazil, Chile, and Peru. Seventy-two living accessions were added to the CIP wild species collection, totaling 1269 accessions. Descriptions of three new species were recently published, thus bringing the total to 13 new species described and published since the collection of wild species was initiated by CIP in 1977. The CIP germplasm collection now contains 91 wild tuber-bearing *Solanum* species, including 19 rediscovered species that were no longer available in the living state. In biosystematic studies of 19 selected wild diploid species, approximately 300 crosses were made to establish the degree of evolutionary relationships among the species involved. These data are being used to interpret the hybrid nature of certain accessions found in the field. The practical purpose of the crossing studies is ultimately to use the wild species gene pool to improve the cultivated species.

EXPLORATION AND CLASSIFICATION

The exploration for, and classification of, the wild species *Solanum* collection continued during 1982. Two trips were made outside of Peru: one to Brazil to search for and collect the near-extinct species *S. calvescens*; and the other to northern Chile near the Peruvian border, an area which is relatively unexplored for collecting wild species. Additional short trips were also made to several localities within Peru to gain additional information on the geographical distribution of some of the little-known wild species.

In Brazil, Caldas, in the state of Minas Gerais, was specifically explored as the type locality of the very rare species *S. calvescens*, last collected more than 100 years ago. A few tubers were re-collected and deposited with the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) in Brazil and the CIP germplasm bank in Peru. Pico de Bandeira, in the state of Rio de Janeiro, and the National Park of Itatiaia, in the state of Minas Gerais, were also explored, since these are previously unexplored zones for wild species. Due to unexpected climatic conditions that restricted travel, no material was found.

In northeastern Chile, the regions Ticnamar and Putre, located close to the Bolivian and Peruvian borders, were explored for *S. lycopersicoides* (Fig. 1). This species was subsequently found for the first time in Chile and added to CIP's germplasm collection.

During several short trips to localities in the Department of Lima, Peru, the following wild potato species were collected as new accessions: *S. bukasovii, S. cantense, S. medians, S. multiinterruptum*, and *S. hypacrarthrum* (Fig. 2). At a northern location near Marcapomacocha (4300 m), also in the Department of Lima, a wild species, *S. chomatophilum*, was found for the first time in this area. Accessions

Figure I-1. *Solanum lycopersicoides* Dun. in its habitat.

of *S. ambosinum* were collected near Carpish and Panao in the Department of Huanuco. A new wild species having a ploidy of 2n=72 chromosomes was discovered in the remote area of Chorro Blanco, which is located in the northeast section of the Department of Cajamarca.

In summary, 72 living accessions were collected during 1982. A total of 1269 accessions of wild *Solanum* species have been collected to date, which include 82 South American species, and 9 species mainly from Mexico. The majority of the living accessions collected so far are of Peruvian origin (Table I-1).

Table I-1. Number of wild species accessions collected and classified by CIP as of December 1982.

	Number of accessions	
Country	Collected	Classified
Bolivia	128	101
Brazil	3	2
Chile	15	14
Colombia	11	4
Ecuador	45	24
Mexico	69	21
Peru	988	496
Venezuela	10	5
Total	1269	667

Figure I-2. *Solanum hypacrarthrum* Bitter, from the Peruvian central Andes, Cuesta de Puruchuco (3400 m), Department of Lima. It is still living in its original habitat 150 years after it was first discovered.

BIOSYSTEMATIC STUDIES

Species mainly of the Tuberosa, Conicibaccata, and Circaefolia series from the CIP collection were selected for biosystematic studies and for use in breeding. Preliminary analyses of F_1 populations are being conducted to study the degree of evolutionary relationships among some species. The data obtained from these analyses will help to interpret the presence of hybrids found in natural field populations, particularly in localities where two or more species overlap.

An analysis of F_1 progenies from reciprocal crosses of *S. coelestispetalum* with *S. ambosinum*—both with 2n=24 chromosomes and considered previously to be synonymous species in the series Tuberosa—confirmed that they were two different species and should be maintained as such.

In the difficult crosses among the wild species, the embryo culture method has been used to produce F_1 hybrids that normally could not be generated from seeds with aborted endosperm. For example, two taxonomically distinct species such as *S. bukasovii* (2n=24, series Tuberosa, highly resistant to frost), from the high Peruvian Andes, and *S. capsicibaccatum* (2n=24, series Circaefolia, resistant to nematode *Globodera pallida*), from the humid tropics of Bolivia, were crossed so that their genes could be used in breeding programs. There was, however, unilateral incompatibility when the female parent was *S. capsicibaccatum*. But it was possible to obtain fruits with a variable number of seeds, usually with aborted endosperm, when *S. capsicibaccatum* was used as the male parent in crosses with female *S. bukasovii*. Through the embryo culture method, F_1 hybrids with the potential of combined frost and cyst nematode resistance have been grown from excised embryos.

Research using this method continues to be of great importance. Through its use, the possibility can be expanded of incorporating selected wild species into potato breeding programs—species that were previously difficult to improve by using normal methods.

Thrust II

MAINTENANCE, UTILIZATION, AND DISTRIBUTION OF TUBER-BEARING SOLANUMS

MAINTENANCE, UTILIZATION, AND DISTRIBUTION OF TUBER-BEARING SOLANUMS

The world potato germplasm collection maintained at CIP was further reduced to about 5000 clones. A total of 105 cultivars have now been placed under long-term storage conditions in vitro.

A new meiotic mutant was extracted from haploids of the Mexican variety Atzimba, thus making it possible to transfer a virtually intact genotype to create a hybrid without recombination or assortment of chromosomes. A total of 250,000 seedlings were evaluated in various breeding projects. Three heat-tolerant and early maturing advanced clones are now available for export to national programs. In progeny tests of 50 advanced clones with high levels of both late blight and frost resistance, 4 clones exhibited high general combining ability for yield and will be used as parents. Among 390 haploids extracted from late blight-resistant tetraploid parents, some had higher levels of general resistance than the parental material. These highly resistant haploids will be intercrossed to create a new population.

Significant progress was made during 1982 in breeding for improved levels of multiple resistance to cyst-nematode pathotypes. From an initial group of 284 clones developed with resistance to *Pseudomonas* wilt, 11 clones had yields greater than 1 kg/plant. This material will be distributed internationally. Research continues on the systematic use of wild species in breeding for bacterial wilt resistance.

In virus resistance breeding, emphasis was placed on resistance to potato leafroll virus (PLRV) and potato virus Y (PVY). Six clones with outstanding yield, horticultural characters, and combined PLRV and PVY resistance were recommended for international trials. A new source of resistance to PLRV in the wild species *Solanum acaule* is being transferred to the cultivated gene pool. A computer simulation model has been developed to predict the behavior of populations undergoing selection. The identification of parental lines with high general combining ability for the production of true potato seed (TPS) has continued. Several clones were identified that produce uniform, high-yielding TPS progenies.

ANDEAN COLLECTION

The collection of Andean cultivars maintained in the field at CIP has been further reduced to about 5000 clones after the identification of 1010 duplicate accessions, which are now preserved as true seed. A program was initiated to preserve the remaining clones in vitro to avoid losses due to natural disasters or disease. A total of 105 cultivars have now been placed under long-term storage in vitro.

BREEDING METHODS AND UTILIZATION

A new meiotic mutant that inhibits normal synapsis and crossing-over was discovered in haploids extracted from the Mexican variety Atzimba (Fig. II-1). When the mutant, a

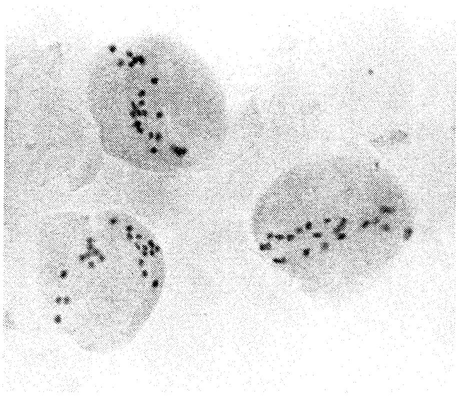


Figure II-1. Metaphase I of microsporocytes in a *ps4* plant showing clear abnormalities due to poor synapsis, such as elongated and curved spindle and high frequency of univalents.

single recessive gene (*sy4*), was combined with the parallel spindle mutant *ps*, it was possible to transfer the virtually intact genotype of the parent without recombination or assortment of chromosomes. When these mechanisms become available in both pistillate and staminate parents, it will be genetically equivalent to, and more versatile than, protoplast fusion.

During 1982 a total of 250,000 seedlings were evaluated in the various breeding projects. In the population adapted to hot climates, several parents were selected with high general combining ability (GCA) for tuber yield, earliness, and heat tolerance. Three heat-tolerant and early maturing clones (LT-5, LT-6, and LT-7) were identified and will be distributed to national programs in 1983 (Fig. II-2). LT-7 is also an outstanding progenitor transmitting high yield and tuber uniformity to its progenies.

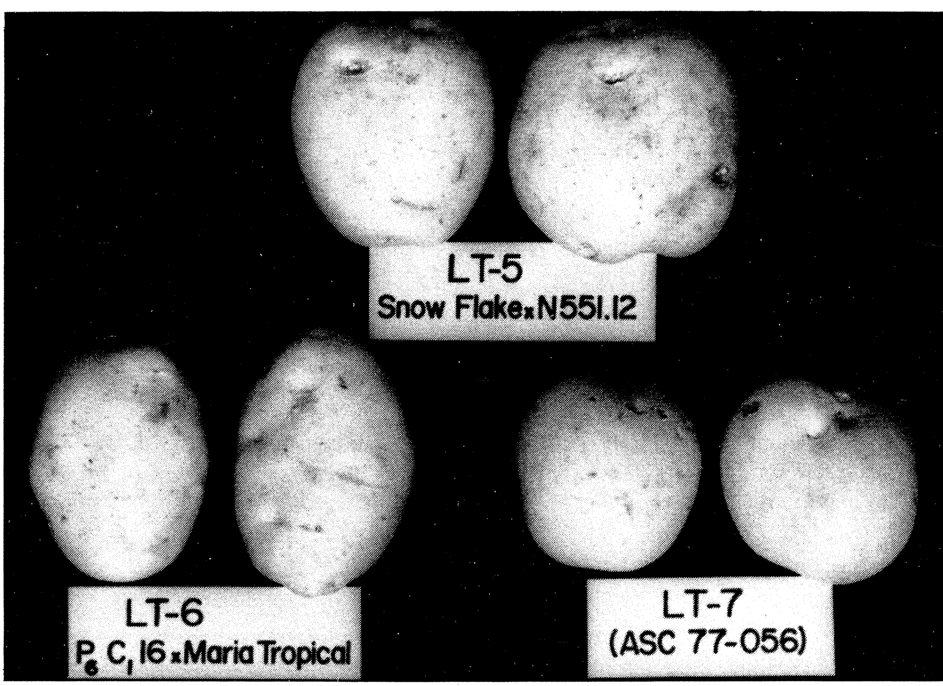


Figure II-2. Heat tolerant and early maturing clones selected for regional distribution.

COMBINING RESISTANCES

Progeny testing to identify parental clones was carried out using 25 advanced clones resistant to late blight and 25 resistant to frost. Significant GCA for tuber yield was found in both samples. Clones selected for good GCA and frost resistance are listed in Table II-1.

Theoretically, a diploid population should possess a higher proportion of superior genotypes than an equivalent autotetraploid population to permit more efficient accumulation of desirable genes through selection. Thus, a sample of 390 haploids ($2n=2x=24$) extracted from late blight-resistant tetraploids was evaluated for horizontal resistance to late blight. As expected, the level of resistance of some haploids was greater than that of their tetraploid parents, although average resistance of the haploids was approximately the same as that of the 4x parent. The haploids that are highly resistant to late blight will be intercrossed to create a new population with a potentially greater average resistance than that of the 4x progenitors. Regression analysis showed that the level of resistance of haploids was strongly dependent on that of the parent (Fig. II-3), suggesting that additive gene effects are important for determining levels of resistance, and that significant progress can be made by phenotypic recurrent selection.

Up to 1978, breeding for resistance was carried out only against

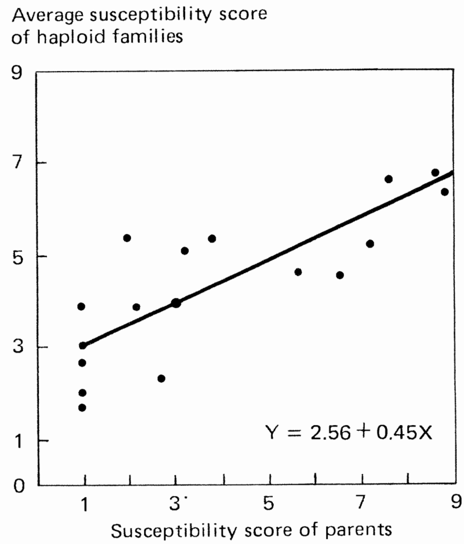


Figure II-3. Linear regression of late-blight susceptible score of haploid families on that of parents.

Table II-1. General combining ability (GCA) effects of a sample of clones with resistance to frost.

Clone no.	Pedigree	GCA effects
375568.12	Cos 69.1 OP x 702204	39.6992
375089.32	(Superior x W5295.7) x Cuz 386	22.9614
376944.10	(Conchita x C. Blanca) x (Ajh x Stn)	22.5529
375089.31	(Superior x W5295.7) x Cuz 386	19.7855
375089.6	(Superior x W5295.7) x Cuz 386	9.8033
376811.2	Cuz 421 x Renacimiento	9.8057
376977.9	69-4-5 x Juz (bulk)	10.1501
376947.5	(Anita x Quindio) x Ajh (bulk)	7.0286
376996.8	Cuz 421 (Cur) x 702266	−37.9426
375057.39	(Ajh x Stn) x CCC 81 (Phu)	−24.6669
375080.23	Cuz 201 x WRF 1643 (Mlt x Vrn)	−20.9482
376250.1	373002.1 (P_2C_5) x 702567	−11.6724

SE $(g_i) = 6.55$ SE $(g_i - g_j) = 9.26$

G. pallida, pathotype P_5A. Intercrossing different sources of resistance and simultaneous selection pressure on pathotypes P_5A and P_4A have been successful in obtaining plants with combined resistance to both pathotypes. By only selecting plants with zero number of females on the root-ball, clones with multiplication rates of less than one were obtained. This advance in levels of resistance places the future of breeding on a solid basis.

In Ecuador two clones selected from tuber families (278068 [I-3-34] and 279138 [I-4-10]) with resistance to the indigenous cyst-nematode pathotype of *Globodera pallida* yielded 55 and 39 t/ha, respectively, and will enter national trials. In Peru two cyst nematode-resistant clones (278072.10 and 278024.8) were selected in the northern zone (Otuzco, Huamachuco) and two (278029.20 and 278024.8) in the southern zone (Cuzco).

The recent harvest of 452 *Pseudomonas*-resistant clones belonging to 11 groups permitted critical selection based on combined performance data (pre-1978 through 1982). Eleven clones were finally selected because of high yield (>1 kg/plant), good agronomic characteristics, adaptation, and combined resistance to *Phytophthora infestans* and *Pseudomonas solanacearum*. Some of these clones have been released by national programs (Fig. II-4). Since 1978, in the development of 4 of the 11 groups, a much higher proportion of potentially useful clones has been identified, clearly indicating progress made with this population. A new tetraploid population that combines resistance

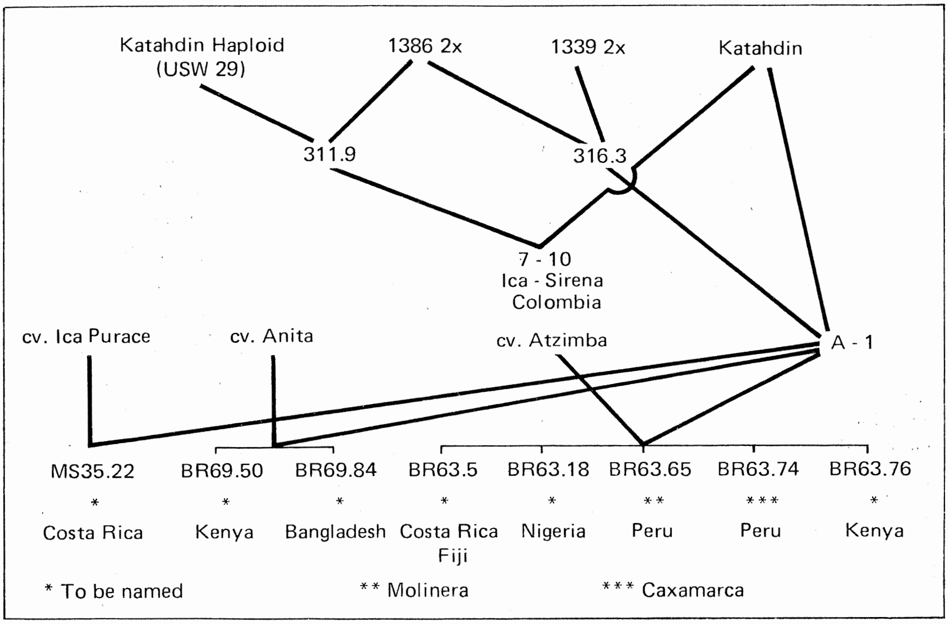


Figure II-4. Pedigree of CIP advanced clones released by national programs.

from at least three specific sources (*S. phureja, S. sparsipilum*, and *S. multidessectum*) was developed in 1982.

The work on the systematic use of wild species concentrated on 1) resistance to *P. solanacearum*, and 2) resistance to the potato tuber moth, *Phthorimaea operculella*. A diploid population highly resistant to *Pseudomonas*, based on the wild species *S. sparsipilum*, was crossed to advanced diploid cultivars possessing good agronomic characteristics and tubers with high dry matter content. Initially, the same wild-based diploid population upon screening contained about 10 percent of clones with high resistance to the potato tuber moth. Under natural storage conditions, these resistant clones withstood the pressure of high tuber-moth infestation.

In virus resistance work, emphasis was placed on screening for combined immunity of potato virus Y (PVY) and resistance to potato leafroll virus (PLRV). Three populations were used as a source of PVY immunity: PVY bulk, PVX+PVY bulk, and PVY-RIII bulk (Table II-2). In some, the female parent also possessed a PVY immunity gene. The highly fertile PVY-RIII

Table II-2. Percent resistant seedlings in PVY screening of crosses combining PVY immunity and PLRV resistance.

Source of PVY resistance	Mean % of resistant seedlings	$S_{\bar{x}}$
PVY bulk	56.7 a*	2.7
PVX+PVY bulk	71.7 b	3.3
PVY-RIII bulk	73.1	2.3

*Means followed by the same letter are not significantly different at 5% level.

bulk is from a population being selected for high genetic diversity with a high frequency of the gene Ry_{adg} and producing tubers with good horticultural characteristics. The fourth cycle (PVY-RIV) of recurrent selection has been carried out. As shown in Figure II-5, the increase in PVY immunity has been consistent and steady. The newest cycle produced 91.3 percent immune phenotypes. A computer simulation model, written to simulate selection for autotetraploid populations undergoing selection in gene frequency disequilibrium, has been developed to compare the observed versus expected progress of this population. According to the model, the frequency of Ry_{adg} gene apparently has increased from 0.125 to 0.39 in four cycles. Further progress in selection, if desired, would be best affected by means of progeny testing to identify duplex and triplex genotypes.

Hereafter, the breeding program will concentrate on obtaining estimates through seedling screening of general combining ability for PLRV resistance by the top-cross method. The heterozygous tester will be the PVY-R populations, which will also be advanced one cycle per year. The objective is now being achieved of obtaining families possessing a high frequency of PVY immunity combined with PLRV resistance.

Greenhouse and field tests for resistance to PVY and PLRV, combined with yield trials at 3 localities in Peru, have identified the following 4 clones that are being passed through meristem culture for export as having high yield, good horticultural characters, and virus resistance:

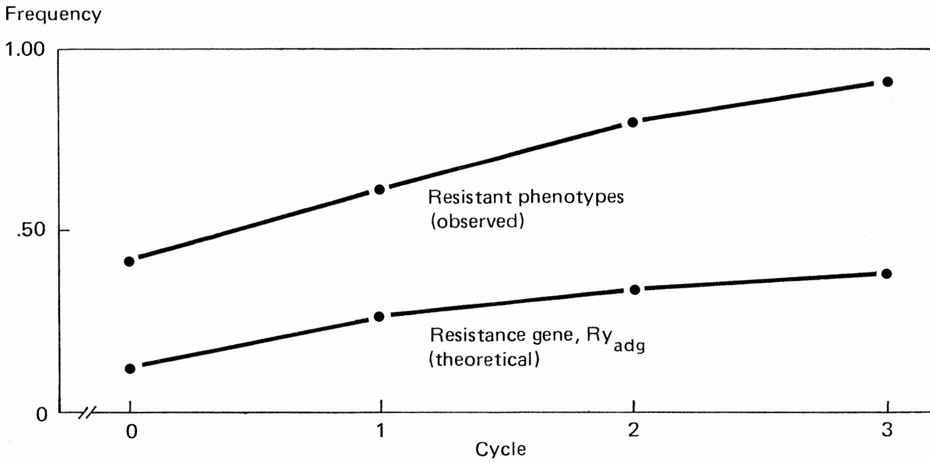


Figure II-5. Observed frequency of resistant phenotypes and theoretical frequency for the Ry$_{adg}$ gene over 3 cycles of recurrent selection for PVY resistance.

Clone	PLRV$_r$	PVY$_i$	PVX$_i$
78C 11.5	x	x	x
Pirola	x	x	
PG 295		x	x
XY 13.15		x	x

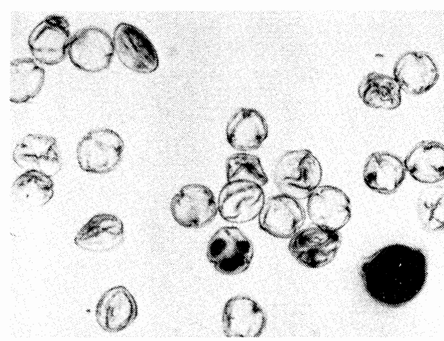


Figure II-6. Aborted pollen from triploid (*acaule* x cultivated diploid) hybrids.

Research to incorporate virus resistance from wild species was done using certain accessions of *Solanum acaule* (2n=4x=48) that have been identified as highly resistant to PLRV. Crosses made with cultivated clones resulted in triploids. Colchicine treatment of the germinating, completely sterile triploid seed resulted in eight hexaploid clones with resistance and fertility. Aborted and fertile pollen for the triploid and hexaploid clones are shown in Figures II-6 and 7. Production of pentaploids is in progress by using the highly PLRV-resistant hexaploids as pollen donors on Tuberosum and Andigena cultivars.

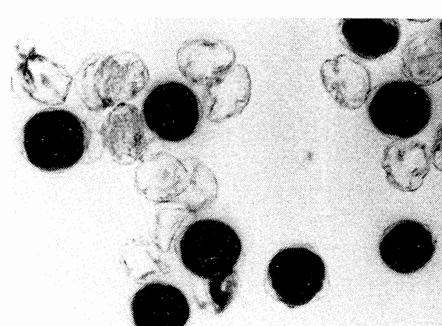


Figure II-7. Fertile pollen from colchicine-doubled hexaploid (*acaule* x cultivated diploid) hybrids.

PRODUCTION OF TRUE POTATO SEED

In true potato seed (TPS) breeding research, efforts have been continued to identify parental lines for TPS production. A study of GCA was conducted by bulk-pollinating a sample of 49 clones with pollen from lowland tropic populations; the TPS progenies were evaluated in replicated trials at CIP's Huancayo station. Several of the 49 clones had high GCA estimates for yield, tuber uniformity, and seedling survival in the field, and 4 had particular importance as potential progenitors. Tuber yields of more than 1.5 kg/plant and uniformity evaluations ranging from acceptable to excellent were found in several TPS families produced from these crosses.

A total of 121 TPS progenies, obtained from intervarietal hybridizations of adapted cultivars and advanced clones from CIP's lowland and highland tropics projects, were evaluated in both the La Molina and San Ramon experimental sites in a 11x11 lattice design. Biotic stress factors reduced yields at both sites; however, a few progenies showed reasonable yield and uniformity.

TPS progenies were also developed from 4x-2x crosses, in which the 2x parents were known to produce 2n pollen by FDR. A total of 20 selected CIP clones were crossed to either one or both of the two diplandroid clones (W 5295.7, W 5337.3) from Wisconsin. TPS progenies from these crosses were compared with progenies from five North American cultivars mated with the same diplandroid clones. The contribution of the diplandroid clones to increased tuber yield was more significant when mated with adapted rather than nonadapted cultivars. The diplandroid clone W 5295.7 was superior to W 5337.3 in improving yield of the TPS progenies.

Two approaches for incorporating late blight resistance into TPS populations are under investigation. One approach is to produce TPS multilines by crossing each of the selected parental clones with each of the late blight differentials containing one or more R genes. The procedure is to mechanically blend equal amounts of seeds obtained from the various crosses and then to evaluate the multiline TPS families in both laboratory and field for late blight reaction. The second approach involves the production of TPS progenies from parental lines in which one or both of the parents are known to have late blight resistance. Preliminary results of the TPS seedling screening test indicated that it is possible to incorporate a high degree of resistance into TPS progenies.

CONTRACT RESEARCH

At the Agricultural University, Wageningen, the Netherlands, new source material for late blight resistance, using the Mexican species *Solanum verrucosum, S. bulbocastanum,* and *S. stoloniferum*, coded VBST, was backcrossed with potato cultivars for further nobilization. In close cooperation with CIP's virus resistance program, crosses were conducted between PLRV immunity-containing species *S. etuberosum* and *S. verrucosum*. New progeny arising from these crosses will complement the extreme resistance to PLRV found in seedling progenies of *S. etuberosum* x *S. pinnatisectum* (4X-EP).

Contract research at North Carolina State University, United States, concentrated on advancing subpopulations of diploids for increased dry matter content, tuber type, and yield. Based on survival and yield, 5400 third-cycle selections for heat tolerance will be reevaluated and integrated with the previous population. High levels of early blight resistance were also identified and combined for further testing for tuber type, yield, and resistance. Clones with very high levels of resistance to *Erwinia* spp. are being intercrossed as an attempt to improve resistance to tuber rot. From subpopulations, selected clones producing unreduced gametes were used as pollen parents in 4x-2x crosses with commercial tetraploids; approximately 8000 seedlings were produced to be evaluated in 1983.

Electrophoretic verification of morphologic duplicate accessions in CIP's world germplasm collection of primitive cultivars was continued at the Institut für Biochemie Biologische Bundesanstalt, Braunschweig, West Germany. During 1981-1982, more than 3000 clones were evaluated by electrophoresis. All unique accessions previously identified were rerun, and photographs of electrophoretic protein patterns were sent to CIP.

At the University of Wisconsin, United States, a new meiotic mutant *sy3* lacking chiasmata was discovered. Combining the *sy3* mutant with parallel spindles mutant allows incorporation of the intact genotype of the 2x parent into all 2n male gametes, permitting transmission of complete parental heterozygosity and epistasis to progeny. Hybrids between haploids of Tuberosum and *S. chacoense* with large tuber yields and 2n gametes have been obtained. Tetraploid hybrids from 4x x 2x (FDR) crosses yielded twice as much as open-pollinated TPS families.

At the National Institute of Agricultural Technology, Balcarce, Argentina, 90 parental clones crossed in 204 combinations yielded 145,700 seeds. From 83,100 seeds, 19,077 new clones were obtained for field evaluation of PVY and PLRV virus resistance and agronomic acceptability. Of 1007 clones planted for assessment of percentage of 2n-pollen production, only 8 clones produced 6 percent or more.

Contract research at Cornell University, New York, United States, has advanced the neotuberosum population into the next cycle of selection by growing 22,000 advanced generation seedlings. All seedlings were inoculated with PVX and PVY, and half of each seed lot was inoculated with late blight fungus. Infected plants were rogued and tubers were harvested from the survivors.

Transfer from *S. sparsipilum* to neotuberosum of resistance to three nematode species of *Meloidogyne* and race 1 of *P. solanacearum* has been achieved. The glandular trichomes of *S. berthaultii* have been transferred to tetraploid types with PVY immunity and reasonable maturity. Glandular trichomes on the interspecific hybrid D860-5 reduced aphid population ninefold, compared with the variety Katahdin.

As part of a contract at the Canada Agriculture Research Station, Fredericton, New Brunswick, eight cultivars were tested at nine global locations to predict yield performance. The mean yield of the control varieties Kennebec and Spunta, as a measure of the environmental index at a site, was used as the independent variable. The six test cultivars were regressed on the independent variable to develop a regression equation. Data from four sites were used as a control in developing regression equations for each of the eight cultivars at the other five sites. Good correlation between observed and predicted values was obtained for four out of five test sites. In 1983, the test will be expanded to include 35 genetically diverse tuberosum lines at ten locations worldwide.

Thrust III

CONTROL OF IMPORTANT FUNGAL DISEASES

CONTROL OF IMPORTANT FUNGAL DISEASES

In 1982 a new protocol for the screening of late blight-resistant material for regional distribution was initiated at CIP-Lima and at a research station in Rionegro, Colombia. From an initial screening of 20,000 seedlings, 174 clones were selected for further evaluation. Thirty clones, selected in previous years, entered advanced regional testing stages in Colombia. Testing for tuber resistance to late blight in clones and populations from various breeding programs was also initiated at CIP-Lima during 1982.

Various chemical and cultural control experiments were evaluated on a number of soil-borne fungal diseases that cause significant losses in potato production in developing countries. No fungal pathogens were found to be transmitted through true potato seed (TPS), although high temperatures in seedbeds increased the susceptibility of seedling transplants to *Rhizoctonia solani.*

LATE BLIGHT

CIP's breeding program for resistance to late blight (*Phytophthora infestans*) was reevaluated based on recommendations arising from a Planning Conference held at CIP in early 1982. A new screening protocol, which resulted from these evaluations, is presented in Figure III-1. Future emphasis will be on supplying CIP regional centers and collaborative national programs with duplicates of progenies previously tested in Colombia and Mexico, which were selected for late blight resistance and earliness as a joint effort of Thrusts II and III. These pathogen-tested duplicates will be sent from CIP-Lima for regional evaluation. The advantage of this sequence is that the duplicates of regionally selected clones are maintained in Lima under quarantine and will not require cleaning-up by tissue culture, after selection in the region.

The first selection cycle of this new breeding program was initiated in the second half of 1981 at CIP-Lima. A total of 20,000 seedlings, selected for late blight resistance under greenhouse conditions, were obtained from 200 families. Two tubers of each of the 2822 clones (163 families) that survived the testing were interplanted with late blight-susceptible varieties at the Instituto Colombiano de Agropecuaria (ICA) research site, Rionegro, Colombia. From these, 174 clones were selected, based on two blight evaluations during the growing season, on performance, and on yield 110 days after planting. Duplicates of these clones were multiplied under quarantine in Lima and will be evaluated in 1983 in cooperation with the Instituto Nacional de Investigaciones Agrícolas (INIA), Mexico. Selected clones from the first selection cycle will be available from 1984 onward for distribution in the regions. The second selection cycle was initiated at CIP-Lima in 1982, with 30,321 seedlings from 79 families.

Progenitors used in the new breeding program have been evaluated under field conditions in Peru, and progenies will be tested for general and specific combining abilities with respect to late blight resistance

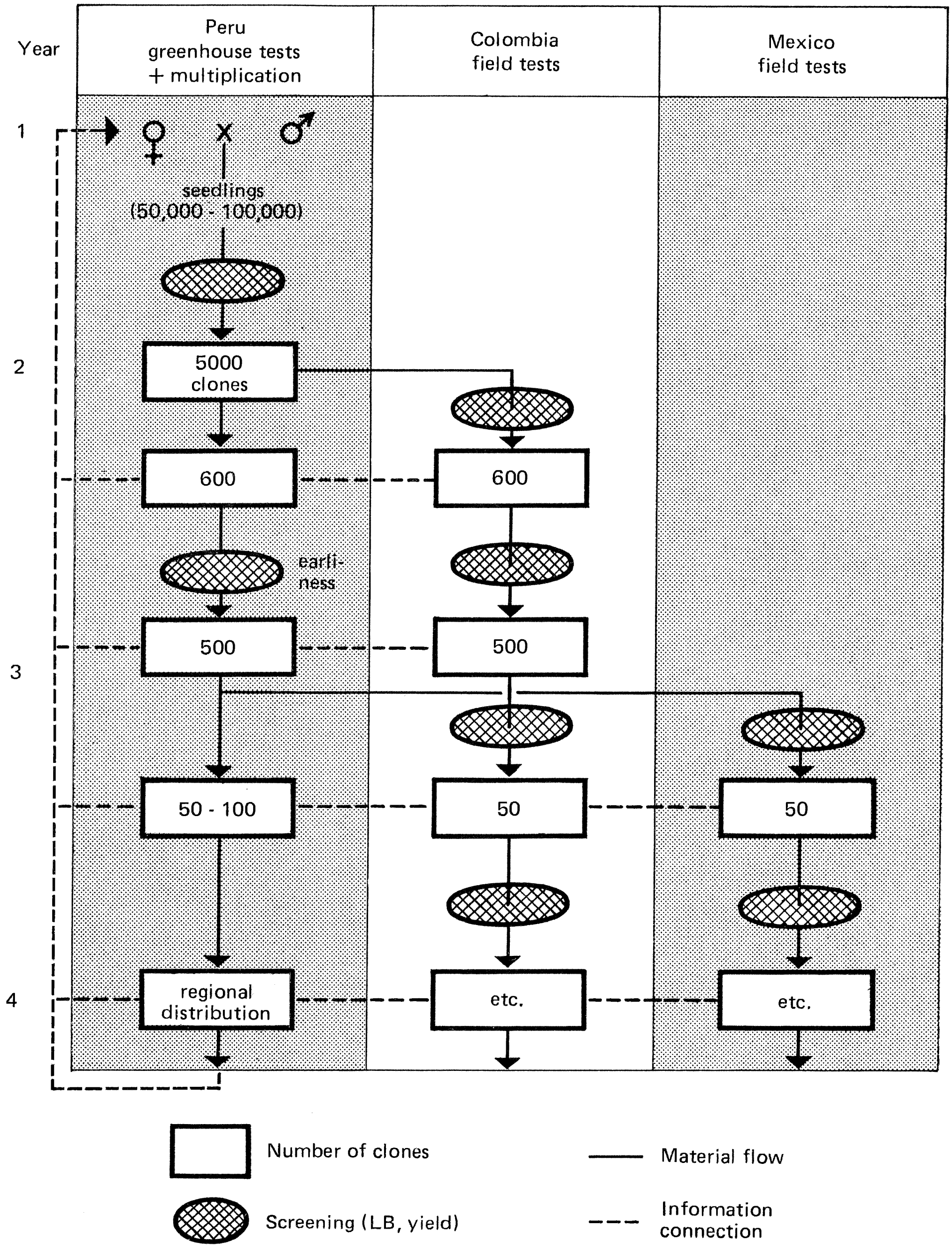


Figure III-1. Protocol for testing for late blight resistance at three locations (Peru, Colombia, and Mexico).

and yield. From 600 clones, including commonly used and potential progenitors, 159 were selected. Most of these clones require a long growing season; however, progenies from many of these clones were crossed with early maturing material and tested in the same fields. These clones matured much earlier, which indicated genetic combination of earliness with late blight resistance. In previous seasons, a total of 154 clones were selected from among the CIP introductions at Rionegro. Of these, 31 were again selected on the basis of late blight resistance and general performance and were entered into the trials of the Colombian national potato programs.

In other experiments, the effect of both field plot design and fungicide use was studied in selecting for late blight resistance. The results showed that when small plots of resistant- and intermediate-resistant clones were interplanted with highly susceptible ones, the differences between the clones in late blight resistance were concealed due to interplot interference. On the basis of infection rates in the nonfungicide-treated plots, clones with a relatively low response to fungicide were more resistant to late blight than those with a high response.

The usefulness of the TPS seedling test, used for critical initial screening of late blight material for export, was further evaluated. In 1981, 100 plantlets from each of 10 families were subjected to the TPS seedling test, while groups of 50 seedlings from the same families were grown without exposure to late blight. Tubers were collected from seedlings, taken to Rionegro, and planted in 3- or 4-hill plots. Late blight readings were taken during the natural epidemic that followed. Correlation coefficients between the score of the seedling test and that of the field selection of screened and unscreened populations were 0.18 and 0.17, respectively. The correlation coefficient between field selection scores of both populations was 0.68, and significant. According to the results in this experiment, TPS seedling screening did not improve field resistance of the surviving screened population compared to the same but unscreened population.

Based on a recommendation from the Planning Conference to incorporate tuber blight resistance into breeding lines and varieties, CIP began to test for general resistance to late blight in tubers. Whole tubers (50% superficially wounded) were sprayed with a zoospore suspension of *P. infestans* and stored for 20 hours at 15°-18°C and 100 percent relative humidity and then evaluated after 14 days at 15°-18°C. The tubers being tested originated from breeding programs for adaptation to lowland tropics, bacterial wilt and late blight resistance, frost tolerance, and from the CIP pathogen-tested collection. Preliminary evaluations showed resistance to tuber late blight, especially in clones from the late blight resistance project (Table III-1).

As a result of cooperative research performed at IPO, Wageningen, the Netherlands, the presence of R-genes obtained from *Solanum demissum* in a number of CIP-

Table III-1. Codes and pedigrees of clones tested for resistance to late blight.

Clone	R-genotype	Other codes and/or pedigrees
CIP 573272	$R_1 R_3 R_4$	AJU-69-1=65 Black-269
575036	$R_1 R_3 R_4$	ABZ-69-1=Black-592
676028	$R_1 R_2 R_3$	AHD-69-1=65 Black-147
676037	R_1	AMR-69-1=Alpha x (US 135-7 x Amarilla de Puebla)
676105	$R_1 R_3 R_{10}$	Hol 37; Dorita=MPI 19268 x Libertas[a]
700138	r	Andigena
701752	$R_1 R_2$	Andigena hybrid
750815	$R_1 R_2 R_3$	
800922	$R_1 R_3 R_{10}$	Radosa; Bintje x MPI 19268[a]
MPI 19268	R_{10}	Demissum-tuberosum (DT_4) hybrid

[a]Libertas, MPI 19268, and Bintje do not possess either R_1 or R_3.

Mexican clones was determined. In other cooperative studies at IPO, progenies of selfed and open-pollinated *acaule-bulbocastanum-phureja-tuberosum* (ABPT) clones with known high levels of resistance to late blight were evaluated by laboratory tests. This was also done with progenies of the same ABPT clones crossed with *Solanum tuberosum* (var. Gineke or Oberarnb. Frühe). Resistances observed in the progenies of the two groups were compared. The selfed and open-pollinated ABPT progenies yielded 50 percent resistant seedlings, while the ABPT x *S. tuberosum* hybrids yielded only 23 percent resistant progeny. These results indicate the potential value of the ABPT clones in breeding for late blight resistance. Foliar resistance to late blight of three neotuberosum clones, which showed considerable field resistance, was compared in growth chamber tests with six ABPT clones and Bintje as a control. The ABPT clones were almost four times as resistant —based on the proportion of successful fungal penetrations—as the neotuberosum clones, but the latter were still thirty times more resistant to infection than the Bintje control.

SOIL-BORNE DISEASES

Pink rot (Phytophthora erythroseptica). Control methods recommended on the basis of earlier reported experiments—general preplanting fumigation with Basamid followed by an in-furrow treatment with Ridomil (granulated) at planting—again resulted in good control of pink rot in the CIP germplasm collection and in seed production fields (Fig. III-2). Disease incidence was serious in the nontreated fields. Experiments were also performed to determine more precise quantities of chemicals required to give optimal control and to test several new fungicides.

Potato smut (Angiosorus solani). Further evaluation of a number of effective fungicides and fumigants that provided adequate control and the epidemiology of potato smut were studied. Healthy tubers of a susceptible variety (Yungay) were planted in a smut-infested soil. Results showed that more than 60 percent of stolon infection had taken place within 25 days after planting and before tuber initiation (Fig. III-3).

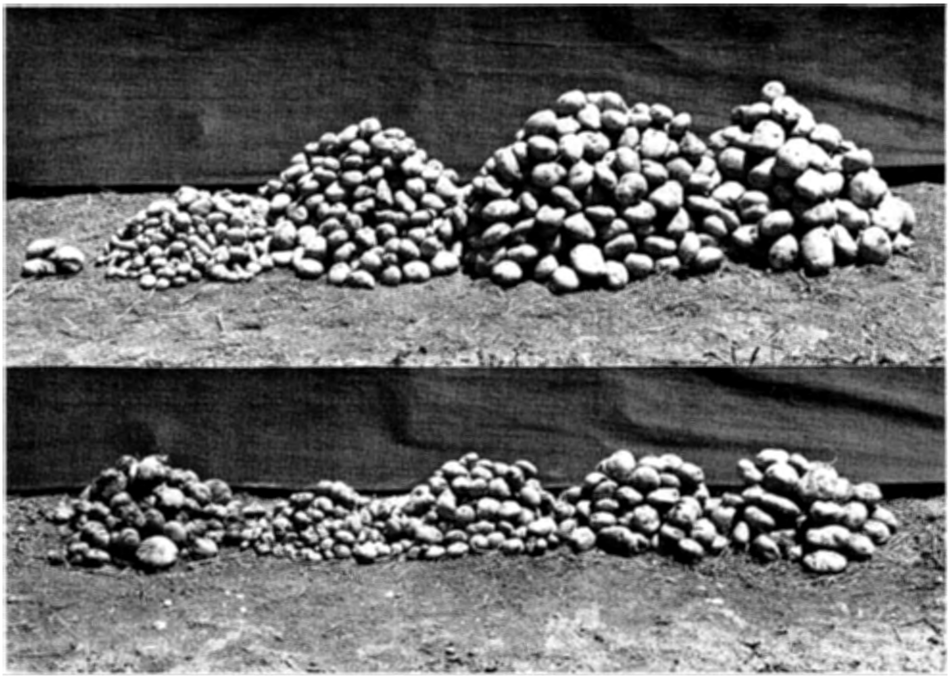


Figure III-2. (*Top*) Potato yield obtained from a field heavily infested with pink rot and treated at preplanting with Basamid and Ridomil. Note at the extreme left that only 3 tubers were found infected. (*Bottom*) Potato yield obtained from the field as above but not treated. Note the large number of infected tubers at the extreme left, and the lower yield and tuber size as compared to *top*.

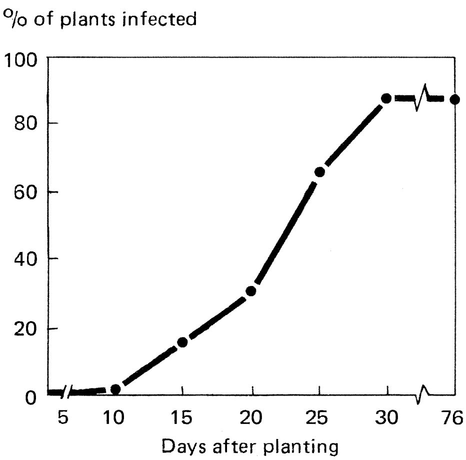


Figure III-3. Percentage of plants infected with potato smut. Healthy tubers were planted in a field heavily infested with *A. solani* and then transplanted at different intervals to sterile soil.

Southern wilt (Sclerotium rolfsii). In soil plate-tests, Vitavax WP was the most effective fungicide used to control germination of sclerotia of this fungus (Fig. III-4). In pot tests, however, Terrazole at 3000 ppm was the best fungicide for controlling infection of potato plants. In a long-term crop rotation experiment at San Ramon, incorporation of maize straw increased the number of sclerotia recovered, but when bean foliage was incorporated, the number was reduced in both the dry and wet seasons. Incorporation of rice straw reduced the number of sclerotia in the dry season only. The incidence of southern wilt in

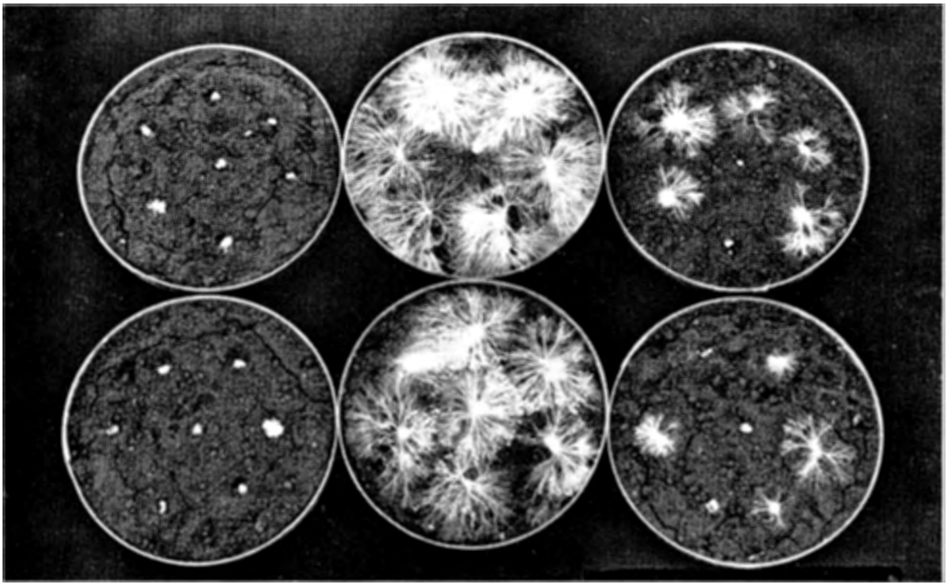


Figure III-4. Chemical control of sclerotia germination of *S. rolfsii* in soil-plate tests. From left to right: Vitavax WP, control, and Basamid (fungicides were applied at 2000 ppm).

control potato plots (no rotation) varied between 3 and 15 percent of the plants infected, with the lower percentage occurring during the dry season.

Black scurf (Rhizoctonia solani). This disease is occasionally of importance in Huancayo and almost always a problem in San Ramon. Various fungicides such as Vitavax, Benlate, and PCNB were tested for control of black scurf at Huancayo and were applied at planting and during the growing season. Some of the fungicide treatments applied during the growing season resulted in increased yields compared with untreated plots and plots treated only at planting; however, the differences were not significant. Similar results were obtained at San Ramon. The results suggested that under the environmental conditions of the above two sites, soil fungicide treatment is not an effective way to control black scurf. Trials on the biological control of *Rhizoctonia*, using various antagonistic isolates of *Trichoderma* spp., were ineffective in field tests. All isolates of *R. solani* from infected potatoes grown in San Ramon and Huancayo belonged to anastomosis group 4.

Black wart (Synchytrium endobioticum). Twenty clones that showed resistance to black wart in earlier field and pot tests were retested in a heavily infested field in Ayacucho, Peru, in cooperation with the University of San Cristobal de Huamanga. Each clone was planted in eight replications of 10 hills each. Fifteen clones did not show any disease symptoms and were also agronomically acceptable.

No pathogenic fungi were found on any sample of TPS studied. However, saprophytes such as *Cladosporium oidiodendrum* were found on TPS and were readily eliminated by seed-surface sterilization with 1 percent sodium hypochlorite. TPS seedlings incubated under 100 percent relative humidity often showed the presence of another species of *Cladosporium*, but these fungi did not offer any problems under normal conditions of germination. Batches of 100 open-pollinated seeds were extracted from each of a number of plants infected with potato smut, bacterial wilt, verticillium wilt, or fusarium wilt. These seeds were examined and planted in replicated experiments. To date, not one of these diseases has been transmitted to the progeny.

High temperatures (35°C) in seedbeds predisposed TPS transplants to damping-off caused by *R. solani* in soil-temperature boxes (Table III-2). Concurrent observations suggested that at each temperature the fastest growing seedlings were most tolerant to *R. solani*. Other experiments using four fungicides (Benlate, Vitavax, Tecto, PCNB) (1 g/kg soil) to control transplant damping-off were conducted in soil boxes, under average soil temperatures of 25°, 30°, and 33°C. Ten days after seedlings were transplanted in soil kept at 25°C and inoculated with *Rhizoctonia*, survival was determined. At low temperature, 90 to 100 percent of the seedlings survived as a result of soil treatment with any one of the four tested fungicides (Table III-3). At 30° and 33°C, Benlate, Vitavax, and Tecto continued to maintain from 80 to 100 percent control. PCNB failed to control the disease at these higher temperatures. This failure to control *Rhizoctonia* at higher temperatures confirms observations obtained in earlier field tests at San Ramon.

Table III-2. Seedling transplant susceptibility to *Rhizoctonia* damping-off.

Variety or clone of open-pollinated TPS	Percent damping-off 14 days after inoculation[a]		
	15°C	20°C	35°C
Yungay	1	20	90
Renacimiento	0.5	30	100
Molinera	1	40	100
Tomasa Condemayta	0	50	80
CFK-69-1	5	45	100
CEX-69-1	4	50	95
Caxamarca	4	35	75
OCH 11983	1	80	100
Ranrahirca	4	50	90
Participación	3	20	95
DTO-33	4	70	100

[a]Average of 2 experiments.

Table III-3. Evaluation of fungicides for damping-off control in TPS under different soil temperatures.[a]

Fungicide (1 g/kg soil)	Transplant (%) survival 10 days after transplanting			
	Average soil temperature			
	30°C[b]	25°C	30°C	33°C
PCNB	1	100	10	0
Benlate	32	96	84	88
Vitavax	2	92	98	90
Tecto	5	100	100	100

[a]Percent damping-off was read 10 days after inoculation.
[b]Control.

Thrust IV

CONTROL OF IMPORTANT BACTERIAL DISEASES

Seedling screening for resistance to bacterial wilt (*Pseudomonas solanacearum*) was conducted with true potato seed from the different projects that use this resistance in developing breeding populations. Bacterial wilt-resistant tuber families were distributed to potato programs in many countries. From 17 advanced pathogen-tested clones developed, 4 were named as varieties by three countries. The variety Molinera continues to be bacterial wilt resistant in the traditional potato-growing climates of northern Peru, areas that were previously quarantined because of bacterial wilt. A new variety, Amapola, has been developed from the original population that gave rise to Molinera.

In contract research in Sri Lanka, several bacterial wilt-resistant clones were selected to be grown in areas in the country where the disease has been highly destructive to commercial crops. Through a contract research project at the University of Wisconsin, antisera to several strains of *P. solanacearum* were developed.

Moderate resistance to *Erwinia* soft rot on tubers was identified under lowland tropic conditions. Under field conditions, *Erwinia* blackleg symptoms are rare in plants grown from true potato seed, but significant latent infection has been noted in tubers. Increased calcium fertilization has been recently shown to greatly reduce the incidence of soft rot in tubers in the field.

BACTERIAL WILT

Seedling screening for resistance to bacterial wilt was continued in support of four breeding projects: bacterial wilt and late blight resistant populations, bacterial wilt and root-knot nematode resistant populations, populations combining new sources of resistance from diploid wild species, and progeny involving ploidy level manipulations using haploids and 2n gametes.

The number of advanced clones in the pathogen-tested program resistant to bacterial wilt, which are available for distribution to national potato programs, was increased to 17 (Table IV-1). Eleven of these clones were sent to the Victoria Department of Agriculture pathogen-tested program in Australia for multiplication. CIP's Region VII will eventually distribute these clones for testing in Asian countries.

Through the years it has been important to determine if the pathogen *Pseudomonas solanacearum* can mutate and overcome the resistance in *Solanum phureja*. To test this possibility, Molinera—the oldest (1977) of the developed bacterial wilt-resistant varieties—was surveyed where it was being grown extensively in the Department of Cajamarca, Peru. Although most of the Molinera crop was healthy, some bacterial wilt was found in areas with heat stress located outside the usual potato-growing zones. In these areas, it was observed that the disease had a tendency to be self-eliminating because the infected plants died quickly before tubers

Table IV-1. Advanced clones resistant to bacterial wilt and late blight that have been incorporated into CIP's pathogen-tested program as of 1982.

CIP no. (clone)	Bacterial wilt resistance verified in (country)	Late blight rating[a] (average)
800212 (BR-63.5)	Nigeria	5
800222 (BR-63.65)	Colombia, Costa Rica, Nepal, Peru (var. Molinera)	3
800223 (BR-63.74)	Kenya, Peru (var. Caxamarca), Sri Lanka	5
800224 (BR-63.76)	Colombia, Indonesia,[b] Kenya, Peru, Sri Lanka	3
800226 (BR-69.84)	Kenya, Peru, Sri Lanka	6
800926 (MS-35.22)	Colombia, Costa Rica (var. Irazú), Nepal, Peru, Sri Lanka	4
800927 (MS-91.18)	Peru[b]	2
800928 (MS-42.3)	Peru, Sri Lanka	2
800934 (MS-35.9)	Indonesia,[b] Nepal	5
800935 (MS-1C.2)	Colombia, Costa Rica, Peru	3
800936 (PSP-30.10)	Peru	2
800937 (MS-1C.6)	Colombia	5
800941 (MS-82.60)	Peru	1
800942 (BR-63.15)	Costa Rica (var. Chicuá), Peru	7
800952 (PSW29.38)	Peru	4
MEX-720118 (Cruza 148)	Indonesia,[b] Peru	1
800953 (MB-5.24)	Indonesia,[b] Peru	5

[a]Susceptibility: 1 = no symptoms; 9 = plant dead.
[b]Greenhouse test.

were formed. Thus, it is unlikely that tuber seed can disseminate the disease under those conditions at Cajamarca. Later, 20 isolations were made from Molinera and other potato varieties. The pathogenicity of these isolates for bacterial wilt was tested on Molinera and on a susceptible variety (Desirée) using a high inoculum dose in a heated greenhouse. All isolates were of race 3 except for one race 1 isolate, which was of low aggressivity and came from the same plant as another race 3 isolate of even lower aggressivity. Isolates from Molinera were not more aggressive than those from the susceptible varieties. Thus, there is no indication as yet that *P. solanacearum* may change and overcome the resistance developed so far.

During the Cajamarca survey, one of the CIP clones that was discarded from the Peruvian screening program in which Molinera was developed was discovered to have been multiplied by a collaborating farmer and was being successfully grown under the name "Amapola." It is reported to be high-yielding, late blight resistant, and readily accepted in the local market. No virus symptoms were observed in the field, which suggests that this variety has some virus resistance. The Peruvian Potato Program is preparing to officially name this variety.

Bacterial wilt-resistant clone next to a susceptible clone.

ERWINIA DISEASES

Bacterial soft rot (*Erwinia* spp.) in tubers prior to, during, and after harvest is the most serious pathogenic problem in adapting the potato to the lowland tropics, especially if planting is done during the wet season.

In the search for resistance to soft rot in tubers, clones were evaluated from three different projects. In the first experiment, out of 113 clones selected for resistance to *Erwinia chrysanthemi*, 1 was moderately resistant, 23 were susceptible, and 89 were very susceptible. In the second, 40 clones from the cyst nematode (*Globodera*) resistance project included 5 moderately resistant, 23 susceptible, and 12 very susceptible to *E. chrysanthemi*. In the third, among 229 clones tested from the germplasm collection, 5 were moderately resistant, 74 susceptible, and 150 very susceptible.

Blackleg, caused by both *E. chrysanthemi* (Fig. IV-1) and *E. carotovora* var. *carotovora*, was found to affect growing potato plants during both the wet and dry seasons in San Ramon, however, little damage occurred, especially during the dry season. To assess the importance of soil-borne infection (the blackleg inoculum is considered to be primarily borne on or in tubers), three experiments using

Figure IV-1. Blackleg symptoms caused by *E. chrysanthemi*. Inoculation method used was by soil infestation prior to planting healthy tubers.

true potato seed were conducted in San Ramon during the previous dry season. Blackleg incidence was 0.61 percent in a population of 11,320 plants. Assays of tubers harvested from these experiments gave 21 percent latent infection (13% *E. carotovora*, 8% *E. chrysanthemi*), which indicates the importance of infection by soil-borne bacteria.

CONTRACT RESEARCH

Research at the University of Wisconsin, United States, confirmed the 1981 results that increased calcium fertilization of potato plants produces tubers with a greater calcium content in periderm tissue. These high calcium potatoes are more resistant to *Erwinia* soft rot at harvest and after months of storage. Available soil calcium may be increased with calcium sulfate or calcium nitrate, or by raising soil pH. Conversely, ammonium fertilizers or those with much magnesium or potassium, or a low pH, inhibit calcium uptake and increase tuber susceptibility to soft rot.

The pectolytic enzymes of *Erwinia* are less effective in maceration of high-calcium potato tuber tissue than in low calcium tubers. High calcium tissue has a greater amount of polygalacturonic acid in the middle lamella and cell walls than does low calcium tissue. Components of the plasmalemma may also be strengthened by calcium cross-linking as indicated by reduced electrolyte leakage from high calcium tissue with increased cell wall strength.

In other contract research at the University of Wisconsin, control of bacterial wilt in potatoes by means of induced resistance and microbial autogonism was investigated. In tests of *Pseudomonas* species as control agents, avirulent (B82) and incompatible (70) strains of *P. solanacearum* and proteolytic (W163) and pectolytic (WP95) strains of *P. fluorescens* caused a significant reduction in bacterial wilt severity when plants were challenged by stem inoculation or inoculation of intact roots. In studies of the attachment of radioactively labeled virulent and avirulent cells of *P. solanacearum* to cultured tobacco cells, the avirulent (B1) cells bound more rapidly and securely than the virulent (K60) bacterial cells.

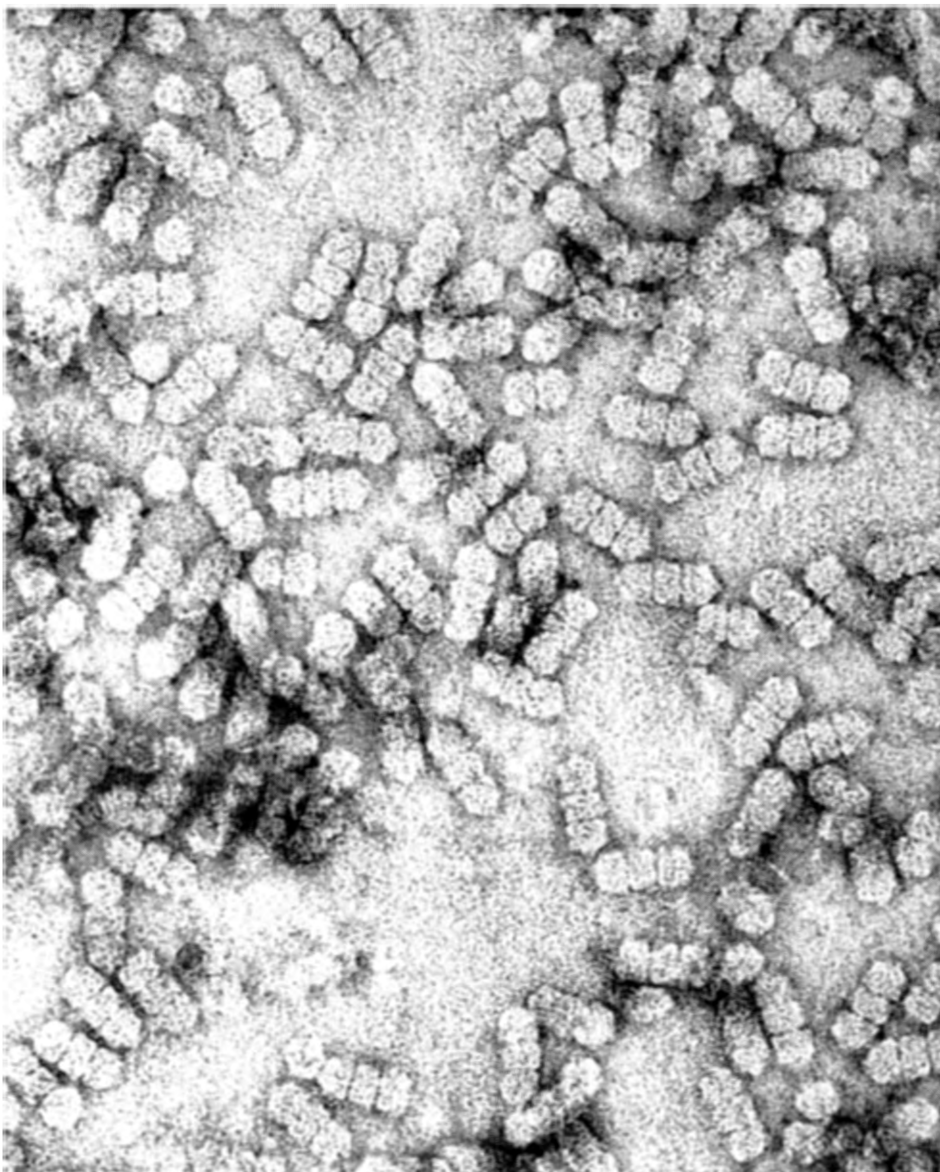
To determine the serological specificity of strains of *P. solanacearum*, antisera were prepared against six strains representing all major races and biotypes. Antigens consisted of glycoproteins extracted from bacterial cell walls. Thirty strains of *P. solanacearum* from 13 different hosts and from different regions (mainly from China) were used to determine serological specificity by cross-absorption, microagglutination, and Ouchterlony double diffusion techniques. Five different serotypes were detected, specificity in some instances being related to host and geographical origin of the different strains. While serotype I was complex and reacted with strains from at least nine different hosts, strains from the potato belonged mostly to serotype III.

The contract at the University of Huanuco, Peru, has tested selected clones in different locations in the Department of Huanuco. Over the past few years clones were tested for resistance to bacterial wilt at Umari, for resistance to late blight at Molinos, and for yield plus other local factors in the cool, seed-producing Chaglla District and in the low, warm Huanuco River Valley. From these sites, 133 advanced clones were selected and are in final screening at Chaglla for adaptation and yield. Local farmers are already asking to be seed producers for the potential new varieties.

In Sri Lanka contract research has progressed rapidly in the development of bacterial wilt-resistant clones for the mid-elevations. The infrastructure is being established for similar work to begin in the seed-producing districts of the higher elevations. At the Rahangala station (1350 m), 9 advanced clones, chosen from 16 previously selected clones, are considered to be promising. Clones (105) developed from CIP tuber families for heat tolerance and wilt resistance were retested and provided 11 advanced clones having acceptable yield. Tests on 147 new clones with heat tolerance and wilt resistance are in progress.

Thrust V

CONTROL OF IMPORTANT VIRUS DISEASES



Major emphasis was placed on studies of resistance to potato leafroll virus (PLRV), potato virus Y (PVY), and potato virus X (PVX). Sources of high resistance were retested under field and controlled conditions to select additional sources with high levels of resistance. Resistance to PLRV in *Solanum acaule* and hypersensitivity to the resistance-breaking strain of PVX (PVX_{HB}) in a wild species accession were promising. Improvement of inoculation and field exposure methods has increased reliability of evaluation trials for PLRV resistance. Likewise, increased sensitivity of virus-testing procedures has improved the quality of breeding for resistant pathogen-tested clones and progenies for export.

The nucleic acid hybridization test (cDNA) has shown high sensitivity in detection of the potato spindle tuber viroid (PSTV) in foliage, tubers, and true potato seed. Improved sensitivity of existing serological techniques, and production and distribution of antisera, are providing developing country programs and basic seed units around the world with tools needed to identify virus diseases.

RESISTANCE TO POTATO LEAFROLL VIRUS

Resistance in wild species. High levels of resistance to potato leafroll virus (PLRV) in seedling progenies of *Solanum etuberosum* x *S. pinnatisectum* (EP) were assayed by grafting EP seedlings onto *Datura stramonium* plants infected with PLRV. Backtesting by a combination of enzyme-linked immunosorbent assay (ELISA) and grafting onto healthy *D. stramonium* plants confirmed this type of resistance. Resistant EP seedlings have been successfully crossed with *S. acaule* in an attempt to transfer this resistance into cultivated potatoes.

In previous work (1981), two accessions, OCH 13823 and OCH 13824 (*S. acaule*), were found to be highly resistant to PLRV. New wild species collections made in the area where these two accessions were found (Department of Ayacucho, Peru) revealed the presence of 17 new accessions, which appear to have the same type of resistance. Studies on the inheritance of this resistance are in progress.

Resistance in clones. Eighty-five clones previously exposed to PLRV infection under field conditions were evaluated by the symptoms of the disease and by ELISA. Thirty-five were found resistant to PLRV and will be retested under controlled infection conditions.

A system developed to identify higher degrees of resistance in clones was evaluated. In this system, single-stemmed plants were inoculated with 5, 25, and 50 PLRV-carrying aphids to expose the plants to different concentrations of the virus. Plants were later observed for symptoms, and PLRV was diagnosed by means of ELISA serology or by backinoculation to *Physalis floridana*. The results suggest that this system can be effectively used to differentiate levels of PLRV resistance. From nine clones tested, four highly resistant cultivars (uninfected either by 5 or 25 aphids, but infected in low proportion with 50 aphids) were identified. ELISA was used to detect PLRV in infected plants without symptoms. All resistant clones remained uninfected under PLRV greenhouse exposure trials conducted in 1981, and field evaluation in 1982.

Improvement of field exposure trials. Screenhouse experiments showed that PLRV-infected *D. stramonium* plants were as good a source of the virus as PLRV-infected potato plants. In the same trials, it was demonstrated that aphids (*Myzus persicae*) multiplied more rapidly on *D. stramonium* than on potatoes. *D. stramonium* is being used routinely at CIP as a source of inoculum in PLRV-field and greenhouse exposure trials, since it is immune to PVY, and PVY can interfere with evaluations for PLRV in plants.

Studies on the variability of PLRV were continued in 1982. A total of 123 field samples showing leafroll or chlorotic dwarf symptoms (*enanismo amarillo*) were collected in the central highlands and coastal valleys of Peru. From these samples, 48 isolates were transmitted to *D. stramonium* and *P. floridana* by means of aphids (*M. persicae*) and grafting. Comparative studies were done to determine symptom expression in these two hosts, efficiency of vector transmission, and serological relationships. Isolates differing in severity of reaction in *P. floridana* were identified. None of the isolates infected shepherdspurse (*Capsella bursa-pastoris*), included to identify possible occurrence of beet western yellow virus (BWYV). Also none reacted to one antiserum of BWYV. All but one of the isolates were successfully transmitted by aphids.


Inoculation of a virus on indicator plant.

RESISTANCE TO POTATO VIRUS Y AND POTATO VIRUS X

Sources of resistance. Cultivars from the CIP pathogen-tested program were evaluated for their reactions to potato virus X (PVX) and potato virus Y (PVY). High levels of hypersensitivity to PVY were found in five cultivars: CEX 69.1, CFE 69.1, Mex 750815, BL 1.5, and 377830.3.

Among wild species, immunity to PVXcp strain was found in several accessions, primarily in *S. acaule*. One accession, OCH 11926 (species undetermined), in addition to being immune to PVXcp and APMV, was hypersensitive to PVX_{HB} (PVX resistance-breaking strain) and to PVY. The nature of its immunity to PVXcp and hypersensitivity to PVX_{HB} is under study. Preliminary results suggest a monogenic dominant control.

Seedling screening for resistance to PVY was continued this year. A total of 7732 seedlings were screened from which 69 percent were selected as being potentially immune to PVY.

Retesting immune selections. Potentially immune seedlings obtained in 1981 were evaluated in the field for agronomic performance; those selected in a second field evaluation were retested for immunity. Immunity to PVY^O (isolate T) or to PVXcp (Cockerham's PVX strain group 2) was determined by grafting potato plants with PVY-infected *Nicotiana occidentalis* or with PVX-infected *N. glutinosa* scions.

Eighty-two percent of 27 clones in two families and 49 percent of 35 clones in a third family were immune to both PVY and PVX. The lower percentage of immunity in the third family was due to adverse environmental conditions that prevailed during the test. Following the same procedure, reevaluation of original sources of immunity indicated that from 16 clones immune to PVX, 10 were also immune to PVY.

Sources of immunity to PVY used in CIP breeding programs are being tested against a wide spectrum of PVY isolates classified in the groups PVY^O, PVY^N, and PVY^C, as well as two strains of PVA. Current results indicate that one clone derived from *S. andigena* and three from *S. stoloniferum* remained immune to all PVY strains tested. However, clone XY 2.4, derived from *S. andigena*, was not immune to all strains and reacted with a high level of hypersensitivity to 5 of 17 PVY strains. Whereas most clones tested were immune to PVA, two clones (XY 2.4 and XY 12.1 from *S. andigena*) were susceptible. These results emphasize the importance of careful and thorough testing of sources of immunity for the breeding program.

ANTISERA DISTRIBUTION AND DETECTION OF VIRUSES

Antibody-sensitized latex was distributed this year to 22 countries to aid in virus detection in research and basic seed production programs (Table V-1). Whole antisera was requested by Brazil, Mexico, Tunisia, and Saudi Arabia. Successful purification of PLRV was accomplished using a mixture of pectinase and cellulase, and antisera to PLRV is now being produced at CIP.

The direct and indirect methods of ELISA were compared for the detection of PVY. The indirect variant, which is more laborious because three types of antisera are needed, was more sensitive than the direct method. The ELISA method, using monoclonal antibodies produced through a research contract with Station Federale de la Recherche Agronomique, Switzerland, is being tested at CIP. Because monoclonal antibodies with the broadest reactivity are being selected, their use should eliminate more effectively the "strain specificity" with some virus-antibody combinations reported on the ELISA direct method.

Some improvements on ELISA for detecting PLRV have been developed at CIP, including the adaptation of a procedure to re-utilize

Table V-1. Antibody-sensitized latex (ASL) used at CIP and distributed to different countries in 1982.

Country	ASL for viruses[a] PVX	PVY	PVS	APLV	APMV
Argentina	25	18	18	10	10
Brazil	226	226	226	5	5
Bolivia	12	12	12	12	12
Chile	10	10	10	10	
China	152	152	152	16	16
Colombia	156	161	150	70	70
Ecuador	135	135	135		
India	50	50			
Kenya	6	6	6		
Mauritius	2	2	2		
Mexico	81	81	81		
Nepal	23	30	30		
Pakistan	38	38	38		
Panama	25	25	25		
Peru	16	16	10	5	5
Philippines	157	157	157		
Saudi Arabia	2	2	2		
Thailand	25	25	25		
Tunisia	25	25	25		
Turkey	61	61	61		
Uruguay	5	10	5	5	
Venezuela	6	6	6		
	1238	1248	1151	133	133
CIP La Molina	466	714	529	379	337
	1704	1962	1680	512	450

[a]Amounts in ml (1 ml=80 tests).

ELISA microtiter plates by washing them with 0.2 M glycine-HCl, pH 2.2. Washed plates do not need to be coated with antibodies, a procedure that saves time and antisera.

DETECTION OF POTATO SPINDLE TUBER VIROID IN TRUE POTATO SEED

Research was initiated in 1982 to develop the best procedures for the sensitive diagnosis of potato spindle tuber viroid (PSTV) in true potato seed (TPS); however, routine detection of PSTV also continued based on polyacrylamide gel electrophoresis (PAGE). In one study, sensitivity was determined by inoculating tomato with extracts from 20 seed lots containing different proportions of PSTV-infected seeds. Symptoms did not develop in all inoculated tomato plants but when developed they were usually mild. PAGE tests done on inoculated tomatoes detected infections without symptoms, even in samples of 20 seeds in which only 3 were infected.

In other experiments conducted at CIP and at Beltsville, Maryland (U.S.), the tomato bioassay was compared to the nucleic acid hybridization test (cDNA or blot test) (Fig. V-1). The nucleic acid hybridization test detected 1 PSTV-infected seed in a lot of 16; whereas in

TISSUE SAMPLE

↓ Homogenize in 200 mM K_2HPO_4
10 mM DIECA
5 mM DTT
0.1% Triton X-100
Clinical centrifugation

CLARIFIED SAP

↓ Transfer 3-5 μl aliquot to nitrocellulose membrane
Bake 2 hrs at 80°C *in vacuo*

PSTV BOUND TO NITROCELLULOSE MEMBRANE

↓ Hybridization with (^{32}P) recombinant DNA
Wash at 55°C

(^{32}P) DNA-PSTV HYBRIDS BOUND TO NITROCELLULOSE MEMBRANE

↓ X-ray film
Intensifying screen

DETECTION OF HYBRIDS BY AUTORADIOGRAPHY

Figure V-1. Outline of nucleic acid hybridization procedure. DIECA, diethyldithiocarbamate; DTT, dithiothreitol.

comparative experiments, tomatoes were only able to detect PSTV when the lot contained 4 infected seeds (Table V-2). This test is considered more appropriate for large-scale testing; however, its inclusion as a routine test is under consideration.

Since 1978, approximately 3000 plants of commercial cultivars grown in the field in the central coastal valleys and the highlands—mainly the Mantaro valley of Peru—have

Table V-2. Comparative sensitivities of tomatoes and the nucleic acid hybridization test (cDNA) for detection of PSTV.

Treat-ment	No. seeds/treatment[a] Infected	Healthy	cDNA[b]	Tomato test[c]	PAGE
A	1	15	+	–	–
B	2	14	–	–	–
C	4	12	+	–	+
D	8	8	+	–	+
E	16	0	+	–	+
F	0	16	–	–	–

[a]Seeds imbibed in water for 5 days and macerated in 0.2 ml of extraction buffer.
[b]Three μl drops were dried on nitrocellulose membranes at 80°C and hybridized with PSTV(^{32}p)cDNA at a specific activity of $\sim 2 \times 10^8$ cpm/ml.
[c]An amount of 0.15 ml of extract was diluted 1/5 and inoculated onto tomatoes. Symptoms were read and presence of PSTV tested by PAGE 30 days later.

been examined for PSTV and found to be negative. Similar results have been obtained from examinations of more than 300 accessions of wild potato species. These observations provide strong evidence to consider PSTV as a pathogenic agent adapted to the potato outside its center of origin in the Andean region. Efforts should be made to prevent its introduction into this region. Because of PSTV's requisite of high temperature for replication and accumulation in plant tissues, it is unlikely that PSTV could become a problem under the cooler conditions of the Andes. It could, however, become a problem should it be introduced to lowland tropical conditions.

Figure V-2. Symptoms of the Solanum apical leaf curling virus (SALCV) on potato.

UNDESCRIBED AND LITTLE-KNOWN VIRUSES

A previously undescribed virus, Solanum apical leaf curling virus (SALCV), was found in Peru in 12 percent of first generation tubers grown from TPS in PLRV resistance trials at San Ramon. SALCV caused symptoms in the field similar to current-season PLRV infection, except that the symptoms were usually more severe (Fig. V-2). Infected plants also resembled those infected with the mycoplasma causing purple top wilt. The virus was found in naturally infected plants of *Solanum basendopogon, Solanum nigrum*, and *Nicandra physalodes* at San Ramon, and in *Physalis peruviana* at Yurimaguas. SALCV is not transmitted by aphids or mechanical means, and its vector has not yet been identified. *D. stramonium* and *Lycopersicon esculentum* are the best diagnostic and propagation hosts. The virus is tuber-perpetuated and limited to phloem tissues in the plant. Purified preparations contain particles *c*. 17x52 nm in which three isometric units are arranged in a straight chain (*see* Thrust V cover photograph). SALCV seems to be an unusual member of the gemini viruses group. The virus is highly immunogenic and an antiserum has been prepared permitting rapid identification of diseased plants by ELISA serology.

SALCV apparently occurs naturally in the jungle and represents an additional example of a plant disease that attacks plants introduced from areas of adaptation to exotic sites for production.

A new potyvirus (code-named UF), found in a clone of *S. andigena* at CIP, showed to be serologically distantly related to PVY^O or PVY^N and closely related to PVY^C-GI and PVY^C-AB. Primary symptoms in the potato consisted mainly of mosaic or systemic chlorotic blotches. Secondary symptoms included premature senescence of lower leaves with formation of green spots or rings and partial vein necrosis of leaf underside.

In 1981 it was reported that a filamentous virus was isolated from the clone Saco, which had yellow vein symptoms. Repeated attempts failed, however, to induce yellow vein symptoms in Saco plants with this virus, which indicated that it was not the cause of the disease.

A study was initiated to identify the vector of Andean potato mottle virus (APMV), since it is a virus that spreads rapidly in crops in the Andean region. Among the several insects tested, only *Diabrotica viridula*, a polyphagous beetle, transmitted APMV to all of the *Nicotiana clevelandii* plants on which it fed, after an acquisition access period of 24 hours.

CONTRACT RESEARCH

The Swiss Federal Agricultural Research Station at Changins, Switzerland, supplied enzyme-labeled and unlabeled anti-PLRV antibodies for more than 50,000 tests during 1982 for CIP's diagnostic needs. Samples of anti-potato PVM and PVY, the latter of monoclonal antibody origin, were also supplied for evaluation. Studies of the serological relationships of a range of PLRV isolates using traditional polyclonal and one source of monoclonal antibodies confirmed the close serological affinity between PLRV from several continents. Monoclonal antibodies improved considerably the sensitivity of ELISA.

Removal of nonconjugated enzyme molecules by Sephacryl chromatography improved the classical enzyme-antibody conjugation by inducing less nonspecific reactions in ELISA. The modified method offers the advantage that immunoglobulin purification and conjugation can be accomplished within two to three days. A simple, leaf sap extraction technique (grinding leaves in small plastic bags) introduced by CIP scientists was evaluated during an ELISA course in Beijing, People's Republic of China. A modification has been developed to facilitate large-scale routine serological identification of viruses.

Thrust VI

CONTROL OF IMPORTANT NEMATODE AND INSECT PESTS

Breeding and screening for resistance to major nematode and insect pests of the potato formed the principal research objective for 1982. Different genetic sources of resistance to the potato cyst nematode, *Globodera pallida*, to major races and species of the root-knot nematode, *Meloidogyne* spp., to the potato tuber moth, *Phthorimaea operculella*, and to other major pests were used to develop progenies with resistance to one or more of these pests. The identification of suitable biological, cultural, chemical, and physical control measures, as well as their integration into a sound, integrated pest management program, continued to be an integral part of Thrust VI activities.

A fungus, *Paecilomyces lilacinus*, that parasitizes nematodes was used in field control of the nematode species *Meloidogyne*. Good results from this control method have been obtained in Panama, Peru, Costa Rica, Philippines, and the United States. Studies of biological control of the potato tuber moth in stores showed that active spores of the bacteria *Bacillus thuringiensis* were more effective in controlling this insect than a synthetic pyrethroid spray. In field plot studies, large-scale trappings of potato tuber moth using synthetic sex pheromones reduced tuber damage to 19 percent, compared to 42 percent in plots receiving conventional insecticide application. A yellow sticky trap, developed to control the leaf miner fly, *Liriomyza huidobrensis,* significantly reduced fly population and plant damage when placed in farmers' fields.

Tuber infestation by potato tuber moth was significantly greater in sole potato plots compared with potato in association with onion, tomato, green beans, soybean, and corn. Damage due to potato flea beetle, *Epitrix* sp., was significantly less on potato-wheat and potato-corn plots compared with damage on sole potato plots. Reproduction of *G. pallida* was greatly reduced in potato associations with carrot, lupine, marigold, horse beans, or peas. On both acid and alluvial soils, potato-rice plots were significantly less damaged by the leaf beetle, *Diabrotica* sp., than the sole potato plots. *Lantana* sp. leaves and *Ochroma lagopus* ash were highly effective in repelling aphids, *Myzus persicae*, in stored potatoes.

NEMATOLOGY

POTATO CYST NEMATODE

The identification of resistance to *Globodera* spp. must be based on an efficient and reliable screening technique, whether tubers or true potato seed.

To improve the efficiency of screening tubers for resistance to potato cyst nematode (*G. pallida*), several techniques (pot test, closed container and petri dish tests) were reevaluated. The pot test is the technique routinely used at CIP. The numbers of immature females on the root-ball of inoculated plants and the final nematode population density are used as criteria in determining resistance to *G. pallida*. The pot test, however, was not always reliable because of low sensitivity. This was improved (Fig. VI-1) by

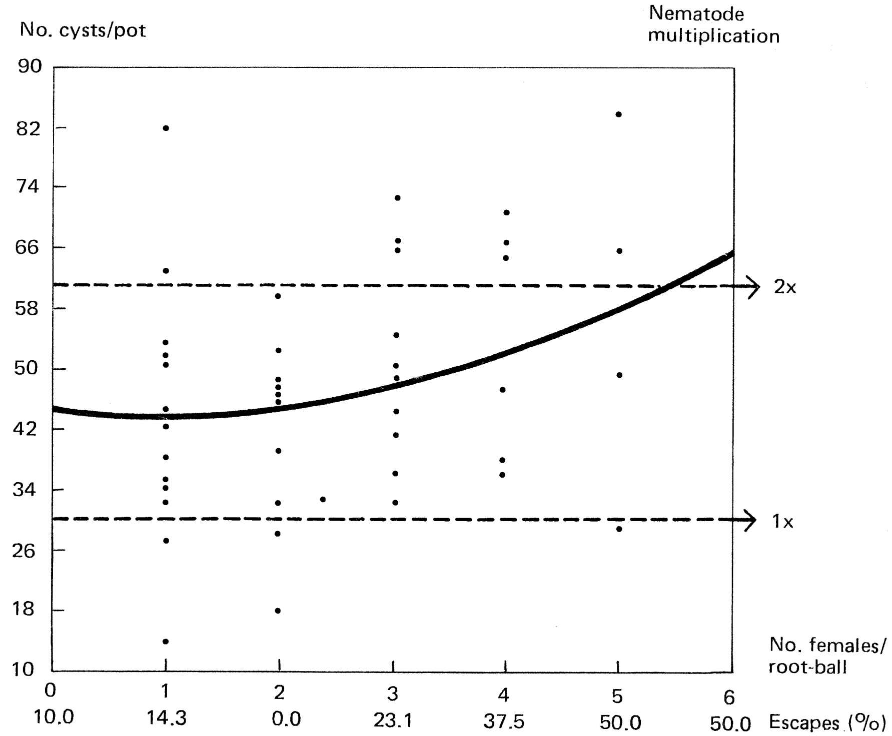


Figure VI-1. Relationships between number of immature females on root-ball and number of cysts per pot in a tuber test of resistant clones.

scoring plants with no more than two females on root-balls as resistant (0% to 14.3%). Previously, up to five females per root-ball were considered as resistant (23.1% up to 50.0%).

The petri dish test is very precise but its value in mass screening is questionable, since it is very time-consuming. This test, however, is quite valuable when used to confirm the resistance of a few selected clones and in studies involving the parasitism and biology of nematodes.

Seedlings from true potato seed (TPS) were screened for resistance to *G. pallida*. Progenies from three crosses previously tested and possessing different segregation for resistance were compared by using different numbers of seedlings inoculated with cysts of pathotype P_4A of *G. pallida* at two different times. Results indicated no significant differences between number of seedlings tested, but significant differences were noticed between progenies from different crosses. There were no significant differences whether plants were inoculated at transplanting or 15 days later.

The same three previous progenies were inoculated with different numbers of cysts at two different times to estimate nematode multiplication rate. The rate was significantly affected by inoculum densities higher than five cysts per pot in progenies with medium and low segregation for resistance (Fig. VI-2). This effect was due to excessive root damage and the resulting competition of nematodes for feeding sites.

Inoculating plants with a low density of nematodes at transplanting was more satisfactory than inoculating plants after transplanting (Fig. VI-3), possibly because the

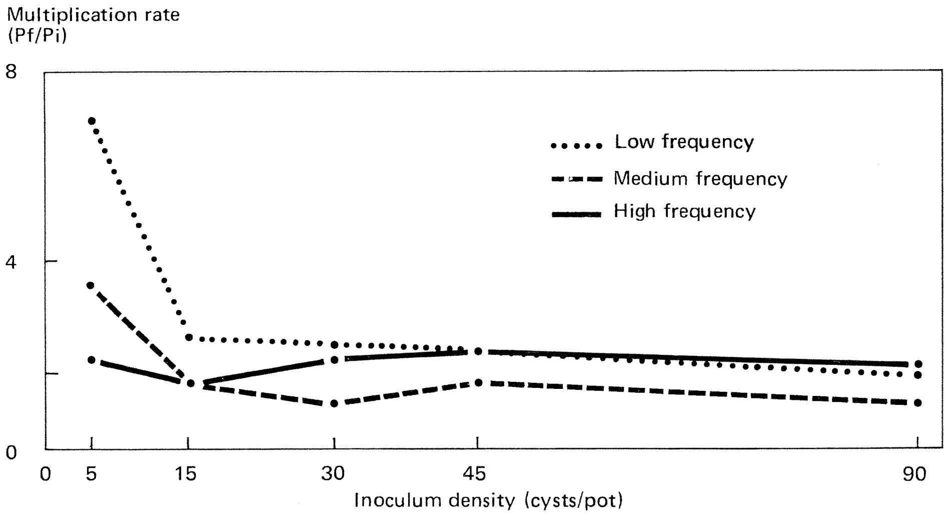


Figure VI-2. Nematode multiplication rate on three seedling progenies with low, medium, and high frequencies of segregation of resistance at several inoculum densities.

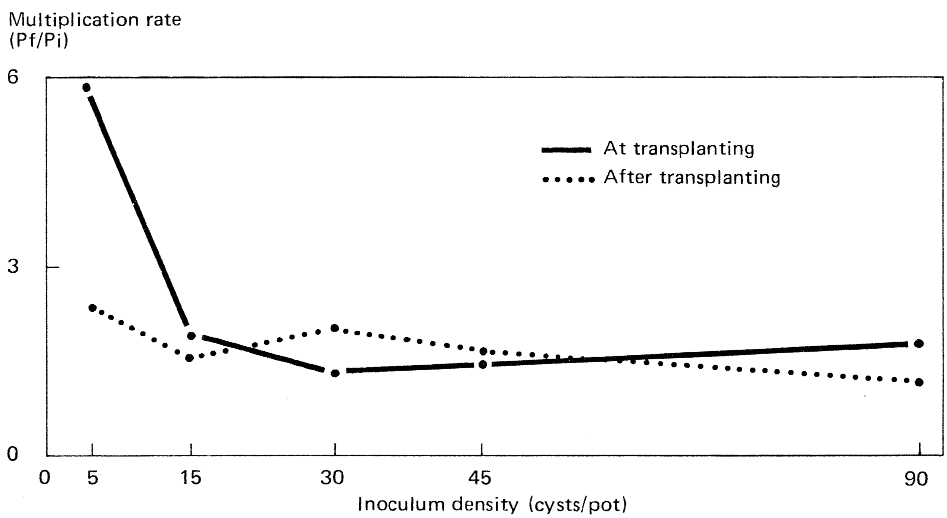


Figure VI-3. Nematode multiplication rate on seedlings at transplanting, after transplanting, and at several inoculum densities.

Evaluation of cyst nematode in pot tests.

time for full nematode development was shorter (5.88 as compared to 2.38). However, plants inoculated with excessively high nematode densities at transplanting did not allow good establishment or development of nematodes due to extensive root damage.

Even though the nematode multiplication rate was lower in mass screening (flat tray, square or circular containers), compared to individual seedling screening tests (cups), it was possible to detect resistance frequencies (Table VI-1). The percentage of resistant seedlings and nematode multiplication rate determined by both mass and individual seedling screening had a similar quadratic relationship and high negative correlations ($r = -0.95$ and -0.81, respectively). This supports the effectiveness of mass seedling screening in containers, although for practical purposes the most suitable seems to be the flat tray.

In breeding for tuber resistance to *G. pallida*, even though resistance

Table VI-1. Effect of interaction between different containers and seedling progenies with three frequencies of resistance on the nematode multiplication rate.

	Resistance (P_f/P_i)			
Container	High	Medium	Low	Mean
Flat tray	1.25	1.60	5.40	2.75
Square	1.65	2.75	6.28	3.56
Circular	2.43	3.13	6.46	4.01
Cups	3.78	3.53	11.88	6.40
Mean	2.28	2.75	7.51	

Between treatments in main part of Table:
$LSD_{.05} = 0.50$
$LSD_{.01} = 0.67$

is controlled polygenetically and is inherited independently for each pathotype, combined resistance was obtained by intercrossing clones with resistance to individual pathotypes. These clones were resistant in field trials conducted in Peru, Ecuador, and Colombia.

ROOT-KNOT NEMATODE

Only 7 clones of 77 accessions from the CIP germplasm collection—clones previously reported as resistant—continued to show moderate resistance to root-knot nematode (*Meloidogyne* spp.). All advanced clones in the pathogen-tested collection, as well as those from tuber families and in vitro cultures, are susceptible to the root-knot nematode group *Meloidogyne incognita*.

Clones of several 4x-2x families with *Solanum sparsipilum* parentage, which were originally selected for resistance to *M. incognita* and later for potato tuber moth resistance, were crossed with material adapted to the hot tropics. A total of 432 progenies were selected as having good agronomic characteristics. Twenty of these were highly resistant to *M. incognita*, while 86 had an acceptable level of resistance. Further field tests will be conducted prior to their use in the breeding program.

Diploid hybrid progenies derived from crosses of *S. sparsipilum, S. chacoense, S. microdontum, S. phureja*, and *S. stenotomum*—which were selected for resistance to *M. incognita* (4 races), *M. arenaria* (2 races), *M. javanica*, and *M. hapla*—were crossed with haploids (2n=2x=24) of *S. tuberosum*. Progenies (1254 genotypes) of these crosses were tested for resistance to *M. incognita* and over 57 percent were highly resistant. This high level of resistance was due to increasing the resistant-gene frequency by four and five cycles of recurrent selection. These results confirmed the effectiveness of the breeding method used to produce new genotypes resistant to these important nematodes.

BIOLOGICAL CONTROL

On-farm trials to test control of nematodes such as *M. incognita, Radopholus similis, Globodera rostochiensis*, and *G. pallida* in potato and other crops, using *P. lilacinus*, were conducted in different countries. In the province of Herrera, Panama, the control of *M. incognita* on tomatoes by *P. lilacinus* was tested on a large-scale basis. The fungus-treated plots had higher yield than control plots and those treated with Carbofuran (Fig. VI-4). In experiments to control *G. rostochiensis* conducted in Cerro Punta, Panama, the results in yield were similar to the previous experiment.

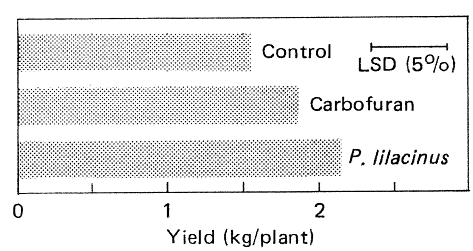


Figure VI-4. Effects of different treatments on yield of tomatoes.

Under greenhouse conditions, the effects of various inoculum concentrations of *P. lilacinus* used in two different inoculation periods on *G. pallida* cysts were investigated. The results indicated that a significantly higher percentage of *G. pallida* eggs hatched in the control or non-inoculated cysts as compared to those inoculated with the fungus. Approximately 50 percent of the apparently healthy *G. pallida* eggs were either infected or damaged by *P. lilacinus* during these two experimental periods. Further experiments are necessary to substantiate possible fungitoxic activity of *P. lilacinus* on nematodes.

ENTOMOLOGY

POTATO TUBER MOTH

Tetraploid progenies derived from 4x - 2x crosses selected for potato tuber moth (PTM) resistance were crossed to lowland tropical clones. In field trials 500 clones were selected; further screening under storage conditions resulted in 17 being selected as resistant. Three of these clones (281605.2, 281611.2, and 281611.14) showed no PTM damage in further field trials. From a group of 173 primitive cultivars subjected to field and storage trials, 16 were selected as resistant to PTM.

Rustic potato stores in nine districts of the Mantaro Valley, Peru, were evaluated and checked for PTM; *Symmetrischema plaesiosema* (Turner) was found to be the major PTM species. Traditional pest control practices used by farmers in the Mantaro Valley such as the use of *Minthostachys* sp., *Eucalyptus* sp., *Spartum junceum, Schinus molle*, and straw and lime dust reduced tuber damage to less than 15 percent in ware and seed potatoes. Traditional practices were also studied in storage trials at San Ramon. Native weeds such as *Lantana* sp. and *Minthostachys* sp. were used to repel PTM, which resulted in significant reduction of sprout damage by PTM and tuber rot (Table VI-2).

Two parasite species of the genus *Apanteles* (Braconidae), found in Peru, were confirmed through the assistance of the Universidad Nacional Agraria (UNA), Peru. The American Entomological Institute, Michigan (U.S.), identified two new species belonging to the genus *Temulucha* (Ichneumonidae), also found in Peru. In the area where these three parasites were found, parasitism of PTM larvae on potato foliage ranged from 29 to 52 percent.

The biological insecticide Dipel (3.2% wettable powder), which contains active spores of *Bacillus thuringiensis*, significantly reduced PTM tuber damage and subsequent

Table VI-2. Effects of traditional control practices against potato tuber moth.

Treatment	Sprout damage (%) Storage period (days) 60	120	Tubers rotted at 120 days (%)
Lantana sp.	11	24	11
Minthostachys sp.	14	36	14
Cymbopogan citratus	32	46	14
Rice straw	32	45	20
Wood ash	33	54	19
Lime	34	60	11
Check	54	74	32
LSD 0.05	10	12	12

rotting when sprayed as a 0.5 percent solution on tubers prior to storage.

Studies were made on the use of dry-funnel sex pheromone traps to control PTM as an alternative to water traps. No significant differences were observed in PTM capture when these traps were tested at ground level and at 40 cm and 80 cm heights. The dry-funnel traps were as effective as water traps, with the added advantage of requiring less field care. Mass trapping studies, which involved placing one dry-funnel trap/225 m² over an area of 5000 m², were conducted at La Molina during the summer. One application of Tamaron was applied to the sex pheromone-treated plots. At harvest, tuber damage in pheromone-treated plots was 19 percent compared to 42 percent in control plots that received normal insecticide applications only. There was significantly lower larval infestation (6 vs 9.4 larvae/plant) in the foliage of plots treated with sex pheromones; a total of 92,000 male moths were captured in 112 days using 21 traps. In storage trials at San Ramon, two funnel traps placed inside each store at the same height as the stacked crates significantly reduced male moth populations and tuber and sprout damage.

Several ratios of PTM 1+PTM 2 at 1 mg loading were tested under field conditions using the pheromone dry-funnel trap. Emphasis was placed on determining mixtures that used only a small quantity of PTM 2 to reduce the cost of the rubber septa. A 9:1 ratio of PTM 1:PTM 2 (0.90 mg:0.10 mg) was found to be an effective and inexpensive combination. Studies are in progress to determine the period of effectiveness of the sex pheromones when used under field conditions.

GLANDULAR TRICHOMES

A screening test using mites (*Tetranychus* sp.) was developed in collaboration with Cornell University, New York (U.S.), to identify clones with high densities of insect-trapping glandular trichomes (epidermal hair structures on plants). Several clones from F_3 families of *S. tuberosum* x *S. berthaultii* having less than 10 percent foliar damage by mites were identified; whereas F_2 seedlings of *S. andigena* x *S. berthaultii* and *S. tuberosum* x *S. berthaultii* had more than 10 percent foliar damage by mites. Future selection will concentrate on F_3 progenies because of the higher selection rate. Thirty-five F_2 families were produced by crossing tetraploid progeny having trichomes with clones resistant to cyst nematode and frost. Only seven clones, with less than 10 percent foliar damage by mites, have been selected for further crosses.

LEAF MINER FLY

Several traps to monitor and control the leaf miner fly, *Liriomyza huidobrensis*, were designed and tested during the winter season at La Molina. For population monitoring, a yellow sticky trap (16 cm x 16 cm, 60 cm height) proved to be very effective. Similar traps (30 cm x 60 cm) are being used in mass trapping studies to determine their effectiveness as a control method. Preliminary results indicated: a) the traps could capture as many as 16-18,000 adults in three days (Fig. VI-5), and b) the leaf miner fly population was significantly reduced in plots with traps in comparison to plots without traps (2.0 vs 9.0 leaf miner flies/plant, respectively).

The resistance of this pest to synthetic pyrethroids was studied using Fenvalerate at 0.2 and 0.4 percent of the commercial formula. An "immersion" method was developed that is practical and permits uniform exposure of the insects to the insecticide being studied. Results from these studies indicated that leaf miner fly developed high levels of resistance to Fenvalerate. Tests are in progress to determine if other insect populations collected from potato fields sprayed with insecticides have developed similar resistances.

PEST MANAGEMENT

Research focused on identifying pest management components that could be incorporated into acceptable, integrated control packages.

CHEMICAL CONTROL

Two factors that affect the efficiency of chemical control are droplet size and droplet distribution, both of which influence deposition and retention of spray particles. For example, potato plants sprayed with an ultra-low volume (ULV) sprayer

Figure VI-5. Yellow sticky trap used in mass trapping of leaf miner fly.

had significantly less damage by leaf miner fly and higher yields than plants sprayed by a hand-operated backpack sprayer. For the same unit area, a hand-operated sprayer used 11.3 times more spray solution than the ULV sprayer, which means immense savings in the quantity of chemical used.

CROP ASSOCIATION

A number of studies were set up at various sites in Peru representing diverse ecologies of potato cultivation. At the La Molina site, tuber infestation by PTM in sole potato plots was significantly higher compared with potato in association with other crops (Fig. VI-6). In similar tests conducted in Huancayo, association of potato with wheat and corn significantly reduced infestation by the potato flea beetle (*Epitrix* spp.). Reproduction of *G. pallida* was also greatly reduced in potatoes associated with carrot, marigold, horse beans, and peas; however, *G. pallida* increased in potatoes associated with onions and corn (Fig. VI-7).

In experiments conducted on alluvial soils, damage to tubers by the leaf beetle (*Diabrotica* spp.) was reduced by 6 percent in potatoes grown in association with rice; the damage increased slightly in association with soybean. In acid soils, however, tuber damage was reduced in potatoes grown in association with soybean (29%), rice (47%), or corn (36%).

In storage trials on aphid control, *Lantana* sp. leaves and *Ochroma lagopus* ash were placed around the tubers. These two treatments repelled aphids and resulted in less than two aphids per sprout as compared with an average of 10 aphids per control sprout.

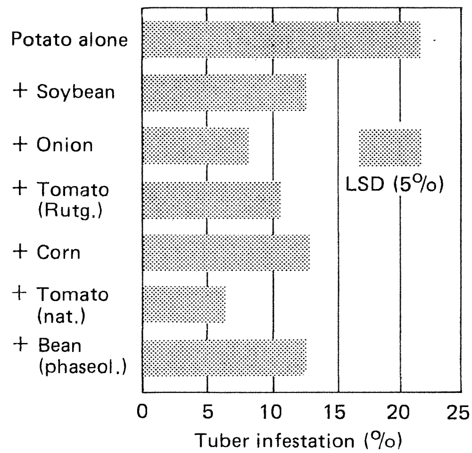


Figure VI-6. Potato tuber moth infestation on potatoes grown in different crop associations, La Molina.

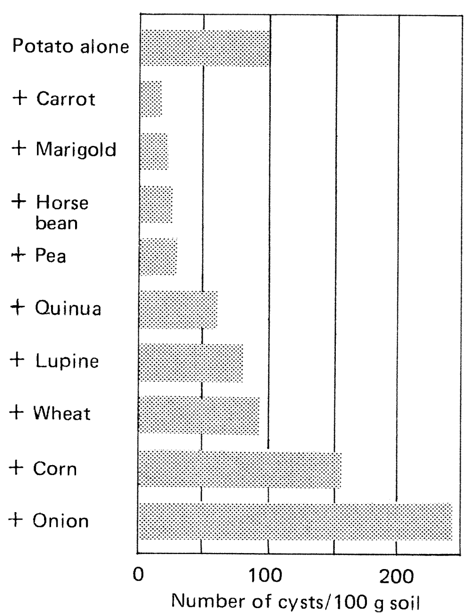


Figure VI-7. Effects of crop association on reproduction of potato cyst nematode.

An integrated pest control program was established to control insects and nematodes using a cropping sequence that included potatoes, beans, and corn. Reduced applications of pesticides used in combination with biological control agents and pheromones significantly reduced crop damage by these pests.

CONTRACT RESEARCH

New techniques in nematode research developed at the Foundation for Agricultural Plant Breeding (SVP), Wageningen, the Netherlands, produced a new apparatus for washing soil samples that is superior to the Fenwick can. An electronic nematode counter has also been developed. Additional materials with resistance to Pa-2 and Pa-3 strains of cyst nematodes have been identified.

Among 16 nematicides tested at Oregon State University, United States, liquid formulations of fenamiphos and oxamyl were found to be the most effective in treatment of both seed tubers and pelletized true seed. Preliminary results from studies to determine nonphytotoxic rates of fenamiphos have indicated a substantial reduction of root-knot galls at a rate of 0.125 to 5 percent. Aldicarb, oxamyl, and sulfone were effective in pelletized true seed treatments.

Tomato and okra treated with the fungus *P. lilacinus* for control of nematodes (*Meloidogyne* spp.) showed average yield increases of 30 percent. This research is part of the continuing evaluation of fungal parasitism of *Meloidogyne* egg masses that is being conducted as part of the International Meloidogyne Project at North Carolina State University, United States. The fungus was most effective in suppressing root-knot nematode populations up to midseason, presumably due to the relatively large population of nematode eggs early in the season.

Thrust VII

PHYSIOLOGICAL AND AGRONOMIC MANAGEMENT OF POTATOES

Agronomic research on growing potatoes from true potato seed (TPS) concentrated mainly on seedling production techniques, seedling establishment, and progeny evaluation. At the seedling production stage, different seedbed substrates were investigated. Best results were obtained with seedbeds having a high proportion of organic matter and a proper content of NPK fertilizer. When seedlings were grown in root blocks, seedling establishment was generally superior to that of normal transplanted seedlings. Studies of temperature effect on seedling growth showed that 20°/10°C day and night temperatures were optimum for the genotypes being studied.

Seedling establishment after transplanting showed marked differences between progenies recovering from transplant shock. Also studied were the benefits of using relay crops to reduce soil temperature during seedling establishment, insect control, timing of nitrogen application, and soil temperature modification by mulching. A total of 155 TPS progenies were evaluated during the year and 45 selections were grown in three different environments.

A group of cultivated and wild potato species from a wide range of altitudes were examined to determine the relationship between tolerance to temperature extremes and the rate of induced chlorophyll fluorescence. Clones identified as tolerant to high or low temperature extremes (0° or 40°C) corresponded to their known altitude range. Clones adapted to heat had a higher capacity to withstand general environmental stress. Wild species from the altitude range of 450 m to 4200 m had an increasing cold tolerance and decreasing heat tolerance as the altitude increased. Diploid and triploid species were more cold-tolerant than tetraploid clones or cultivars.

Further studies were made on management of the potato under high temperature conditions during the first critical month after planting. Management factors that favored early emergence and canopy development included: dark storage of tubers, planting in beds, mulching, shading by intercrops, and liming to reduce aluminum toxicity, which is encountered in 30 percent or more of tropical soils. Quick emergence, rapid branching, and large leaf size favoring fast ground cover for soil temperature modification should be combined with early maturation. However, in genotypes that emerged and covered the soil surface more slowly, delayed tuber initiation was generally accompanied by a greater leaf area during the tuber bulking period, as well as increased tuber yield within the same maturity period.

POTATOES FROM TRUE POTATO SEED

Agronomic research concentrated on those factors that appeared most critical for the potential adoption of true potato seed (TPS) technology. Preliminary experiences in farmers' fields in four vegetable growing areas of Peru have contributed to a more accurate assessment of required characteristics for

Figure VII-1. Potato production from TPS in a farmer's field, Tarma, Peru: a) plant stand 50 days after transplanting, b) harvest.

TPS technology. The farmers' fields were located in three coastal areas of intensive farming: Cañete, Huachipa and Callao, and a highland, vegetable-growing area in Tarma (Fig. VII-1).

SEEDLING PRODUCTION

At the seedling stage, the fertility and structure of the seedbed substrate as well as seedling management practices have been shown to be important in improving the production of good quality seedlings. Thirteen different seedbed substrates, composed of available materials and fertilizers, were evaluated under different environments; for example, a compost of decomposed fodder corn and manure, used either alone or mixed with soil and fertilizer, resulted in good seedling growth. In general, best results were obtained in seedbeds with a high organic matter content, especially when fertilized (Fig. VII-2). However, in most of the experiments farmers' seedbeds that were comprised of soils of appropriate fertility levels and structure produced potato seedlings of acceptable quality (Fig. VII-3). In all of these soils, organic matter—usually in the form of manure—had been periodically incorporated by the farmers.

Phosphorus (P) requirements increased with an increase in seedling density. Using a peat moss/sand

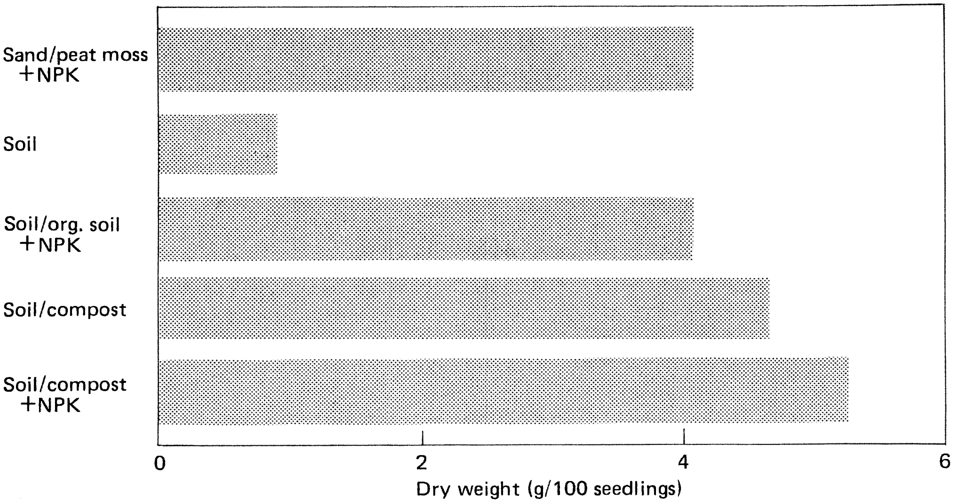


Figure VII-2. Dry weight of tops of potato seedlings grown for 30 days in different substrates.

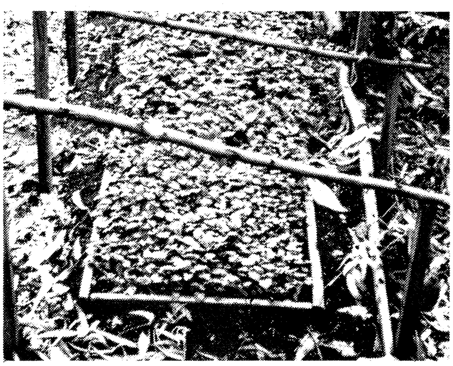


Figure VII-3. Potato seedlings ready for transplanting in a farmer's field, Tarma, Peru.

mix (1:1 by volume), the response of three density levels to increasing rate of P was analyzed. At a seedling density of 500 plants/m^2, rates of P_2O_5 up to 100 ppm produced best seedling growth; greater rates of P did not produce additional growth. At seedling densities of 1000 and 2000 plants/m^2, P_2O_5 requirements increased considerably for best seedling growth. In a soil of low pH (pH 5.2), typical of soils from many regions in the tropics, sturdier potato seedlings were produced by the addition of diammonium phosphate and triple superphosphate. These fertilizers were more effective than rock phosphate, single superphosphate, or an organic source of phosphorus.

Proper seedling management is particularly important in areas of heat stress, typified by conditions at San Ramon during the summer season. Under heat stress, root blocks (Fig. VII-4) to reduce transplant shock significantly improved seedling survival and yield when compared with normal transplanting methods (Table VII-1). Root blocks of peat moss and sand promote growth of adventitious roots at the expense of the tops, which is a favorable characteristic for transplanting. Different materials that have been evaluated and have shown excellent characteristics for

Table VII-1. Effect of using root blocks on seedling survival and yield of potatoes during two seasons at San Ramon.

Transplant method	Seedlings per block/hill	Winter		Summer	
		Survival (%)	Yield (t/ha)	Survival (%)	Yield (t/ha)
Root block	2	89 a*	14.4 a*	90 a*	9.9 a*
Root block	4	90 a	14.7 a	92 a	11.2 a
Normal	2	88 a	16.8 a	78 b	7.2 b
Normal	4	92 a	15.5 a	81 b	7.9 b

*Means followed by the same letter are not significantly different at 5% level.

root block composition are 1) compost alone, or mixed with soil and fertilizers, 2) soil of high organic matter content (approximately 70% organic matter), and 3) a mix of shredded peat moss, soil, and NPK.

In an experiment conducted in a farmer's field on the coast of Peru, potato seedlings were transplanted using both root blocks and normal transplants. No differences in seedling survival were observed; however, plants from root blocks yielded 21.5 t/ha compared to 14.8 t/ha of plants from normal transplanted seedlings. Although seedling survival was not affected by the method of transplanting, the use of root blocks probably accelerated growth recovery.

High temperature is an important factor that affects seedling growth and later establishment in the field. The effect of different day/night temperature regimes on the development of potato seedlings was studied under controlled conditions: regimes were all combinations of 20° or 30°C day with 5°, 10°, or 20°C night. Light intensity was 2500 foot candles for a duration of 12 hours, and relative humidity was kept constant at 70 percent. The best combination in

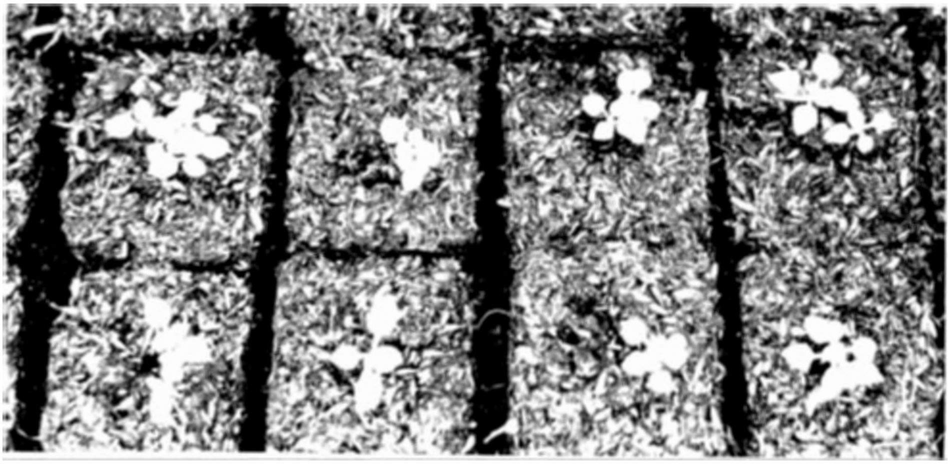
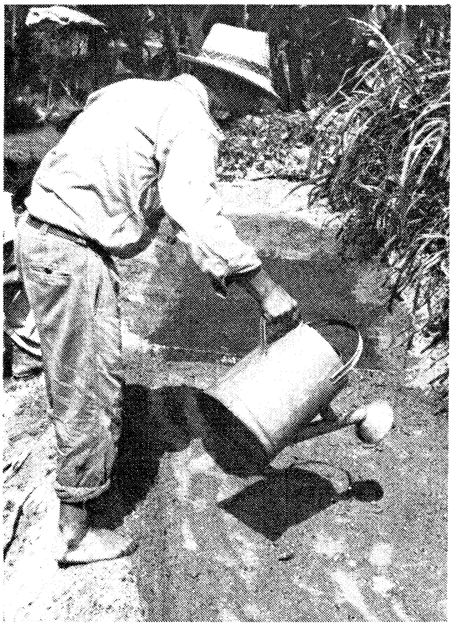


Figure VII-4. Ten-day old seedlings grown on root blocks.



On-farm trials have been used for identifying important agronomic characteristics that potatoes for TPS should have to best suit farmers' conditions.

terms of seedling development was 20°/10°C day and night temperatures for the particular progeny (DTO-33 open-pollinated) under study (Fig. VII-5).

Seedbed temperatures in hot environments can be reduced consid-

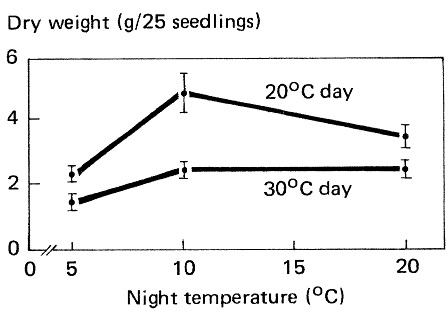


Figure VII-5. Dry weight of seedling foliage (35 days after sowing) at different day and night temperature combinations.

Table VII-2. Effect of different periods of shading after sowing on emergence, height, and stem diameter of seedlings.

Days of shading	Emergence (%)	Seedling height[a] (cm)	Stem diameter[a] (cm)
0	86.3 b*	6.1 b*	0.23 b*
10	89.0 b	8.0 ab	0.27 a
15	92.8 ab	9.4 a	0.26 a
20	97.0 a	10.8 a	0.23 b
35	98.0 a	9.6 a	0.22 b

[a]Data taken 35 days after planting.
*Means followed by the same letter are not significantly different at 5% level.

erably by shading. A higher rate of uniform seedling emergence and sturdier plants was produced in San Ramon when the seedbed was shaded to a level of 70 percent of transmitted light for periods of 15 to 20 days after sowing (Table VII-2). In longer shading periods, elongated and thin seedling stems were produced.

SEEDLING ESTABLISHMENT

Seedling survival after transplanting was greatly improved by transplanting under proper climatic conditions and by good seedling management. Seedling establishment was influenced by the progeny reaction to environmental conditions present at the time of transplanting. Marked differences among the progenies were observed in their ability to recover from transplant shock; a transplant-sensitive progeny (DTO-33) took longer to return to its original growth rate than a more tolerant progeny (Atzimba x R128.6) (Table VII-3).

For effective seedling establishment, it is important that insect

Table VII-3. Growth rate per seedling the day of transplanting (GRT) and period needed to recover that rate (PRR), in two TPS progenies and two seasons, Lima.

	Winter		Spring	
Progeny	GRT (g/day)	PRR (days)	GRT (g/day)	PRR (days)
DTO-33	0.14	19.4	0.17	13.2
Atz x R128.6	0.12	12.7	0.13	10.3

damage be reduced to a minimum. Various insecticides and application methods at transplanting were evaluated in San Ramon where the activity of cutworms and foliar-feeding insects is greatly enhanced by the warm, humid environment. The seedlings were protected during the establishment period by several insecticide treatments, which caused significant improvements in seedling survival and yield (Table VII-4).

Nitrogen (N) applied to soils of low N content hastened the recovery of seedling growth after transplanting. In San Ramon, for example, the application of 150 to 300 kg/ha of N resulted in vigorous growth of seedlings after transplanting and in higher yields at harvest. Half of the N was applied at transplanting and the other half at hilling. Manure incorporated into the soil at transplanting at the rate of 20 t/ha increased final yields, but did not significantly affect early growth after transplanting (Table VII-5).

Table VII-5. Yield of potatoes from transplanted DTO-33 seedlings as affected by rates of nitrogen (N) and manure applications.

N rates kg/ha	Manure rates 0	Manure rates 20 t/ha	Mean yield (t/ha)
0	19.1	24.3	21.7 b*
150	22.1	27.8	25.3 a
300	21.5	26.8	24.2 a
450	20.5	23.1	21.8 b
Mean yield (t/ha)	20.8 b*	25.5 a	

*Means followed by the same letter are not significantly different at 5% level.

PROGENY EVALUATION

Of 155 progenies evaluated during the year, 45 were grown in three different environments and selected for uniformity, yield, and improved tuber size distribution. Also, new emphasis is being placed on the identification of high-yielding, open-pollinated progenies. However,

Table VII-4. Effect of different insecticides on survival and yield of DTO-33 seedlings during winter season, San Ramon.

Insecticide	Method of application	Seedling survival (%)	Relative yield (%)
Furadan 75 WP	Plant base sprayed	85.7 a*	170 a*
Lannate	Plant base sprayed	89.0 a	168 a
Aldrin 2.5%	Powdered on ridge	85.0 a	166 ab
Sevin 20%	Powdered on ridge	83.3 a	138 bc
Ambush	Plant base sprayed	72.3 b	148 bc
Bait (Dipterex 20%)	Band application	69.7 bc	132 c
Temik 10 G	Hole for transplant	61.0 c	86 d
Sevin 80%	Plant base sprayed	61.0 c	80 d
Control		63.3 bc	100 d

*Means followed by the same letter are not significantly different at 5% level.

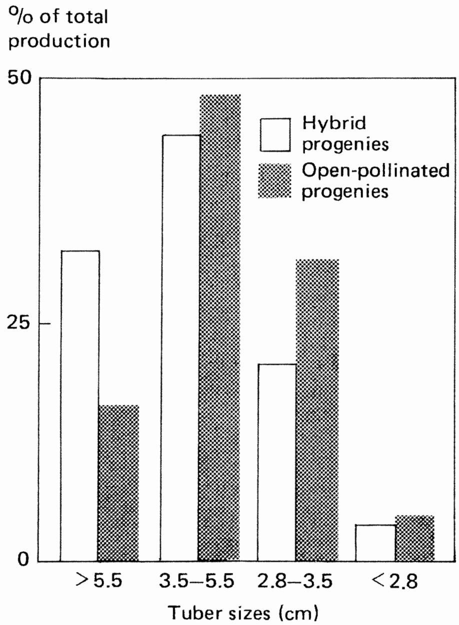


Figure VII-6. Proportion of different-sized tubers produced by the three highest yielding hybrids and open-pollinated progenies in the winter, Lima.

when the proportion of different-sized tubers produced by the three highest yielding hybrids or open-pollinated progenies was compared, the advantage of the hybrids was evident (Fig. VII-6).

POTATO ADAPTATION TO TEMPERATURE STRESS

Through a consultancy to Thrust VII, the possible relationship between tolerance to high or low temperatures and the rate of induced chlorophyll fluorescence was studied in a group of potato clones and several wild potato species collected from a wide range of altitudes in Peru. The cultivars evaluated were considered to be adapted to warm or cool climates. Heat and cold tolerances were determined by the decrease in the rate of induced chlorophyll fluorescence in mature leaves heated at 41°C for 10 minutes, or kept at 0°C. With one exception, clones identified by the test as tolerant to either temperature extreme corresponded to their known adaptation range. Cold tolerance was closely correlated with heat tolerance, indicating a higher capacity in clones adapted to hot temperatures to withstand general environmental stresses.

A *Solanum phureja* accession collected at low altitudes in the Andean region showed a heat tolerance similar to those clones adapted to heat; whereas highland cultivated species had a lower tolerance. In wild potato species collected from altitudes ranging from 450 m to 4200 m, cold tolerance tended to increase with increasing altitudes but heat tolerance decreased. These two contrasting adaptations, however, were not closely correlated and appeared to vary independently of each other in response to climate. Diploid and triploid cultivated species were considerably more cold tolerant than tetraploid clones or cultivars.

CROP MANAGEMENT IN THE HOT TROPICS

Additional studies were carried out on techniques with the potential for reducing soil temperature during the first month after planting—a period that is critical for crop establishment. One example of the techniques being tested is manipulation of tuber physiological development before planting. Tubers stored in the dark and planted without desprouting had faster plant emergence than those stored for the same duration (40 days) in diffused light. Other positive results of the 40-day dark storage that benefited tuber yield were earlier tuber initiation, greater leaf area at tuber initiation, and a longer bulking period.

Traditional techniques already successfully used to reduce soil temperature and improve yield, such as mulching and shading, also have added advantages. Mulching suppressed weeds and reduced the need for hilling; both weed suppression and no hilling represent reduction in labor input. Dried grass mulch treatment applied during the rainy season was compared to two weeding treatments, herbicide and manual (Fig. VII-7). Yields of the mulch treatment were greater than the herbicide and once-weeded treatments, particularly for the clone DTO-33.

Under hot conditions, mulching can obviate the need for hilling, thus root disturbance and the likelihood of bacterial wilt infection are reduced. Preliminary data from the dry season indicated less incidence of bacterial wilt in non-disturbed (i.e., without hilling) plots. There is evidence, however, that mulch used during the rainy season has a tendency to enhance

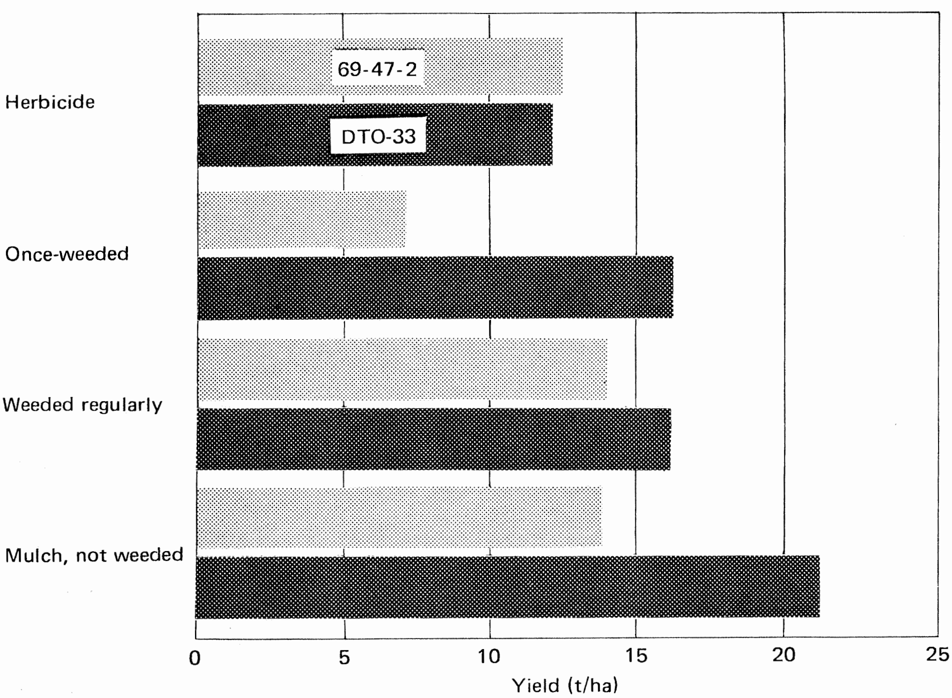


Figure VII-7. Yield of two potato clones (69-47-2 and DTO-33) affected by mulch and weed control.

bacterial wilt incidence. The latter was probably due to maintenance of moist conditions in the soil conducive to infection. Another technique used for reducing bacterial wilt incidence is crop rotation: the objective is to break the natural carry-over cycle of the organism. Tests were conducted on a heavily infested soil, using a nine-month crop rotation with either a pasture grass (*Brachieria* sp.), or with rice followed by maize. These rotation systems significantly reduced in the next season the initial loss of potato plants due to bacterial wilt. This work remains of high priority, since the presence of bacterial wilt normally negates the beneficial effects of other agronomic treatments.

When the potato is planted, shading the soil reduces soil temperature and improves plant emergence. Best results were obtained when the potato was planted within senescing intercrops. Although the intercrop reduced the available light for the potato during the period of shading, earlier emergence and a quicker ground cover enabled the shaded potato to intercept more radiation per unit land area than the control. The ideal situation was to reduce the intercrop shade component to zero, either naturally or by harvest, just after complete potato cover. Shade provided by intercrops also has the potential for reducing pest and disease incidence. For example, although yields of potatoes intercropped in Yurimaguas did not differ significantly from the potato monocrop, the proportion of insect (*Diabrotica* spp.) damaged tubers was reduced by more than 50 percent in intercropped plots.

The effectiveness of various maize-planting densities and spacing patterns on yield of intercropped potato was studied. The interrelationships among maize-planting density, percent of transmitted light, and soil heating were studied. Transmitted radiation, independent of the spacing patterns, was inversely related to maize stem-planting density. The amount of soil heating was also linearly related to the amount of radiation reaching the soil surface. Therefore, a range of soil temperatures, as a result of differing shade intensities, can be effected by manipulation of maize stem density. Studies comparing the effectiveness of short periods of dense shade versus longer periods of sparse shade indicated much variation between clones in their rates of emergence and tuber yields.

Effective liming is an important consideration for achieving optimum potato yields on acid soils. Lime reduces the toxic effect of aluminum on root development and acts as a source of calcium for the plant in otherwise deficient soils. Tuber yield response to different lime rates increased with depth of incorporation, but deeper soil tillage without lime incorporation also enhanced tuber yields. Although the heaviest (2.2 kg/m^3 of soil) lime rate was excessive for the potato during the initial season, the carry-over effect of that rate on the subsequent peanut crop gave similar yields to the same amount applied at peanut planting. For the rice crop that followed peanuts, and for the potato crop, which was fourth in the sequence, grain and tuber yields were improved by deeper tillage and greater amounts of lime. However, the newly applied, heaviest lime rate was again excessive for one of two potato clones.

The effectiveness of various sources and levels of P_2O_5 (80 and 160 kg/ha) on potato growth and yield and their residual effects on subsequent maize and rice crops were studied, using a soil with 3 ppm available phosphorus. The single application of phosphorus favored growth and yield of all three crops. When another low pH soil from a hot, tropical area (Alfisol pH 5.3) was used, considerable yield increases were obtained by applying NPK at a rate of 160-160-160 kg/ha, respectively, compared to half of such rate and to the control.

PLANT CHARACTERS FOR POTATO ADAPTATION TO HOT TROPICS

Results from studies in which heat stress conditions were modified to better suit the potato are being used to define characters that could be incorporated into the potato for better adaptation to hot conditions. In an experiment where genotypes emerged and covered the soil surface slowly, a delay in tuber initiation was generally accompanied by greater leaf area durations during the bulking period and increased tuber yields within the same maturity period (Table VII-6). However, the combination of quick emergence, rapid branching, and a large leaf size could result in a fast cover of the soil surface; important to combine with the earliness of advanced breeding clones.

Since over 30 percent of the soils in the tropics have high aluminum (Al) saturation, potato clones identified as being tolerant to adverse effects of high Al should improve the prospects for potato adaptation to hot, tropical areas. In continued evaluation of varieties and clones from diverse origins, plants were exposed to increasing concentrations of Al, and their yields were used to indicate the corresponding level of tolerance to Al. The varieties Utatlan-69 and Santo Amor, and the clone DGV-33, were not adversely affected by Al concentrations as high as 6 meq/100 g of soil.

A possible screening technique for identifying Al tolerance in segregating families was tested. The

Table VII-6. Delay of tuber initiation by extended daylength treatment and its effects upon leaf area duration (LAD) and tuber yield.

Clone	Treatment	Tuber initiation (days)	LAD during bulking period (days)	Tuber weight/plant (g)
DTO-33	Control	52	138.5	874
	Long days	70	171.9	990
LT4	Control	55	70.4	365
	Long days	63	117.3	997
Desirée	Control	55	141.6	660
	Long days	70	155.1	962
Rosita	Control	57	169.3	411
	Long days	70	160.8	519

roots of young potato seedling were stained with hematoxylin and bathed in nutritive solutions with added Al. The more intensive root staining was related to the susceptibility of second generation tubers of the same genotypes to acid soils. The predicted response of TPS families to acid soils is being studied using the same screening technique.

Thrust VIII

DEVELOPMENT OF STORAGE AND PROCESSING TECHNOLOGY

DEVELOPMENT OF STORAGE AND PROCESSING TECHNOLOGY

During 1982 continued emphasis was placed on the transfer of diffused-light seed storage technology. In conjunction with the Social Science Department, research concentrated on understanding farmer adoption of rustic seed stores. Support research on technical problems encountered during this technology transfer indicated that low levels of light radiation were adequate to provide good suppression of sprout elongation. Resistance to infection by *Erwinia* spp. was increased under conditions of diffused light storage. Seed tuber quality and origin greatly influenced the application of this technology to hot climates.

Potato tuber month is one of the major factors limiting storage in hot climates. In the hot, humid tropics (800 m), consumer potatoes produced in the dry season were stored in a moist charcoal-walled store for up to three months with acceptable levels of loss. In the highlands (3280 m), under cooler, less stressful conditions, repeated trials have shown that good management practices permit storage in a range of simple stores for up to six months, with approximately 2 percent total loss per month.

STORAGE FOR DEVELOPING COUNTRIES

Joint research with the Social Science Department continued to focus on understanding farmer acceptance or rejection of diffused-light storage technology for tuber seed. As the number of countries increases where this technology is being introduced, it becomes more difficult to keep abreast of the number of farmer adopters. Figures presently available indicate that 855 farmers in 11 countries have adopted or adapted this technology, and 12 countries are in the process of testing it.

The three transfer stages in technology adoption by farmers are 1) testing by national scientists on local research stations; 2) adaption by modifying the technology to local requirements—commonly done by on-farm trials by national scientists; and 3) adoption by farmers through phases of demonstration, training, and continued farmer experimentation.

Information collected in Africa, Asia, and Latin America on seed

Experimental stores for consumer potatoes, Thailand.

storage adoption indicated that successful transfer occurred where 1) national scientists were committed to improving seed storage as part of an overall seed program—a technology can be appropriate in agroeconomic terms but will not be extended if there is no commitment to promote it; 2) the approach to research and transfer was farmer-oriented for determining all conditions necessary for introducing the technology; 3) a storage trainee, previously trained by CIP, was directly involved through research with extension workers and farmers; 4) a strong link existed between the involved national scientists and CIP regional and headquarters staff.

Studies on the quantification of light energy requirements for successful diffused light storage under both highland (Huancayo) and tropical lowland (San Ramon) conditions continued in 1982. In simple light tunnels, radiation levels and sprout length following six months of storage indicated that sprout growth was both more extensive and more sensitive to light quantity under highland conditions (Fig. VIII-1). These results suggested that the temperature in San Ramon was above optimum for sprout growth and provided inhibition to sprout elongation. Different times of daily exposure to natural diffused light affected sprout growth after six months' storage under Huancayo conditions (Table VIII-1), resulting in over 50 percent reduction in sprout length. All results indicated that small quantities of light produced large reductions in sprout growth.

Research in cooperation with the Pathology Department has confirmed that resistance to infection by *Erwinia carotovora* subsp. *carotovora* increased during storage, and that resistance was further increased ($P < 0.01$) by storage under diffused light conditions (Fig. VIII-2). In similar studies with three different *Erwinia* species, the spread of disease from previously inoculated to healthy tubers was also reduced by diffused light storage. Since *Erwinia* spp. are among the most important postharvest pathogens of potatoes, it is significant that diffused light seed storage not only provided unfavorable conditions for disease development but also enhanced tuber

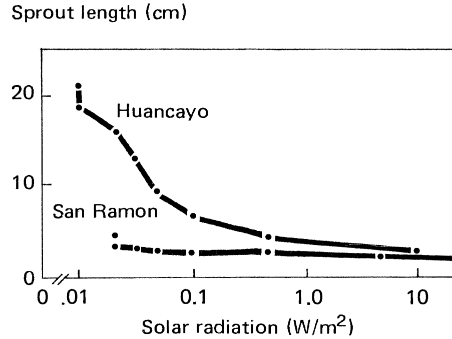


Figure VIII-1. Effect of solar radiation on sprout growth under highland and tropical lowland conditions.

Table VIII-1. Effect of exposure to natural diffused light on sprout growth.

Exposure to diffused light (hr/day)	Sprout length after six months' storage (cm)	Reduction in sprout growth (%)
0	23.2	0
0.5	10.3	55.6
1	8.2	64.7
2	7.6	67.2
4	6.3	72.8
6	5.3	77.1
8	4.3	81.5
12	2.8	87.9

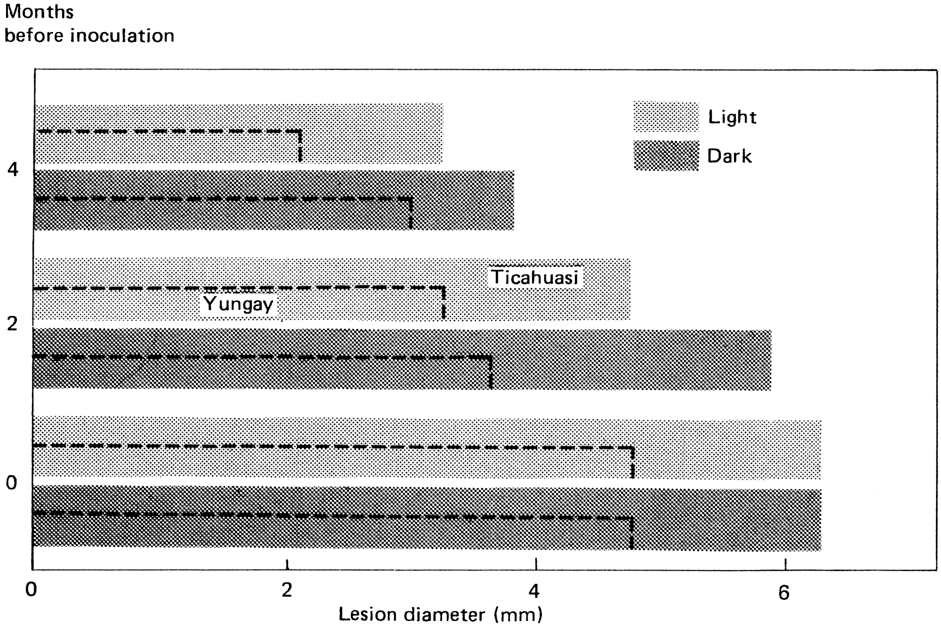


Figure VIII-2. Effect of tuber greening on resistance to infection by *Erwinia carotovora* subsp. *carotovora* in the varieties Ticahuasi and Yungay, under light and dark storage conditions.

resistance to infection and disease spread.

During seed storage trials in San Ramon in which PTM infestation was chemically controlled, the origin and quality of tubers influenced storage losses (Fig. VIII-3). Seed tubers produced in Huancayo or in San Ramon during the dry season sustained considerably less storage losses than those produced in San Ramon during the rainy season. These findings were confirmed in trials on the storage of consumer potatoes at San Ramon (Figs. VIII-4 and 5). Storage losses in Huancayo-produced tubers were more than doubled after five months of storage in San Ramon compared to storage in Huancayo. In San Ramon, storage deterioration in tubers from the local rainy season crop was very rapid in all simple store types available; whereas, well-selected tubers from the dry season crop were stored for up to three months in

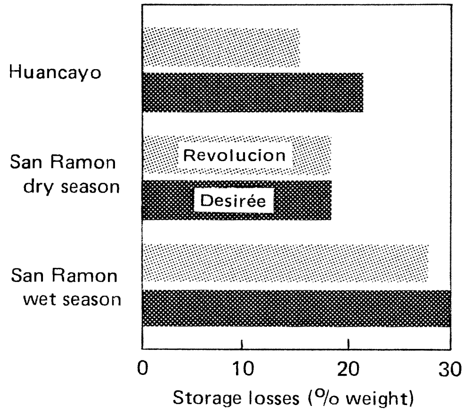


Figure VIII-3. Storage losses in seed tubers grown in different areas and seasons kept in diffused light stores, San Ramon.

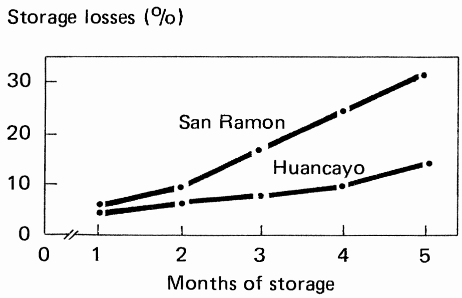


Figure VIII-4. Storage losses of Huancayo-produced consumer potatoes stored in Huancayo and San Ramon.

the wet-charcoal store, sustaining only 10 to 15 percent total losses. Even under the high, relative humidity conditions in San Ramon, use of moist charcoal-walled stores reduced internal temperatures by 2° to 4°C during the daily high-temperature peaks.

Continued trials on the storage of consumer potatoes under the less stressful conditions at Huancayo have confirmed that with good management tubers can readily be stored for up to six months with total losses of approximately 2 percent per month in either simple field clamps, small rustic timber stores, or in larger 35-ton naturally ventilated stores.

VILLAGE LEVEL PROCESSING

No additional research was done on the CIP pilot processing plant or modifications made during 1982; however, it has been kept in working condition and was used on several occasions for demonstration purposes and for training a scientist from Brazil.

A follow-up study was made on the transfer of CIP potato-processing technology within Peru. The findings indicated that even though there was an interest in the technology, there were difficulties that surfaced during the initial transfer

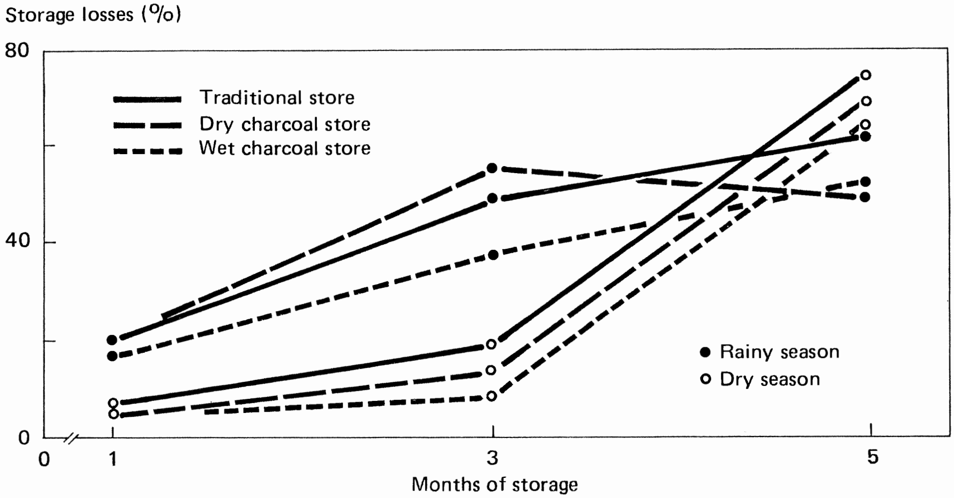


Figure VIII-5. Storage losses of rainy season and dry season consumer potatoes in three types of stores, San Ramon.

phase. These difficulties focused on the limited demand for *papa seca* (form of dehydrated potato) as presently marketed and used, the high cost of mechanizing traditional processing, the high cost of potatoes in 1982, and the lack of technical support for possible adopters. The viability of adoptions is being studied, and the experiences gained will be used to develop future plans for potato processing research.

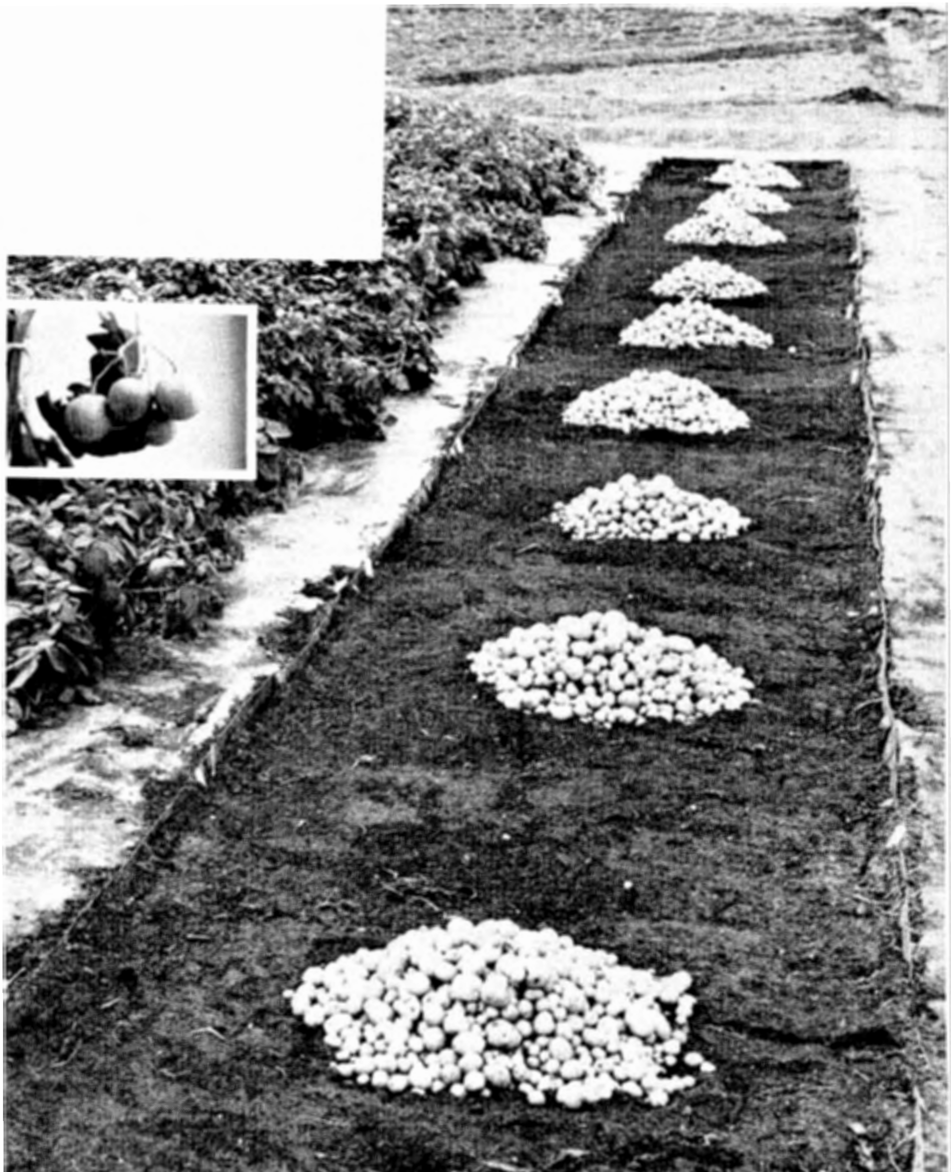
CONTRACT RESEARCH

A study on the effect of diffused light storage on sprout growth of seed tubers was initiated in December 1981 at the University of Glasgow, Scotland. Preliminary experiments showed that under controlled temperature and light conditions, light retarded growth of sprouts but not the dormancy break. Tubers of Pentland Javelin held 22 weeks at 18°C had 18.8 mm sprout growth in the light (12 Wm^{-2}) and 473.6 mm in the dark. Sprout growth was generally linear after dormancy was broken. When sprouting tubers were transferred between light and dark treatments, sprout growth was slightly affected by the previous history of the sprout.

The Department of Chemical Engineering at the University of Santiago de Chile has produced and characterized a food, based on hydrolyzed potato and milk, for malnourished infants. The product contains 17 percent protein and will be used in studies on infant nutrition at the Instituto de Investigación Nutricional, located adjacent to CIP-Lima.

Thrust IX

SEED PRODUCTION TECHNOLOGY



Hybrid true potato seed (TPS) was produced in the screenhouse at CIP's Huancayo site. An increase in efficiency and quantity of seed is anticipated by improving flowering and pollination. Results reemphasized the importance of seed quality for improving uniformity of seed germination and seedling growth and vigor. Direct seed sowing in the field by using pelleted seed or by fluid drilling of pregerminated seed was successful, although further improvements are required. Cultural practices for seedling tuber production from TPS in nursery beds were improved and resulted in yields of up to 12 kg/m^2 nursery bed.

The pathogen-tested in vitro collection is composed of 167 accessions, 50 of which are in long-term storage. This year, 31 new pathogen-tested introductions were received, and 3500 plantlets of 110 clones were produced in vitro. Fourteen in vitro shipments of 73 clones were sent to 11 countries. In vitro storage studies indicated the importance of adding mannitol to media used in combination with low temperature for long-term storage. Induction of tuberlets in vitro was successful and may be of importance for propagation, distribution, and maintenance of germplasm in vitro.

PHYSIOLOGIC AND AGRONOMIC STUDIES ON TRUE POTATO SEED

Preliminary studies on pollination biology using cv. Renacimiento resulted in an average production of 4.6 self-pollinated berries per inflorescence (maximum of 9) when insect and wind pollination were prevented by enclosing inflorescences in glassine bags. This demonstrated that this cultivar has considerable ability to produce fruits through selfing. In another trial, fruit yield of emasculated, uncovered inflorescences of cv. Renacimiento was also determined. Eighteen inflorescences were pruned to four buds each, and 11 berries were produced containing from 0 to 470 seeds. This suggested that low levels of natural cross-pollination can occur if emasculated flowers are not protected by bagging.

A first attempt at large-scale production of hybrid seed was conducted at Huancayo in 120 m^2 of screenhouse space. Approximately 50 berries/m^2 were obtained, representing a seed yield of about 1 kg. This low seed yield resulted from poor growth and sparse flowering, especially in the clones nonadapted to environmental conditions in Huancayo. Moreover, low pollen fertility restricted fruit yield during the first two weeks of flowering. By minimizing such problems, yields can be increased markedly in future plantings.

A range of seed quality tests were evaluated with the cooperation of researchers at the Universidad Nacional Agraria in La Molina. The tests included: weight of 100 seeds, germination in petri plates, and germination and number of abnormal seedlings on slant boards where seeds are placed between two moist filter papers on inclined glass plates. Based on percent usable seedlings and average seedling stem length, germination data from petri plates was the best measure of seed quality, although all indices were significantly correlated with the seedling count.

Seed of open-pollinated DTO-33 with 3, 7, and 14 percent moisture content, along with seed desiccated over toasted rice with a moisture content of less than 5 percent, were stored in sealed vials for a maximum of 28 weeks at −10°, 5°, 20°, and 30°C. Samples were taken periodically and evaluated for seed germination. Seed at 3 or 7 percent moisture content maintained good germinability over the entire storage period regardless of temperatures (Fig. IX-1). The damaging effects of the −10°C treatment on seed at 14 percent moisture content were attributed to the repeated freezing and thawing that occurred during sampling. Seed at 14 percent were adversely affected by storage at all temperatures, except 5°C (Fig. IX-2). These results reemphasized the importance of standardizing storage temperature and moisture content for determining seed longevity.

In preliminary studies on seed quality to determine the potential of seed pelleting for direct field sowing, experimental quantities of seed were pelleted with Celite and gum arabic as an adhesive. Field sowing of Atzimba x DTO-33 seed, pelleted in two sizes, resulted in acceptable stands of seedlings, but seed in large pellets gave slower emergence than unpelleted seed, or seed in small pellets.

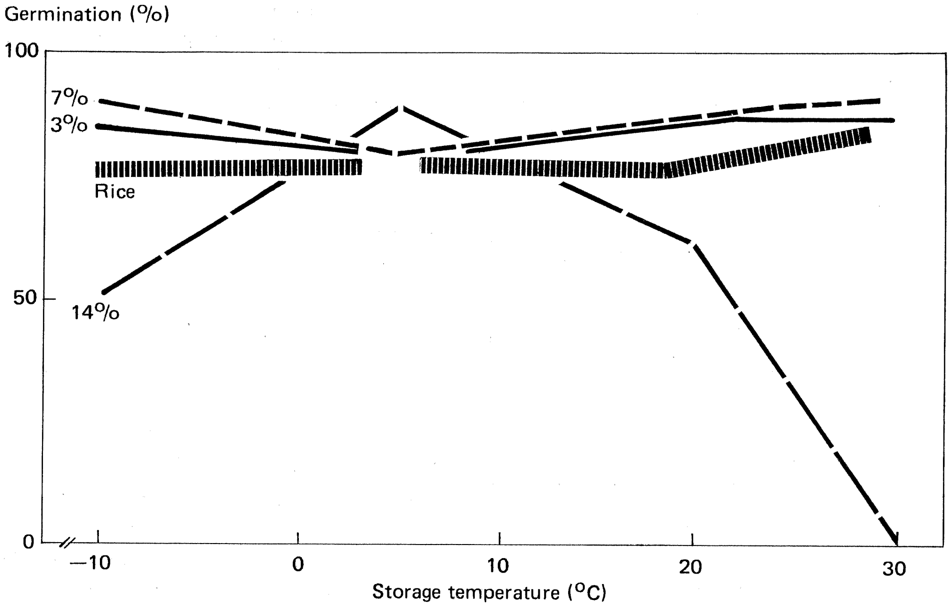


Figure IX-1. Effect of storage for 28 weeks at various temperatures on germination of open-pollinated DTO-33 seed. Seed at three moisture levels, or desiccated over toasted rice.

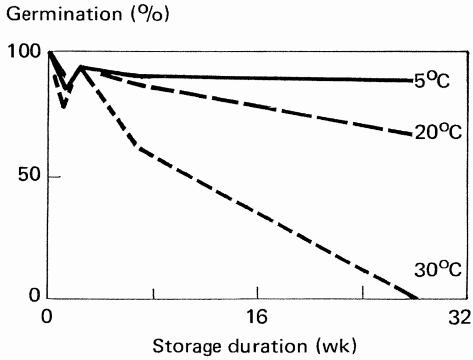


Figure IX-2. Effect of storage duration and temperature on open-pollinated seed DTO-33 with 14% moisture content.

Trials with fluid drilling of seed in the field resulted in good seedling establishment. Seed was pregerminated at 15°C in petri dishes to achieve 50 to 80 percent germination, then transferred to a gel solution viscous enough to maintain seeds in suspension, and finally sown by pouring the gel into 1-cm deep groves in the soil surface. Seed was fluid-drilled into a soil mixture of sand and peat moss, using a 0.8 percent gel solution of a commercial hydrocolloid, Laponite 508 (Laporte Industries Ltd., England). Fluid-drilled seed resulted in faster emergence than the dry seed sown in the normal manner (Fig. IX-3). Different periods of pregermination (at 15°C) were used. Worth noting is that for Atzimba x DTO-33, fluid drilling of ungerminated seed gave better results as compared to four days of pregermination. In contrast, eight days of pregermination were best for open-pollinated Renacimiento seed. The difference in response of the two progenies was attributed to high temperatures in the screenhouse, inhibiting germination of Renacimiento, with the result that only pregerminated seed gave rise to seedlings. This suggested that fluid drilling of pregerminated seed provides a way to overcome high temperature inhibition of seedling emergence. Additionally, fluid drilling proved to be much faster for sowing flats than traditional hand sowing; although in this experiment, difficulty was encountered in controlling uniformity of spacing between seedlings.

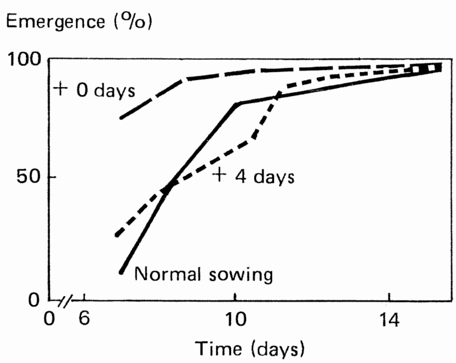


Figure IX-3. Emergence of fluid-drilled seed without (+0 days) and with (+4 days) pregermination. Time axis includes pregermination period. Atzimba x DTO-33.

PRODUCTION OF SEEDLING TUBERS

The system of producing seedling tubers (seed tubers produced from seedlings) in nursery beds was further developed (*see* Thrust IX cover photo). In previous years, seedling tubers were produced in nurseries with 1:1 peat/sand substrates. To improve fertilizer and moisture retention, several rates of loamy soil were incorporated into the nursery substrate and evaluated. Substrates containing 20 percent soil resulted in lower tuber yield than those without soil (Table IX-1). Substrates containing plant compost performed similarly to substrates with peat moss, while substrates with manure showed reduced yield, possibly due to poor decomposition of the manure or its high salt content.

The effect of seedling population density on tuber production in directly sown nurseries was studied. A population density of 100-150 plants per m^2 after thinning proved adequate for the production of a large number of seedling tubers (Table IX-2).

An experiment was conducted during the hot summer months at La Molina to determine the amount of fertilizer needed in the nursery substrate at sowing to promote adequate seed germination and seedling growth. Seedling growth was adversely affected when grown in substrates containing more than 100 ppm each of N and K_2O (Fig. IX-4). Additionally, substrate salt concentration increased significantly with increasing N and K_2O levels, while up to 800 ppm of P_2O_5 had no adverse effect on initial seedling growth. These results indicated that for optimum, initial seedling growth in nursery beds, only P should be applied at sowing, while N and K may be applied after plant establishment.

Since many seedling tubers produced from TPS in nursery beds are small, an experiment was conducted to determine whether or not these small tubers represent genotypes that are characterized by a large number of small tubers per plant. This information is necessary because such genotypes are less suitable for ware production. Seedling tubers of four sizes (generation I) were multiplied in separate blocks, and at harvest tubers of 20-60 g range (generation II) were selected from each block and replanted to

Table IX-1. Tuber yield from seed directly sown in different substrates containing 50% sand.

Organic matter (%)		Soil[a] (%)	Yield (kg/m^2)
Peat moss	(50)	–	6.9 a*
Peat moss	(30)	20	4.2 b
Compost	(50)	–	6.5 a
Compost	(30)	20	5.3 b
Manure	(50)	–	2.7 c
Manure	(30)	20	2.9 c

[a]Soil type: 46% sand, 42% silt, 12% clay.
*Means followed by the same letter are not significantly different at 5% level.

Table IX-2. Effect of seedling population on seed tuber production in directly sown and thinned nursery beds (seed from DTO-33 open-pollinated plants).

Spacing (cm)	Plants/m^2	Surviving plants (%)	Number of tubers/m^2: 1-10 g	10-20 g	>20 g	Total >1 g	Total yield (kg/m^2)
14 x 14	50	86	287	118	40	445	4.5
10 x 10	100	63	441	132	35	608	5.3
8 x 8	150	52	443	136	51	630	5.5
7 x 7	200	43	462	150	32	644	5.4
LSD 0.05			64	NS	NS	79	NS

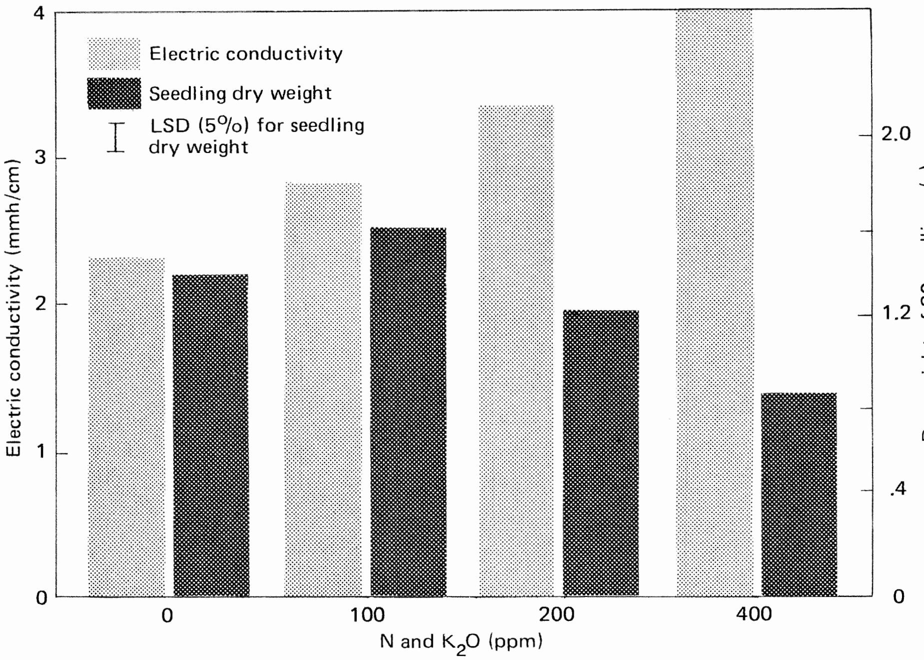


Figure IX-4. Electric conductivity and seedling weight 25 days after sowing at increasing N and K_2O levels (sources: ammonium nitrate and potassium magnesium sulphate.

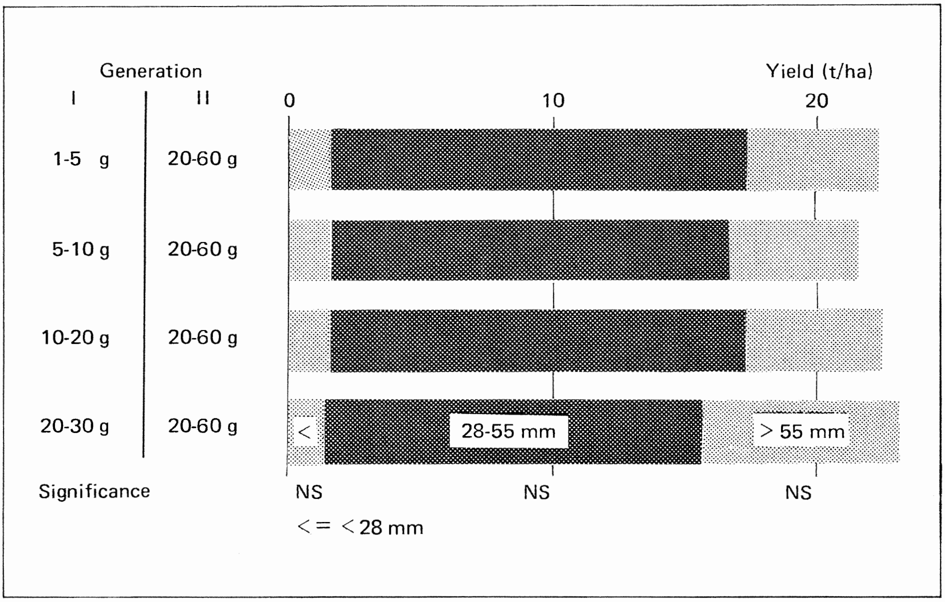


Figure IX-5. Yielding capacity of second generation (II) tubers produced from different sizes of first generation (I) seedling tubers (open-pollinated DTO-33).

evaluate their yielding capacity. The results showed that there was no significant difference in total yield and size distribution (Fig. IX-5), suggesting that small seedling tubers produced in nursery beds were as equally suitable for multiplication into basic seed tubers as the large ones.

Various-sized grades of seedling tubers produced from TPS were compared with clonal seed tubers and with seedlings transplanted with and without rooting blocks. Results showed that 1-5 g seedling tubers performed similar to seedlings transplanted in rooting blocks, but significantly better than seedlings transplanted without rooting blocks. Seedling tubers of 5-20 g yielded similar to 40-60 g clonal seed tubers when planted at similar weight/ha, possibly due to a higher number of stems per unit area. Under conditions at La Molina, healthy, first generation (I) small seedling tubers were more suitable for ware production than the larger (40-60 g), second generation (II) seedling tubers with lower health status.

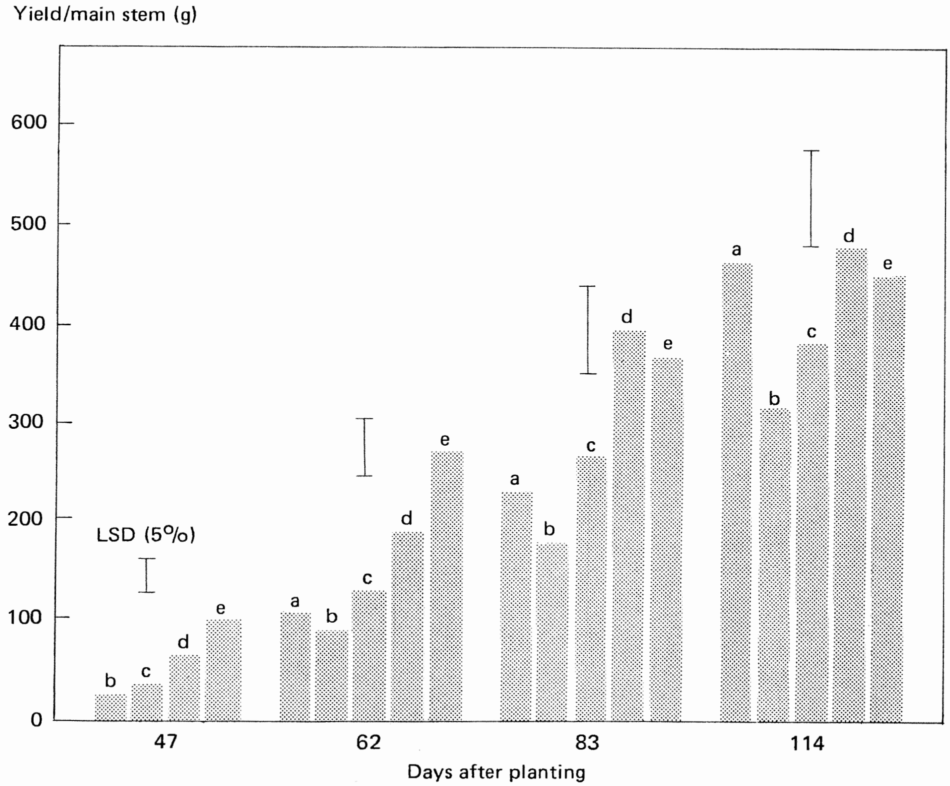
In an attempt to distinguish between the effect of stem density and planting material, the growth of various planting materials was compared on the basis of one main stem per unit of planting material. Throughout the growing period, 5-20 g seedling tubers yielded more per stem than transplanted seedlings of the same progeny, but less than 40-60 g seedling tubers (Fig. IX-6). Stems from 5-20 g seedling tubers developed more rapidly and produced more foliage per stem than transplanted seedlings, which resulted in higher yields per stem. Also, seedling tubers produced fewer and larger tubers per stem than transplanted seedlings of the same progeny.

TISSUE CULTURE AND GERMPLASM RESEARCH

The in vitro collection of pathogen-tested clones includes 167 accessions, 50 of which are now in long-term storage. From the 31 new introductions of this year, 18 were freed of pathogens at the Research Institute for Plant Protection (IPO), Wageningen, the Netherlands; 1 at the Plant Research Institute, Victoria, Australia; and 12 at CIP. From the pathogen-tested collection, 3500 plantlets of 110 clones were produced in vitro and transferred in pots to the greenhouse. Also, 14 in vitro shipments of 73 clones were sent to 11 countries.

For in vitro long-term storage, it is necessary to identify a medium that can reduce plantlet growth rate, but without affecting the survival potential. To improve the medium presently being used, the effect of sucrose and mannitol, incorporated into Murashige-Skoog (MS) basic medium, on the growth and survival of several clones was evaluated. Media containing 4 percent mannitol and either 0.5 or 3 percent sucrose appeared satisfactory for long-term in vitro storage at 8° to 10°C.

In vitro-produced tubers could have a good potential for use in propagation, distribution, and maintenance of pathogen-tested material. Plantlets propagated in vitro were incubated in MS basic medium, supplemented with 8 percent



a = seedlings (Atzimba x DTO-28)
b = seedlings (DTO-33 open-pollinated)
c = 5-20 g seedling tubers (DTO-33 open-pollinated)
d = 40-60 g seedling tubers (DTO-33 open-pollinated)
e = 40-60 g seed tubers (DTO-33 clones)

Figure IX-6. Yield per main stem from transplanted seedlings, seedling tubers, and clonal tubers at different intervals after planting.

sucrose and different concentrations of chlorocholine chloride (CCC), and benzylaminopurine (BAP), and incubated in the dark or in an eight-hour photoperiod. Using five clones, an average of one tuber per shoot was obtained on at least one medium (Fig. IX-7). Tuber production was faster when plantlets were induced to tuberize in the dark rather than in the photoperiod.

Modification of specific traits of established varieties or advanced breeding lines may be achieved through the use of naturally occurring or artificially induced genetic variations. Induction of adventitious buds, which originate from one or more cells, may be an appropriate tool for such purposes. Tuber sections incubated on MS basic medium, supplemented with 5 percent sucrose, 1 ppm zeatin, 1 ppm indoleacetic acid, and 10 ppm gibberellic acid produced many adventitious buds. These buds generated shoots after they were transferred to a multiplication medium. The

Figure IX-7. Tuber formation in cv. Mariva after one month of growth under tuber-inducing conditions.

plants, which have been propagated, will be transferred to the field for evaluation.

Protoplast culture can be useful for finding variants and for combining incompatible genotypes or different advanced breeding lines. Protoplasts of three genotypes have been isolated and cultured. From the developing colonies, plantlets have been regenerated from one genotype. Protoplast fusion has been achieved by incubating isolated protoplasts of two genotypes (EP, AntVB) in the presence of polyethylene glycol (40%), pH 9.5, and Ca-ions (100 mM). Although in vitro plantlets have been developed, fusion products have not been verified.

Results obtained in the successful culture of embryos from true seed of wide crosses led to more detailed studies on the conditions for general application of this technique. Coconut milk or casein hydrolysate in the culture medium had no effect on the germination of embryos.

No difference was found between the MS basic medium and Nitsch-Nitsch (NN) basic medium; but seedling vigor was superior in the NN medium, with or without casein hydrolysate.

In an experiment on embryo culture, it was found that isolated, well-developed embryos had no dormancy and, therefore, started to grow immediately on the culture medium even when obtained from immature berries. For embryo germination it was not always necessary to isolate embryos from the seed, if the seed coat and endosperm layer were cut before being transferred to the culture medium. This technique was sufficient to terminate dormancy. Embryos from seeds of 31 different crosses of 43 species were cultured. Plantlet establishment by embryo culture was compared with that obtained by conventional germination of seeds. Isolating and cultivating embryos lead to greater development of plantlets. In one case, germination increased from 12.5 percent (whole seed at 46 days of germination) to 88.4 percent (embryo culture at 6 days).

In some of the wide crosses, embryos showed wide morphological variation. In addition to previously classified types A-E, three other types, F-H, were found during the present investigation (Fig. IX-8). Plantlets were obtained from all types; however, in globular- (E) or heart-shaped (F) embryos, only a few developed in the culture (Table IX-3).

Virus eradication. The possibility of eradicating potato virus S (PVS) from infected plants by Virazole and tissue culture was investigated by two methods: by applying the chemical in hydroponic culture or as a foliar spray.

In the first method, stem cuttings from PVS-infected plants were grown in hydroponic cultures containing 200 ppm Virazole. After one month, meristem tips were excised and cultured on MS basic medium. Forty-nine plantlets were tested by the ELISA method and only three were PVS-infected. The rest were retested by inoculation on *Chenopodium quinoa* and all tests were negative.

In the second method, 10 plants infected with PVS were sprayed once with a solution containing 200 ppm Virazole. Meristem tips were excised after two months and the generated plantlets were tested

Table IX-3. Germination ratios of embryo types in two wide crosses.

	Embryo type (germinated/total)					
Cross	Horseshoe-shape (B)	Y-shape (C)	Globular shape (E)	Heart-shape (F)	Torpedo-shape (G)	Right-angle cotyledon-shape (H)
OCH11865 x OCH13588	1/1	9/15	2/16	3/29	2/12	7/7
OCH11851 x OCH11295	9/9	23/26	0	0/1	0/3	0

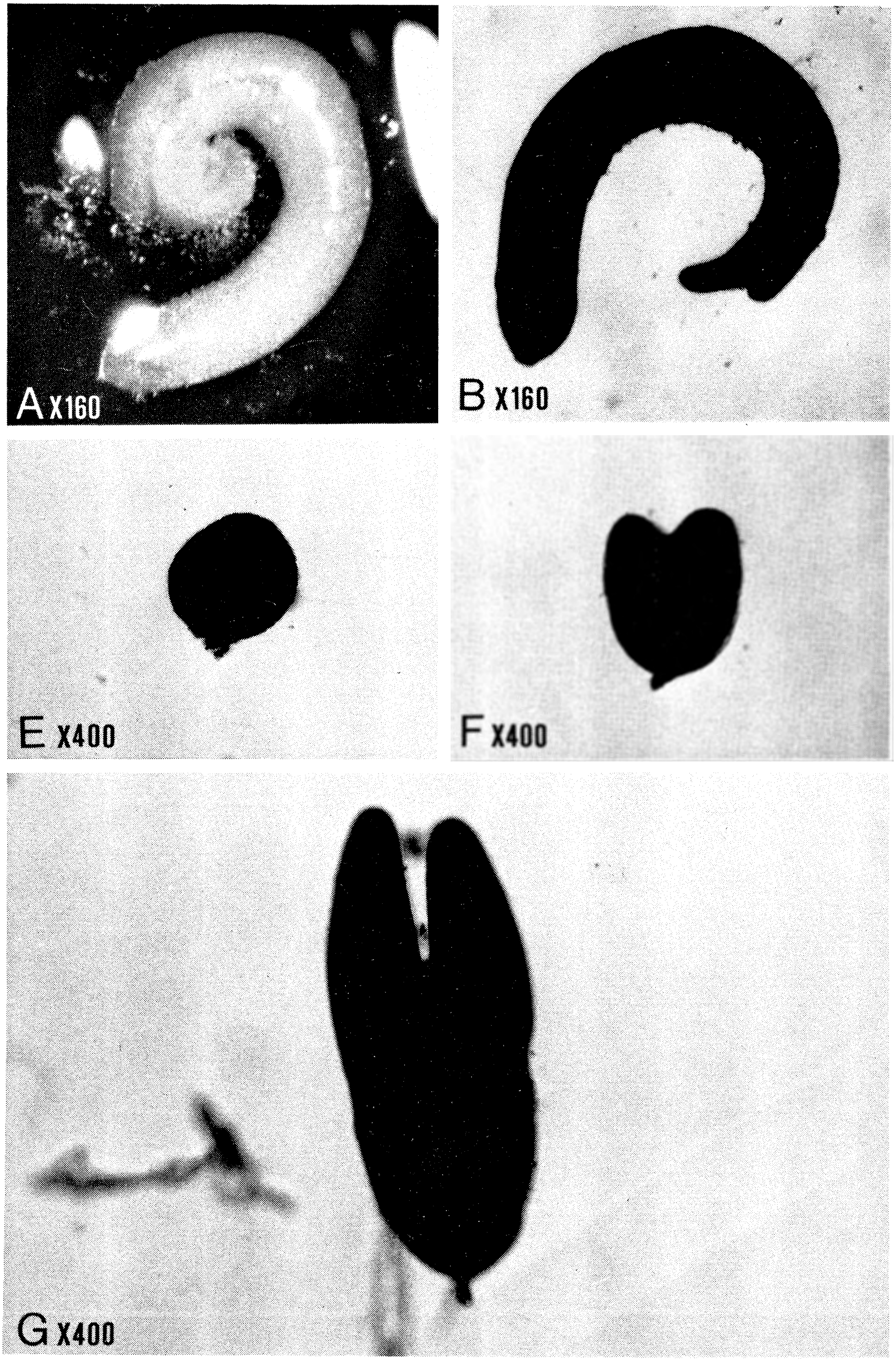


Figure IX-8. Different embryo types found in seeds of wide crosses.

as above. Thirty-six regenerated plantlets were PVS-free.

These results showed that Virazole application followed by meristem tip culture can lead to a high eradication rate of PVS, a difficult virus to eradicate. Virazole treatment, therefore, can be used to replace thermotherapy when necessary.

CONTRACT RESEARCH

The contract at the Department of Agriculture, Burnley, Australia, involves the pathogen testing and multiplication of clones from CIP and other sources for distribution in Southeast Asia. Clean-up procedures include in vitro multiplication, virus indexing, including potato spindle tuber viroid detection, and multiplication of tubers under quarantine conditions. During the year, various amounts of genetic materials were distributed to Burma, Fiji, Guam, Indonesia, New Caledonia, Papua New Guinea, Peru, Philippines, Salomon Islands, Thailand, and Vanuatu.

Regional Research and Training

Acronyms Used in this Section

BARI—Bangladesh Agricultural Research Institute

BPI—Bureau of Plant Industry (Philippines)

EMBRAPA—Empresa Brasileira de Pesquisa Agropecuaria (Brazil)

IADS—International Agricultural Development Service

ICA—Instituto Colombiano Agropecuario (Colombia)

INIA—Instituto de Investigaciones Agropecuarias (Chile)

INIAP—Instituto Nacional de Investigaciones Agropecuarias (Ecuador)

INTA—Instituto Nacional de Tecnologia Agropecuaria (Argentina)

NAFED—National Agricultural Cooperative Marketing Federation (India)

PRECODEPA—Programa Regional Cooperativo de Papa (Central America)

SAPPRAD—Southeast Asia Program for Potato Research and Development

REGIONAL DEVELOPMENTS

Four major administrative changes took place in the regions during 1982: The new regional headquarters for Region II, Brasilia, opened in March; Region V headquarters was established in April by agreement with the Government of Tunisia and was in full operation by August; SAPPRAD officially began to operate in March, when the finance agreement was signed with the Government of Australia; and a new special project in Burundi was initiated in August with the assistance of a CIP scientist.

Meetings were held with administrators and potato scientists in three regional locations: Central Africa, and the Andean and non-Andean zones of South America. Agreements were signed between the participating countries for the formation of regional and cooperative potato research associations similar to PRECODEPA and SAPPRAD.

An agreement was signed with the Government of Egypt permitting CIP to send a scientist to develop research on true potato seed (TPS) and other technologies. CIP's senior physiologist will be on temporary assignment for this appointment.

With the assistance of IADS, a new funding arrangement was concluded that permitted the CIP scientist in Bangladesh to continue his work for a further three years. The Government of Australia is the new donor taking over the original funding of the World Bank.

REGIONAL RESEARCH

GERMPLASM EVALUATION AND DISTRIBUTION

Region I. A CIP-bred variety (374080.5) selected by INIPA was named Perricholi by the President of Peru. This variety was selected for its late blight resistance, as was another CIP clone (377520), named "INIAP-Bastidas" in Ecuador.

In Colombia, work has continued in collaboration with ICA on developing an efficient screening program for late blight at the La Selva Experimental Station, Medellin. By mid-year, 3449 tubers had been tested. Without fungicide treatment, selected clones yielded between 15 to 50 t/ha. Advanced clones tested in farmers' trials yielded 19 to 59 t/ha compared with local controls of 14 to 30 t/ha. There was a clear correlation between yield and resistance level of the clones. Without fungicide, nine late blight-resistant clones averaged 1.4 kg/plant compared with 0.3 kg/plant for a susceptible clone (BR 63.65). With fungicide the differences were less but still considerable.

The national program of Bolivia continued to test for frost resistance for the third consecutive year. Results showed that improved CIP material gave very high yields compared with controls. The system applied by breeders for preference rating resulted in few clones being selected. Five clones, however, were rated better than local varieties on all counts.

Region II. In Brazil, major effort was concentrated on identification of clones adapted to the *cerrado* areas. In Brasilia, EMBRAPA tested 250 advanced clones selected from previous years; some of these may soon be considered for final evaluation and naming as new cultivars.

Genetic material carrying virus resistance, particularly to potato leafroll virus (PLRV), entered its third year of testing in Argentina. This work was part of a research contract between CIP and INTA. A total of 31 new families were introduced in 1982, with 131 clones being selected for reevaluation.

Through the research contract with INIA, the screening of CIP material under long-day conditions at Osorno (41°S), Chile, has continued. Results were promising and more introductions of genetic material have been made.

Region III. Collaboration with the Plant Quarantine Station in Kenya continues to be an extremely productive association. The flow of CIP introductions for multiplication and redistribution to other countries of the region is very efficient. Over 240 clones were released from quarantine and multiplied in the screenhouses. It has been necessary for CIP to construct a third screenhouse to handle the increased volume of germplasm being introduced for redistribution. Region III distributed germplasm to 17 African and 2 Asian countries. Through the research contract with the National Agricultural Laboratories, the testing of CIP clones for resistance to Kenyan races of bacterial wilt continued. Three clones were found to be resistant in laboratory tests and are being field-screened.

A large amount of germplasm was screened for resistance to bacterial wilt and late blight in Rwanda; four clones were selected and named as new varieties. Yields of these new varieties averaged 8.6 t/ha more than Sangema, considered the best variety commercially grown (Table 1).

In Zaire, 2 clones previously selected in Rwanda were named as varieties; in Burundi, 12 clones are in the final stages of evaluation before naming; and in Mozambique, CIP clone 800169 (DTO-28) has already been released. Madagascar, Tanzania, and Kenya have also selected CIP introductions with variety potential.

Region IV. During 1982, additional tuber families with resistance

Table 1. Yield of new potato varieties released in Rwanda, 1982.

Clone	New name	Yield (t/ha)	Origin
CIP 378699-2	Kinigi	25.6	CIP
Uganda 11	Gahinga	24.4	Uganda
CIP 378711-6	Not yet named	23.2	CIP
CIP 720097	Petero	22.4	Mexico
CIP 720055	Nseko	21.2	Mexico
Sangema (local variety)		14.8	

principally to PLRV were received from CIP by the Turkish National Program. Several of the CIP clones introduced into Turkey since 1979 are giving yields 60 percent greater than the best local variety and are being considered for varietal status. During 1982, additional CIP tuber families with resistance principally to PLRV were introduced by the Turkish National Program.

In October, a regional germplasm management course was held in Turkey at the Aegean Agricultural Research Institute, Menemen, Izmir, and at Bozdag, a nearby highland site. Course participants, who helped with the harvest of the genetic material, were sufficiently convinced of its potential value to request samples for their own countries.

Region V. This region, covering North and West Africa, became fully operational late in the year, thus research on genetic material has not yet been implemented. However, during initial contact with some of the countries in West Africa, it was discovered that Senegal had selected one of CIP's lowland tropical clones 800174 (DTO-33) and had named it "Naataange."

Region VI. In India, the evaluation of CIP germplasm is limited to selected material. During 1980-1981, this included material with resistance to frost, viruses (PVY or PVX), bacterial wilt, cyst nematode, and late blight. Several clones were released from quarantine and testing was started in 1982. In Bangladesh, Sri Lanka, and Bhutan, genetic material with resistance to late blight, bacterial wilt, and heat stress have been evaluated. In Sri Lanka, three selections showing good resistance to bacterial wilt were selected and are being multiplied for large-scale field trials. A number of heat-tolerant clones are also showing bacterial wilt resistance. Four introductions (two of which are CIP clones) have been identified in Bangladesh for future varietal release. It will be possible for these new varieties to be multiplied in the basic seed program, which has already started. In Bhutan, one CIP clone that performed well in trials at the research station level will be included in the national variety trials.

Region VII. In the Philippines, 70 advanced cultivars and 1770 clones from tuber families were evaluated for specific resistances and yield, and 86 gave better yields than local control varieties. In collaboration with BPI in Mindanao, Philippines, cultivars and CIP clones are being evaluated for resistance to bacterial wilt. Of the commercial varieties, Greta showed good resistance and 14 CIP clones were superior to the resistant clone CIP 800226. This latter clone has shown good resistance in Fiji, and negotiations are underway to supply commercial quantities of seed tubers through the CIP contract in Victoria, Australia. Other CIP clones have been distributed from Victoria to New Caledonia, Solomon Islands, and Papua New Guinea for trials.

The regional multiplication and distribution station in Sta. Lucia, Philippines, finally became operational after having been destroyed by a typhoon in 1981. A screenhouse, housing, offices, and a small laboratory were erected. A small meristem unit will be started in 1983 to multiply clones from in vitro plantlets received from the university at Los Baños. The Ministry of Agriculture will inspect and certify all clones produced for export.

In Vietnam, where CIP introduced in vitro clones for evaluation in 1980, three were selected for high yield and superior late blight resistance. Two are Mexican varieties and the other is from Argentina. A high demand for planting material resulted in Vietnamese scientists developing a rapid multiplication system based on in vitro meristems. The farmers are doing all cultivation work, propagation, and selling of rooted plantlets. This very simple system of rapid multiplication could be extremely useful in many Asian countries where intensive vegetable production exists.

POTATO PRODUCTION FROM TRUE SEED

Region I. A detailed program of progeny evaluation of TPS families was made in Colombia. Three groups were evaluated: 1) hybrids received from Lima, 2) open-pollinated seed with late blight resistance from La Selva, Colombia, and 3) Colombian cultivars of high quality. This project has supported the research of a M.S. degree student from the National Agrarian University of Colombia.

Yields of TPS progenies were good, ranging from 15 to 25 t/ha. There were considerable differences among progenies for resistance to late blight, earliness, tuber uniformity, cooking quality, and yield. Some families gave adequate production of tubers under late blight attack without fungicide application.

Region III. Three areas of research were initiated in Rwanda: 1) seedbed management in nursery and field, 2) field management, and 3) use of seed tubers from TPS. The best system for seedling production is to grow them in trays in a soil medium-rich in organic matter and then to transplant. NP fertilizer added to the organic matter greatly increased plant yield. Costs need to be analyzed to determine the optimum dosage of organic matter and fertilizers.

Local varieties of potatoes crossed with CIP clones produced late blight-resistant hybrid seed that was high-yielding. Trial yields varied greatly depending on which season was used. In the August harvest, a comparison was made between hybrid seedlings and clonal seed of Sangema, a local variety. There was little statistical difference in yields although one hybrid progeny outyielded the clone by nearly 60 percent (Table 2).

Region IV. In Turkey, a number of experiments were conducted to assess the yield potential of TPS under the existing environmental conditions. Local open-pollinated and hybrid seed were used. The transplanted seedlings of the local open-pollinated progenies yielded 36 t/ha; however, segregation was high and many tuber characteristics were unacceptable. Twenty-five clones with adequate uniformity were selected with an average yield of 1.9 kg/plant. The hybrid plants of Atzimba x DTO-28 were uniform and yielded 29 t/ha.

Table 2. Yield of TPS hybrids in Rwanda.

February harvest		August harvest	
Hybrid	Yield (t/ha)	Hybrid	Yield (t/ha)
CIP 720055 x Sangema	46.2	CIP 720055 x Montsama	24.2
CIP 720055 x Atzimba	42.0	CIP 720055 x Atzimba	18.1
CIP 720055 x Montsama	40.3	Atzimba x Montsama	16.0
CIP 720055 OP[a]	39.4	Sangema OP	15.0
Atzimba OP[a]	27.4	Atzimba x DTO-33	13.4
Sangema clonal tubers	45.0	Sangema clonal tubers	15.4
LSD 0.05	4.9	LSD 0.05	4.2

[a]OP = open-pollinated.

Region VI. In India, there is an intensive program of basic TPS research being carried out, with the regional scientist supervising the research of three M.S. degree students. Results have shown that embryo type is important in determining the vigor of the seedling and thus greatly influences plant population, the wild type of embryo being the most vigorous. Seed weight also shows a strong correlation with tuber yield. Two TPS hybrid progenies have been identified that gave yields, under farm conditions, similar to that from tuber seed.

Bangladesh has a program for selecting TPS progenies for yield and uniformity; three families gave yields comparable to a crop raised from seed tubers. In Bhutan, a TPS research program has recently started with emphasis on seed production. Sri Lanka, the leader country of SAPPRAD for TPS research, has developed its program rapidly. Their program scientists grew a crop from open-pollinated seeds of Desirée and Siro, with yields of 27.7 and 24.0 t/ha, respectively. There is considerable farmer interest in this technology in Sri Lanka, following the success of one farmer in Sita Eliya. Experimenting since 1962, he finally raised a crop of seedling tubers from open-pollinated Desirée and used them to plant 4 ha.

Region VII. Seed tuber production from TPS was studied in the Philippines, and the optimum plant density required in seedbeds was determined. The hybrid Atzimba x DTO-28 initiated tubers after 59 days, whereas open-pollinated seed of variety Conchita took 76 days. Further use of these seedling tubers for the production of a ware potato crop is being investigated.

A preliminary test was made by Korean scientists on the ability of local farmers to use the TPS methodology by applying their traditional methods for producing vegetable crops. Results were variable due to distinct differences between the spring and fall seasons. The most important point to emerge was that unimproved seed had insufficient yield potential.

POSTHARVEST CROP MANAGEMENT

Region I. The testing and demonstrating of diffused light as a storage technique for seed potatoes continued in Peru and Colombia. Results were in accord with previous experiences that showed less weight loss, less rotting, and more and better sprouts compared with traditional systems. A project on ware potato storage was started in Colombia in collaboration with ICA. Sprout suppressant CPC was included as a treatment, and a tasting panel evaluated the flavor at the end of the experiment. In the next phase, traditional farm buildings and farmers' methods of storage will be adapted at the most economical cost, using improved storage principles.

Region II. In the south of Chile, INIA has continued to evaluate diffused light storage technology among small farmers. Five prototype stores or modified farmer stores were established for research and demonstration purposes. The percentages of losses were low and the material stored has been planted to observe its field performance.

Region III. Improved stores for ware potatoes were tested at two sites in Kenya: one at high altitude (2400 m), the other at a lower altitude site near Nairobi (1800 m). In all stores at both sites, weight loss due to rotting was similar and only averaged 0.8 percent. At both sites, total weight loss due to rotting, sprouting, metabolic activity, and evaporation was 11 percent in naturally ventilated stores with flap control, and 7 percent in loose piles covered with straw. At the lower altitude site, in naturally ventilated stores without flap control, in one-cubic meter slatted boxes, and in loose piles with underneath ventilation, total weight losses (9-12%) were double those at the high-altitude site. This was due to greater moisture loss and sprouting.

There has been a rapid increase in the use of diffused light stores since they were first introduced in Rwanda, Burundi, and Zaire in 1980. Presently more than 130 stores have been built by research institutes, rural development projects, and farmers.

A simple method first tried in Rwanda for breaking dormancy by placing seed tubers in a pit was further evaluated. When tubers are immature, temperatures frequently rise too high and rotting occurs. An alternative method was tried by placing seed potatoes in plastic bags together with maturing bananas to test the effect of the ethylene emitted by the fruit. Four weeks after harvest, tubers of Sangema were stored for two weeks either with or without ripening bananas. Storing the tubers with bananas helped in breaking dormancy (Table 3). This convenient method of treating tubers shows considerable promise in Rwanda, where the time between harvest and planting is very short.

Table 3. Dormancy breaking using ripening bananas.

Number of sprouted eyes per tuber	Percentage of tubers with sprouted eyes after storage: With bananas	Without bananas
0	0	60
1	6	33
2-5	94	7

Region IV. Postharvest research in Egypt, Tunisia, and Turkey concentrated on control of potato tuber moth (PTM) in stores. Chemical control was effective and economical using synthetic pyrethroids and other insecticides with low mammalian toxicity. Tuber damage was reduced to 10 to 15 percent compared to 100 percent infestation in untreated stores. In Tunisia, a synthetic pyrethroid, sprayed on a crop two to three weeks before harvest, reduced PTM damage from 10.3 to 3.6 percent. This treatment could substantially reduce the number of infested potatoes entering the stores.

In Egypt, a trial was conducted on the efficiency of sex pheromones to reduce PTM populations in stores. Water traps using pheromones were found to be more effective than Sevin dust in reducing PTM buildup (Table 4), demonstrating a good way to safely control this pest, which can damage more than 75 percent of the stored crop.

Table 4. Control of potato tuber moth (PTM) in storage using sex pheromone traps, Egypt, 1982.

Treatment	Mean percent tuber damage by PTM[a] (days from initiation of storage) 30	60	75
Sex pheromone traps	6.0	8.6	13.5
Sevin 10% dust 1.5 kg/t	10.6	19.3	26.0
Control	25.0	37.3	62.0

[a] $\overline{X}$ values over three potato lots in the same store.

In Tunisia, a comparative study was done on the effect of diffused light and cold storage on subsequent plant emergence. Twenty-four commercial varieties were stored for eight months; of these, only eight varieties had good plant emergence after either type of storage. It is therefore important to recognize, when recommending this technology to small farmers, that there are different varietal responses to diffused light storage.

Region VI. Postharvest research in India was coordinated with NAFED in New Delhi. An evaporative-type, rustic cool store was constructed and full-scale trials will begin in 1983. In Bangladesh, seed tubers after being four months in rustic stores and then four months in cold storage were still in good condition, and losses due to rotting were low. In the traditional potato-growing areas of the plains and the midhills of India, diffused light stores were constructed. Seed tubers kept in the stores for six months were in excellent condition with strong green sprouts. Preliminary trials in Bangladesh and Bhutan on low-cost starch production using existing fruit-processing equipment indicated that yields of 8 percent high-quality starch from second-grade tubers could be obtained.

Region VII. In the Philippines, storage methods for ware potatoes are being evaluated. A preliminary survey is being made on methods currently used in the highlands of Mountain State Province. Based on these findings, decisions will be made on the type of methods to introduce. This is being coordinated with the Postharvest Training and Research Center, University of the Philippines at Los Baños.

ADDITIONAL RESEARCH PROJECTS

LOWLAND TROPICAL POTATO

Brazil. The screening of germplasm continued at Itaguaí, Rio de Janeiro, during the May-August season when temperatures (16°-18°C) and rainfall are relatively low. EMBRAPA scientists screened European and Brazilian varieties and 158 CIP clones; 8 varieties and 2 clones yielded more than 500 g/plant.

Philippines. Experiments were carried out at a lowland site in Luzon to test the effects of mulch, the planting system, and cultivars on growth of the potato in the hot tropics. Mulch reduced soil temperature at 6 cm by 3°C during the day. As the plant canopy developed, the difference in temperature between the mulched and uncovered soil became less. After 94 days, the yield of total dry matter for the mulch treatment was 12 t/ha, and for the uncovered soil 5.6 t/ha. However, tuber yields were low as the number of main stems per plant was only 1.6. It will be necessary to concentrate on increasing the number of main stems to improve yield.

At a mid-elevation site (800 m), European and U.S. varieties tuberized readily at 35 to 40 days after planting. Two European varieties gave 24 t/ha tuber yield at 91 days, while Mexican varieties, adapted to the higher altitudes, gave 15 t/ha.

AGRONOMY

Rwanda. A simple rotation of potato-beans-potato was compared with continuous potato to study the effect on incidence of bacterial wilt. In the fourth season, an additional rotation of potato-green peas-wheat-potato was compared. The results were not statistically significant, although there were indications that rotation slightly reduced the number of wilted plants (14%) compared to continuous cropping with potato (20%). The effect of the intense dry season was far greater than any of the rotation effects in reducing bacterial wilt incidence.

Bangladesh. Jointly with BARI and IADS, five different cropping systems incorporating potato were evaluated for intensity of cropping, both in time and productivity, per unit land area. Potato-potato-mung bean-black gram, and potato-wheat-mung bean rotations gave the best economic returns and were equally efficient in using residual P and K fertilizer applied to the potato crop.

Philippines. Experiments were conducted to 1) determine the P requirements of diverse germplasm, 2) determine the P requirements of various soils of the region, and 3) examine the mycorrhizal association with P application. The P requirement was high, but there was little or no mycorrhizal association on any of the cultivars tested even though spores were present in all soils. Inoculation of roots with mycorrhizal fungi in a pot experiment did not significantly affect plant growth.

ON-FARM RESEARCH

Rwanda. In two seasons, 83 experiments were conducted and four factors tested: 1) control of late blight by fungicides, 2) use of compost, 3) improved varieties, and 4) storage. In late blight control, the use of fungicides was profitable in some cases where farmers' yields increased by more than 100 percent. In 11 experiments, control was ineffective in only 2 of them. In the previous year, compost was not effective in raising yields on non-volcanic soils; however, in further trials this year, better and well-rotted compost was applied either in rows or broadcast. Of seven trials, five were profitable with only three having a rate of return greater than 2. For most of the farmers, it seems that it is worthwhile to promote the use of compost using row placement, due to the general low quality of the compost.

Social Sciences

The Social Science Department conducts research and training on potatoes in the food systems of developing countries. Macro-level studies analyze patterns and trends in potato production, marketing, and consumption. Micro-level studies focus on key aspects of seed, production, and postharvest technology. Socioeconomic analysis contributes to establishment of CIP priorities, development and transfer of appropriate technology, and monitoring its use and adaptation by farmers of developing countries. Training activities are linked to priority research areas. During 1982 research was conducted on: world trends in potato production and use, Peruvian potato agriculture in comparative perspective, consumer patterns of potato consumption and its nutritional value, market demand for potatoes, economics of tuber and true seed systems, and farmer adoption of postharvest technology.

WORLD TRENDS IN POTATO PRODUCTION

A data bank with national, regional, and world statistics has been established. Analysis has indicated that in most developing countries potato production is increasing rapidly, in contrast to temperate-zone industrial countries where production is gradually declining. Potato consumption is increasing most rapidly in Africa and the Far East where the average per capita consumption is still low. One important reason for low consumption levels is the high retail price, due to high production and marketing costs. On the average, energy and protein derived from potatoes cost the developing country consumer about three times or more than energy and protein derived from wheat and rice (Table 1). Continued rapid expansion of potato production and consumption will require a substantial reduction of production costs and retail prices per kilogram.

Table 1. Per capita potato production and percent change in production: by world region.

Region	Per capita production 1978 (kg)	Percent change production 1961/65-1980
Developed market economies		
North America	79	12
Western Europe	143	−34
Oceania	60	49
Developing market economies		
Africa	9	119
Latin America	32	40
Near East	26	132
Far East	9	150
Centrally planned economies	121	−21

PERUVIAN POTATO AGRICULTURE

An anthropological study of potato farming in Peru was conducted in the four main zones where CIP conducts research. A global study of potato production systems is being conducted that involves comparisons with the Peruvian zones. During 1982 considerable progress was made in collecting and organizing descriptive information on potato farming systems in developing countries. From this data, a typology of potato production systems is emerging, and mapping of production zones will be possible. This descriptive data also demonstrates gaps in knowledge about the important producing regions.

POTATO CONSUMPTION AND NUTRITIONAL VALUE

This project examined the current role of the potato in diets, and the potential for, and obstacles to increased potato consumption in Bangladesh and Bhutan.

Bangladesh. This study was conducted in cooperation with the Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute-Potato Research Center (BARI-PRC), the Women's Section of the Planning and Evaluation Cell of the Ministry of Agriculture and Forests, and the International Agricultural Development Service (IADS).

The officially reported annual per capita consumption of potatoes is only 11 kg; however, survey results for selected sites indicated much higher average levels of potato consumption and a wider range of usage patterns. Surveys in northwestern Bangladesh found that the average per capita consumption was over 50 kg/yr, but with great variation among socioeconomic groups. Because of seasonal rice scarcities, many people reported mixing potatoes with rice to extend the main dish or substituting potatoes for rice during the months immediately following potato harvest. While potato producers consumed more than nonproducers, even landless laborers were found to consume well over the official national estimate. In Dhaka, average consumption was 45 kg/yr with a substantial variation between households—from 13 to 160 kg/person/yr. The poorer Dhaka families reported average annual potato purchases of 60 kg/person/yr, while wealthier households consumed approximately 30 kg/person/yr. In general, rural potato consumption was the greatest during the four months after harvest, with urban consumption remaining stable throughout the year. Potatoes played a weaning food role in the diets of children; however, no specific preparations for this purpose were noted.

Bhutan. The study was conducted with the National Potato Development Program and officers from the Department of Agriculture. Many food planners and analysts in Bhutan believe that potatoes are produced as a cash crop strictly for export. Annual per capita consumption is estimated at less than 5 kg. This study, however, showed that considerably greater quantities are consumed domestically: rural household interviews revealed an average per capita consumption of about 45 kg/yr; urban consumption was found to be higher than officially reported; and there was also considerable use of potatoes by institutions.

Producers normally stored their own potatoes for consumption and rarely purchased, but urban residents normally purchased every week. During half of the year, the market supply is domestic; during the other half, potatoes are imported from India. Since potato consumption is high in Bhutan, attention should be given to the potato in domestic food policy decisions and should be focused on consumer education regarding potato consumption, particularly as a nutritional food for schoolchildren and weaning infants.

MARKET DEMAND FOR POTATOES

A typology of potato-consuming countries was developed based on a quantitative analysis of potato demand. This typology suggests that Andean countries with high levels of per capita production and consumption, such as Bolivia, Chile, Colombia, Ecuador, and Peru, have demand parameters that are closer to those of most developed countries than to other developing countries. Developing countries such as India and Mexico, with low levels of per capita potato consumption and high population growth rates, appear to have greater potential for increased potato demand that the Andean countries.

A study was done on potato demand in Lima, Peru, and secondary data for the last 20 years were analyzed with simple econometric models. Increased deliveries of white (hybrid) potatoes in Lima's wholesale market were found to be associated with downward movements in wholesale prices. In contrast, increased deliveries of yellow (native) potatoes had little impact on prices. This result implies that consumers differentiate between types of potatoes, and that price is an important factor in influencing consumption of the more abundant hybrid varieties sold in Lima.

Consumption of both native and hybrid potatoes was negatively associated with real wages. In other words, if—holding everything else constant—wages go up, potato consumption can be expected to decline. This result (using local statistics) tends to corroborate classification of Peru (using international data) with developed countries, where the relationship between income and potato consumption is usually weak and negative.

SEED POTATO PROGRAMS

Research is being conducted to identify ecological and socioeconomic conditions that influence performance of seed potato programs in Rwanda and Tunisia. An evaluation of socioeconomic benefits of seed certification programs is also beginning.

Rwanda. The study was conducted with the Programme National pour l'Amelioration de la Pomme de Terre (PNAP), created by an agreement between Rwanda's Ministry of Agriculture and CIP.

Rwanda, one of the most densely populated countries of Africa, has satisfied its rapidly growing demand for food primarily through expansion of cultivated areas, although yields for most crops still remain low. Future yield increases will be needed to meet food requirements of the growing population. PNAP has been one of Rwanda's most successful commodity programs in diffusion of improved technologies, such as varieties resistant to late blight (the principal factor limiting potato yields in Rwanda).

PNAP's research and extension priorities are based on on-farm research, including informal surveys, observations, and experiments. PNAP has focused on testing and introducing improved seed of late blight-resistant varieties. Since 1978, PNAP has produced over 350 tons of basic seed of two late blight-resistant varieties. This basic seed is delivered to the Selected Seed Service and to a number of special projects that multiply and sell seed to farmers throughout the country. Through this distribution system, it has been possible to increase use of quality seed of resistant varieties from approximately 25 percent in 1978 to 50 percent in 1982. Results of on-farm trials indicated that use of improved seed in these new varieties resulted in a substantial increase over yields of traditional varieties, which are susceptible to late blight and infected with viruses (Table 2).

Tunisia. This study was conducted with the Programme Tunisien de la Pomme de Terre, established in 1976 through an agreement between the government of Tunisia and CIP.

In Tunisia, potatoes are supplied to the market during three seasons: early, main, and late. Seed tubers are imported for the early and main crops, but part of the production in the early and late seasons is exported. During its first five years, the Tunisian Potato Program supplied over 2000 tons of improved seed to farmers. The principal short-term goal is to supply seed in good physiological condition for planting in the late season; a long-term goal is to reduce seed import by providing quality seed for the early season. On-farm trials demonstrated that in the late season project seed yields approximately doubled that of farmers' common seed (Table 3).

In both studies, strong demand for potatoes has provided a favorable environment for establishment and operation of seed programs. The institutional organizations established for producing and delivering improved seed differ radically between Rwanda and Tunisia: CIP has played a central role in the creation and management of the Rwanda

Table 2. Average yields resulting from use of farmer seed and project seed of two varieties in 15 on-farm experiments, Rwanda.

		Yield of project seed			
		Sangema variety		Montsama variety	
District	Yield of farmer seed (t/ha)	t/ha	% change over farmer yield	t/ha	% change over farmer yield
Kidaho	12.8	17.4	36	17.0	33
Nkumba	9.7	22.1	128	18.3	88
Kinigi	32.4	50.0	54	46.3	43
Giciye	8.2	17.5	113	12.1	48
Karago	12.2	12.4	2	10.9	−11
Average	14.3	21.4	50	19.2	34

Table 3. Average yields resulting from use of alternative seed sources in on-farm experiments, Tunisia.

Season	Experiments (no.)	Project seed (t/ha)	Farmer seed (t/ha)	Imported seed (t/ha)
Late season				
1978	4	24.6	13.6	–
1979	8	20.6	11.6	–
Early season				
1979	7	18.1	–	10.9
1980	8	26.3	–	23.3

program; in contrast, CIP's role has been primarily catalytic in Tunisia, where the seed program operates through a complex network of local institutions.

In both countries, the amount of improved seed delivered to farmers increased steadily after the programs were initiated. Both programs focused on a small number of key seed-related factors limiting potato yields: in Rwanda, on evaluation and introduction of late blight-resistant varieties; in Tunisia, on supplying farmers with seed of better physiological condition than alternative sources (imported or local).

TRUE POTATO SEED TECHNOLOGY

Socioeconomic research contributes to the generation and transfer of true potato seed (TPS) technology, which is economically viable and culturally acceptable to farmers and consumers in developing countries. On-farm research was conducted in Peru in one highland and three coastal sites. Informal surveys provided baseline information on the farming systems and factors influencing the agronomic and economic performance of TPS in these areas and its acceptance by farmers. In the highland site (Tarma), surveys were followed up with a single-visit survey to 72 individual horticulturalists and a multiple-visit survey to 4 key informants. Survey results are being used for preparation of a CIP-sponsored M.A. thesis on the economics of TPS in horticultural farming systems.

The results from all experiments to date have indicated that the cost of producing consumer potatoes from TPS was lower than producing from tuber seed on a per hectare basis. The magnitude of cost reduction depended primarily on two factors: the cost of seed tubers replaced by TPS, and the additional cost of labor required for use of TPS.

In all experiments, yields and the proportion of large tubers were higher for conventional tuber seed than for TPS. In areas where good quality seed tubers are not available, the yield gap between crops grown from seed tubers and TPS should be considerably smaller or negative.

All farmer cooperators—horticulturalists experienced in transplanting—were successful in producing viable seedlings from TPS. Factors such as soil preparation, irrigation, fertilization, and pesticide application influenced quality seedlings, but in no case did management practices limit production of seedlings of reasonably good quality. Farmers tended to apply the same management practices to crops growing from TPS as they did to their normal potato crops growing from seed tubers. This created some problems, particularly during the first month after transplanting, when irrigation and timely application of pesticides are critical for transplant establishment.

More labor was required for production of potatoes from TPS, resulting primarily from seedling production and transplanting, than from tuber seed. Small producers relying primarily on family labor were more concerned with the increased labor requirement than larger producers employing machinery and salaried workers. Labor requirements may be significantly reduced in the future as farmers become accustomed to the technology.

Given the present knowledge of TPS and factors influencing farmer adoption of new technologies, it is concluded that TPS is most likely to be used by farmers where the following conditions are met: environmental and growing conditions are suitable for production of potatoes and other vegetables, good quality seed tubers are either unavailable or very expensive, and skilled labor is inexpensive.

POSTHARVEST TECHNOLOGY AND MANAGEMENT

The Social Science Department continued its interdisciplinary research with biological scientists in Thrust VIII postharvest technology and management. CIP's postharvest team has also concentrated on developing models of technology generation and transfer that are relevant to small farmers in developing countries. The team operates under the assumption that research must *begin* and *end* with the farmer, that problems to be solved must be precisely defined, and that research involves a constant interplay between experiment station and actual farm conditions.

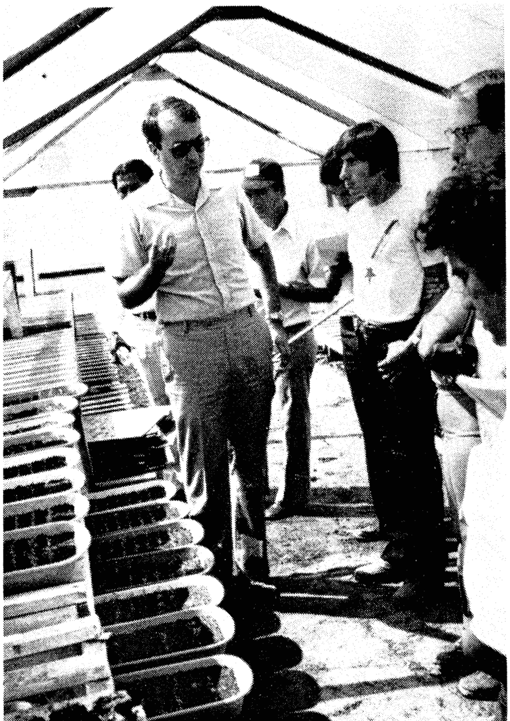
CONSUMER POTATO STORAGE

Ethnographical research on farm-level problems in consumer potato storage began in Peru this year, which complements on-going experiment station research. The purpose of research at this stage is to describe and understand traditional methods of consumer potato storage. Preliminary findings point to complex systems that vary according to agro-ecological zones (coast vs highlands). Findings also indicate a parallel phenomenon with the case of seed storage problems. It appears that adoption of new varieties and an increasing market orientation have placed stress on traditional consumer storage methods. Farmers note that while new varieties are higher yielding, they are more prone to insect damage. These farmer perceptions are presently being investigated at both farm and experiment station levels. If, as in the case of seed storage, it appears that traditional storage practices are not functional for new varieties, then adaptive research must be done to build on traditional systems to assist farmers in improving storage of their new, higher yielding varieties.

TRAINING ACTIVITIES

During the year, social science staff participated in courses in Peru's National Agrarian University and supervised four Peruvian university theses research projects. A six-week course on farming systems analysis was organized and conducted in conjunction with Peru's National Institute for Agricultural Research and Promotion (INIPA). Social scientists also participated in CIP regional training activities involving on-farm research, seed production systems, and postharvest technology. Informal, on-site training of several national scientists was conducted in Bhutan and Bangladesh in conjunction with the potato consumption research project.

Training & Communications



INTRODUCTION

CIP's profile to the year 2000 calls for the development of a global network of national researchers, extensionists, and educators in potato research and training. Therefore, the objective of CIP's training program is to advance the progress of national potato workers in:

- identifying research needs and priorities,
- identifying relevant technology for their needs,
- conducting and evaluating research,
- communicating research results with others,
- transferring adequate technology within their countries and to surrounding countries, and
- training others to: identify research needs, priorities, and relevant technology; conduct and evaluate research; and participate in the technology transfer process.

The activities and services of Training and Communications are designed to achieve the training objectives stated above.

TRAINING

Each year CIP updates it five-year training program, which involves an assessment of training needs identified by national program scientists and CIP regional scientists, and an assessment of the various improvements in new technologies emerging from CIP's research program. The five-year program has two major types of training: production-oriented and specialized.

Production-oriented training focuses on the general principles of potato production. It is conducted in the CIP regional network and involves substantial input in organization and instruction by national program workers. It is directed principally at researchers and extensionists to enable them to respond to farm-level problems. In 1982, there were ten courses, workshops, or symposia in which over 300 scientists participated.

Specialized training is mainly research-oriented and concentrates on topics where CIP is the principal source of expertise—it may be a group activity or individual training. Presently, training is mostly at CIP headquarters, although it is now expanding into the regional network as local expertise becomes available. Specialized training includes post-doctoral research and advanced degree theses supervised by senior CIP scientists. In 1982, 306 scientists received this type of training.

The degree of CIP's direct involvement in organizing and conducting either production-oriented or specialized training events depends to a large extent on the progress and state of development of the national institutions. In many cases, national program staff are capable of conducting training courses without direct support from CIP. In 1982, for example, the National Agrarian University, Peru, assumed full responsibility for the

CIP assists Peruvian national potato programs in training.

organization and instruction of a production course with emphasis on seed production. Of the 16 participants, 4 were from other countries in South America.

SPECIAL TRAINING PROJECTS

United Nations Development Program (UNDP). A two-year special project for technology training in root and tuber crops, in collaboration with the Centro Internacional de Agricultura Tropical (CIAT) and the International Institute for Tropical Agriculture (IITA), was extended by UNDP for a second five-year phase.

During the first two-year phase, CIP, in collaboration with national programs, conducted six storage courses in Colombia (1), Peru (1), and Sri Lanka (4); two on-farm research methodologies courses in Rwanda and the Philippines; two seed production courses in Bangladesh and Peru; and five training or research development events with CIAT and IITA. More than 350 national scientists participated in these activities. One of the primary goals of the project is to catalyze the exchange of technological information between countries. In this respect, in the ten courses organized by CIP alone, 95 national scientists participated as instructors, with participants representing 18 countries. In 1982, 8 of the 25 training events listed in Table 1 were sponsored by this project.

German Foundation for International Development (DSE). In 1982, this foundation sponsored courses on seed production in Brazil, on

Table 1. CIP training activities, 1982.

Region	Activity	Number of participants	Number of countries	Type
Region I				
Peru	Production Course with Emphasis on Production of Seed[a]	16	5	Production
Colombia (CIAT)	CIP/CIAT/IITA Root and Tuber Germplasm and Quarantine Workshop[a]	21	10	Specialized
Colombia (CIAT)	CIP/CIAT Tissue Culture Course[a]	8	5	Specialized
Venezuela	Field Inspection Short Course	18	1	Specialized
Peru	Farming-Systems Analysis Course[b]	15	1	Specialized
Colombia	Practical Virology Short Course[c]	13	7	Specialized
Peru	CIP/UNA Fertilizer Courses (4)	155	1	Production
Region II				
Brazil	Bacterial Wilt Workshop	17	5	Specialized
Brazil	Seed Production Course[c]	22	4	Production
Region III				
Burundi	Potato Production Course	9	1	Production
Madagasc.	Seed Production Course	14	1	Production
Rwanda	Seed Production Course	14	2	Production
Ethiopia	Research and Training Development Workshop[a]	25	12	Specialized
Nigeria (IITA)	CIP/IITA Root and Tuber Crop Germplasm and Quarantine Workshop[a]	19	11	Specialized
Region IV				
Turkey	Germplasm Management Course	14	6	Specialized
Region VI				
Bangl.	Seed Production Course[a]	24	5	Production
Bhutan	Tuber-Borne Diseases and Pests Seminar	16	4	Specialized
Bhutan	Potato Production Course	18	1	Production
India	CIP/CPRI Potato Production Course	7	3	Production
Region VII				
Philip. (VII HQ)	CIP/CIAT Root and Tuber Crop Germplasm and Quarantine Workshop[a]	21	8	Specialized
Philip.	On-Farm Research Methodologies Course[a]	18	7	Specialized
Philip.	Seed Production Course	22	1	Production
Headquarters in Peru				
Germplasm Management Course		9	9	Specialized
Production from True Seed Course		12	10	Specialized
Nematology Research Course[c]		13	11	Specialized
Individualized On-the-Job Training		16	8	Specialized
Training for Course Leaders		1	1	Specialized
Scholarships		9	6	Specialized
Student Assistantships		16	1	Specialized
Pre-Professional Internships		18	2	Specialized
Postdoctoral Research		7	5	Specialized

[a]UNDP
[b]World Bank
[c]DSE

Specialized training at CIP headquarters provides national scientists with opportunities in laboratory research.

virology in Colombia, and on nematology research at CIP headquarters. These three courses were attended by 48 participants from 14 Central and South American countries.

World Bank. A course on farming-systems analysis was held in Peru with 15 participants and funded by the World Bank. A USAID training officer assisted with the course.

W. K. Kellogg Foundation. A three-year project to develop training materials was extended for an additional two years, to the end of 1984. During 1982, a framework for production-oriented training materials was nearing completion with the development of a 30-day production course. This course is designed to be flexible in content and length and is intended for use by national programs in the regional network. Five major sets of training materials were completed during the year, and an additional 25 are in advanced stages of preparation.

EVALUATION OF TRAINING PROGRAM ACTIVITIES

Nearly all courses were evaluated for organization and content. Each period of instruction was evaluated by the participants on the basis of knowledge acquired, usefulness, depth of treatment, effectiveness of the instructor, quality of training materials, and time allotted. This formative evaluation permits modifications to be made as courses develop. An evaluation at the end assists course organizers in making improvements to similar courses in the future. This evaluation system has been extremely beneficial.

Due to the existing lack of knowledge on the impact of training at the user level, a questionnaire was designed to ellicit responses that would indicate this impact. A pilot questionnaire, designed for quantifiable data, will be mailed in the near future to former course participants and has already been tried out in personal interviews.

COMMUNICATIONS SERVICES

The communications support unit has continued to provide the following services to administration, research, and the training program: writing and editing, translating, design and layout, typesetting, printing, binding, distribution, visuals production, and photography. During the year, 22 documents and 21 abstracts were translated into either English or Spanish. Table 2 reflects the 23 percent increase over 1981 in communications jobs completed.

The unit's ability to provide this support was primarily due to a reorganization of the work flow; a redistribution of existent workspace, which was 80 percent completed by the end of the year; and a marked improvement in coordinating the work of the various subunits, even though there was no staff increase. Additionally, text preparation time was substantially reduced with the introduction of a word-processing system. As the year ended, plans were being made to codify and update CIP's mailing lists for incorporation into one master list on the word processor. As in the past, a committee composed of senior scientists and directors continued to assist in establishing priorities for communications work. This committee reviews all proposals for publications and visuals, and names review boards to ensure scientific accuracy.

Logistical support in terms of scheduling, arranging, and managing audio-visual equipment was provided to 367 group meetings held at

Table 2. Communications jobs processed in 1981-1982.

	Publications (Annual report, technical bulletins, circulars, etc.)				Others (Visual aids, translations, graphs, etc.)				
Year	Admin.	Res.	Trng.	Subtotal	Admin.	Res.	Trng.	Subtotal	Total
1981	14	65	45	124	180	291	278	749	873
(%)	2	7	5	14	21	33	32	86	100
1982	31	63	54	148	309	321	293	923	1071
(%)	3	6	5	14	29	30	27	86	100

Communications personnel coordinating production of CIP publications.

CIP headquarters. This included 18 seminars conducted by CIP staff from headquarters and the regions, as well as by visitors or visiting scientists as they concluded their period of training.

LIBRARY SERVICES

A strong information support unit is essential to the development of a global communications network. From both the main library in Lima and the branch unit in Huancayo, services were given to all CIP staff and to visiting scientists (Table 3). Peruvian national potato program specialists and university students involved in theses research also made use of the library facilities.

The library collection significantly increased this year, especially in the areas of technology transfer, training, seed physiology, tissue culture, multiple cropping systems, potato production from true potato seed, potato marketing, stress and survival of vegetable crops, and nutritional value of the potato.

Two of the services provided included 1) bibliographies on the enzyme-linked immunosorbent assay (ELISA) and on potato theses from the National Technical University of the Highlands in Puno, Peru, and 2) retrospective searches and selective dissemination of information using computer-based bibliographic services for research topics on the potato.

Ties were strengthened with the World Agricultural Information System (AGRIS) and the Inter-American Agricultural Information System (AGRINTER). Furthermore,

Table 3. Library collection additions and services, 1981-1982.

	Total 1981	Additions 1982	Total 1982
Collection			
Book collection	4160	409	4569
Journal titles	384	14	398
Journals by subscription	74	9	83
Annual reports	128 (532)[a]	8 (81)[a]	136 (613)[a]
Bulletins	343	17	360
Reprints	3009	417	3426
Services			
Loans to CIP staff and training program	4830		5168
Interlibrary loans	482		427
External users	391		350
International exchange	271 (66)[b]		321 (68)[b]

[a]Different titles (actual numbers of annual reports).
[b]Libraries (countries).

while reviewing and updating exchange agreements with key libraries around the world, a special effort was made to strengthen relations with the libraries in Peru. Fifty libraries were added to the exchange agreement list, which now totals 320 libraries in 68 countries. A complete list was provided to regional research staff for quicker access to publications and for referrals by national researchers and extensionists.

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For reprints please refer directly to main authors.

Financial Statements

INTERNATIONAL POTATO CENTER – CIP

FINANCIAL STATEMENTS
December 31, 1982 and December 31, 1981

SUPPLEMENTARY INFORMATION
December 31, 1982

CONTENTS

US$ = United States dollar
S/. = Peruvian sol

Moreno Patiño y Asociados
FIRMA MIEMBRO DE PRICE WATERHOUSE

LAS BEGONIAS 441
APARTADO 2869
LIMA 27, PERU
TELEFONO 40-0555
TELEX 20008 PRIWATR

April 8, 1983

REPORT OF INDEPENDENT ACCOUNTANTS

To the Board of Trustees
International Potato Center - CIP

We have examined the balance sheets of International Potato Center - CIP as of December 31, 1982 and December 31, 1981, and the related statements of source and application of funds and changes in financial position for the years then ended. Our examinations were made in accordance with generally accepted auditing standards and, accordingly, included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the financial statements referred to above present fairly the financial position of International Potato Center - CIP at December 31, 1982 and December 31, 1981, and the results of its operations and the changes in its financial position for the years then ended, in conformity with generally accepted accounting principles consistently applied.

Moreno, Patiño y Asociados

Countersigned by

-----------------------------------(partner)
Francisco J. Moreno
Peruvian Public Accountant
Registration No. 155

BALANCE SHEET (Note 2)

ASSETS

	At December 31, 1982 US$	1981 US$
CURRENT ASSETS		
Cash on hand and in banks	219,908	590,317
Short term investments	1,020,728	81,369
Accounts receivable		
Donors	609,961	633,174
Advances to principal and support staff	49,365	38,871
Loans due from principal and support staff-current portion (Note 3)	144,425	182,128
Advances to organizations for research work	59,208	200,640
Other (Note 4)	180,686	147,263
	1,043,645	1,202,076
Inventories of laboratory, spares and other supplies	457,619	515,874
Prepaid expenses and other assets	41,399	57,992
Total current assets	2,783,299	2,447,628
LOANS DUE FROM PRINCIPAL AND SUPPORT STAFF - LONG TERM (Note 3)	754,527	688,512
FIXED ASSETS (Note 5)	6,707,572	6,013,603
	10,245,398	9,149,743

LIABILITIES AND FUND BALANCES

	At December 31, 1982 US$	1981 US$
CURRENT LIABILITIES		
Bank loan and overdrafts (Note 3)	168,693	204,166
Accounts payable to suppliers	773,150	625,621
Accounts payable to organizations	80,957	20,599
Special project funds payable to donors	30,652	-
Other payables	89,785	48,700
Total current liabilities	1,143,237	899,086
GRANTS RECEIVED IN ADVANCE (Note 6)	-	389,887
PROVISION FOR SEVERANCE INDEMNITIES, net of advances of US$15,771 in 1982 and US$15,375 in 1981	185,980	167,923
LONG TERM DEBT		
Bank loan (Note 3)	741,526	679,757
FUND BALANCES		
Funds invested in fixed assets	6,707,572	6,013,603
Unexpended funds		
Working funds	745,000	702,000
Core programs	191,562	2,806
Special projects	473,521	294,681
Capital funds	57,000	-
	1,467,083	999,487
	8,174,655	7,013,090
GRANTS PLEDGED (Note 7)		
	10,245,398	9,149,743

STATEMENT OF SOURCE AND APPLICATION OF FUNDS (Note 2)

	For the year ended December 31, 1982 US$	1981 US$
SOURCE OF FUNDS		
Operating grants		
Unrestricted	3,716,094	3,804,203
Restricted	5,271,601	4,702,011
	8,987,695	8,506,214
Special project grants	971,894	712,387
Capital grants	563,049	545,765
Working fund grants	745,000	702,000
Other income, net	124,253	207,841
	11,391,891	10,674,207
APPLICATION OF FUNDS		
Core operating expenses		
Potato research program	2,453,021	2,139,377
Research support	883,620	860,158
Regional research and training	2,549,481	2,561,562
Library, documentation and information service	423,829	384,846
General administration	967,697	813,396
General operating costs	1,331,698	1,951,911
TAC review and symposium	254,041	-
	8,863,387	8,711,250
Special projects		
Expenses	467,720	417,705
Payable to donors	30,652	-
	9,361,759	9,128,955
Capital		
Additions to fixed assets	563,049	545,765
	9,924,808	9,674,720
UNEXPENDED FUNDS	1,467,083	999,487

STATEMENT OF CHANGES IN FINANCIAL POSITION

	For the year ended December 31, 1982 US$	1981 US$
FINANCIAL RESOURCES PROVIDED FROM:		
Operations		
Unexpended funds	1,467,083	999,487
Provision for employee indemnities	28,074	45,881
Financial resources provided from operations	1,495,157	1,045,368
Increase in long term debt	228,340	523,896
Transfer of current portion of loans due from principal and support staff in year	210,904	222,369
Increase in grants received in advance	-	250,151
Cost of fixed assets replaced to be retired or sold	259,079	306,920
	2,193,480	2,348,704
FINANCIAL RESOURCES APPLIED TO:		
Fixed asset acquisitions - additions	563,049	545,765
Fixed asset acquisitions - replacements	389,999	1,069,056
Advances and payments of employee indemnities	10,017	13,249
Financial resources applied to operations	963,065	1,628,070
Increase in loans due from principal and support staff	276,919	535,976
Transfer of current portion of long term debt in year	166,571	206,512
Decrease in grants received in advance	389,887	-
Net increase in funds invested in fixed assets	(693,969)	(1,307,901)
Unexpended fund balance from prior year	999,487	807,925
	2,101,960	1,870,582
Net increase in financial resources	91,520	478,122
	=========	=========
CHANGES IN FINANCIAL RESOURCES REPRESENTED BY:		
Increase in current assets	335,671	847,812
(Increase) in current liabilities	(244,151)	(369,690)
Net increase in financial resources	91,520	478,122
	=========	=========

NOTES TO FINANCIAL STATEMENTS
DECEMBER 31, 1982 AND DECEMBER 31, 1981

1 OPERATIONS

The International Potato Center - CIP was constituted in 1972, in accordance with the Agreement for Scientific Cooperation between the Government of Peru and North Carolina State University, United States of America, signed in 1971 and expiring in the year 2000. The Center is a member of the group of International Agricultural Research Centers which is supported by the Consultative Group for International Agricultural Research.

The CIP is a non-profit organization centered in Lima, Peru, with programs located throughout America, Europe, 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.

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) 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 translated at an exchange rate, which approximates the official exchange rate at the year end. Translation gains and losses are included in the statement of source and application of funds as Other income, net.

b) Grant transactions are accounted for principally on an accrual basis.

   Unrestricted and restricted operating and special project grants are accounted for in the period stipulated by the donor. Capital and working fund grants are recorded when received or when transferred through annual budget approvals. Other income, net, is recorded when earned and is comprised primarily of interest on investments, proceeds from sales of fixed assets and translation gains and losses.

In accordance with the instructions from the Consultative Group for International Agricultural Research, the unexpended fund balances at year end, if authorized by donors, are treated as a source of funds in the next year in order to absorb corresponding expenses, otherwise the unexpended balances are recorded as liabilities.

Firm orders for purchases of fixed assets and services are recorded in the year of their commitment. Expenditures made by international programs are recorded on the basis of advices received. Expenses related to special projects are applied against the respective income when incurred.

c) Short term investments are principally comprised of certificates of deposit bearing interest at current bank rates and are valued at cost.

d) Inventories of laboratory, spares and other materials are generally valued at estimated actual value, which approximates cost.

e) Fixed asset additions are applied against capital grants, while replacements are recorded as core operating expenses in the statement of source and application of funds. Simultaneously, the acquisitions are capitalized at their purchase cost.

It is not the policy of the CIP to reduce the value of fixed assets and the related capital account for depreciation. When assets are replaced to be retired or sold, their cost is removed from the fixed asset and the related equity accounts.

Maintenance and repairs are recorded as operating costs in the year incurred.

f) It is not the practice of the CIP to accrue a liability for employee vacations. Generally, vacations are taken in the year when earned and are charged to operations as salaries and wages.

g) Indemnities to local staff are accrued in full in accordance with Peruvian legislation.

h) The costs of providing the various programs and research projects have been summarized on a functional basis by cost center in the statement of source and application of funds. Accordingly, certain costs have been allocated to special project expenses in order to more appropriately reflect benefits received.

3 LOANS DUE FROM PRINCIPAL AND SUPPORT STAFF

The balance of the loans due from principal and support staff for home and vehicle purchases at December 31, is presented in the balance sheet as follows:

	1982 US$	1981 US$
Loan-current portion, including interest receivable of US$3,736 in 1981	144,425	182,128
Loan-long term portion	754,527	688,512

Substantially all loans to principal and support staff have been financed by a line of credit from Citibank N.A. - New York totalling US$1,000,000 in favor of the CIP. Interest is charged at 1 1/2% per annum over the Citibank N.A. - New York prime rate on the aggregate unpaid principal balance. Total outstanding credit at December 31, 1982 and 1981 was US$899,428 and US$872,070, respectively. Loans to qualifying principal and support staff are secured by first mortgages on properties acquired. Payment terms extend to 10 years with interest charged at rates which absorb the related CIP liability to Citibank N.A. - New York. Under the amortization program established, the current portion of payments on the outstanding credit totals US$157,902 (US$192,313 in 1981), including accrued interest of US$9,996 (US$12,501 in 1981), and is shown under current liabilities in Bank loan and overdrafts in the balance sheet.

4 ACCOUNTS RECEIVABLE - OTHER

This account comprises the following at December 31:

	1982 US$	1981 US$
Travel advances and revolving funds to principal and support staff	64,717	65,113
Advances to contractors and others	36,747	29,009
Reimbursable costs incurred on behalf of Instituto Nacional de Investigación y Promoción Agropecuaria - INIPA	79,222	-
Current account of "Proyecto Suelos Tropicales - Yurimaguas" of North Carolina State University	-	50,199
Guarantee deposit	-	2,942
	180,686	147,263

5 FIXED ASSETS

Fixed assets at December 31, comprise the following:

	1982 US$	1981 US$
Buildings and construction in progress	2,169,648	1,932,617
Research equipment	771,235	712,429
Vehicles and aircraft	1,672,133	1,538,951
Furniture, fixtures and office equipment	536,180	458,516
Operating equipment	249,925	225,276
Installations	742,801	676,310
Site development	317,026	290,025
Communication equipment	173,093	107,140
Other	75,531	72,339
	6,707,572	6,013,603

Vehicles and other fixed assets replaced to be retired or sold are transferred from the fixed asset and related equity accounts to a memorandum account. The balance of this memorandum account at December 31, 1982 is US$391,027 (US$252,065 in 1981).

6 GRANTS RECEIVED IN ADVANCE

Donations received in advance to be utilized in the following year are as follows:

	1982 US$	1981 US$
Swiss Government	-	381,553
French Government	-	8,334
	-	389,887

7 GRANTS PLEDGED

During 1982 the following donations were pledged to the CIP for special projects in 1983 through 1987:

	1983 US$	1984 US$	1985 US$	1986 US$	1987 US$
Swiss Development Cooperation and Humanitarian Agency	385,000	281,000	326,000	306,000	335,000
United Nations Development Program	114,500	138,000	199,000	181,000	155,500
W.K. Kellogg Foundation	56,100	69,100	-	-	-
Federal German Government	34,400	16,000	-	-	-
Belgian Government	41,200	-	-	-	-
	631,200	504,100	525,000	487,000	490,500

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April 8, 1983

REPORT OF INDEPENDENT ACCOUNTANTS

To the Board of Trustees
International Potato Center - CIP

In our opinion, the accompanying information, presented in Exhibit 1 to 4 is stated fairly in all material respects in relation to the financial statements, taken as a whole, of International Potato Center - CIP for the year ended December 31, 1982, which are covered by our report dated April 8, 1983 presented in the first section of this report. The accompanying information is presented as additional data and is not necessary for a fair presentation of the financial position, source and application of funds, and changes in financial position. Our examination, which was made primarily for the purpose of forming an opinion on the financial statements taken as a whole, included such tests of the accounting records, from which the additional information was compiled, and such other auditing procedures as we considered necessary in the circumstances.

Moreno, Patiño y Asociados

Countersigned by

---------------------------------------(partner)
Francisco J. Moreno
Peruvian Public Accountant
Registration No. 155

Exhibit 1

ACCOUNTS RECEIVABLE - DONORS
DECEMBER 31, 1982

	US$
Belgian Government	300,752
Commission of the European Communities	194,320
OPEC Fund for International Development	52,500
United Nations Development Program	30,000
Government of Spain	25,000
Swiss Development Cooperation and Humanitarian Agency	4,159
International Development Research Center	3,230
	609,961

Exhibit 2

FIXED ASSETS
DECEMBER 31, 1982

	Balance as of 1.1.82	Acquisitions		Retirements	Balance as of 12.31.82
		Additions	Replacements		
	US$	US$	US$	US$	US$
Buildings and construction in progress	1,932,617	233,464	5,966	2,399	2,169,648
Research equipment	712,429	57,902	47,410	46,506	771,235
Vehicles and aircraft	1,538,951	84,433	200,097	151,348	1,672,133
Furniture, fixtures and office equipment	458,516	66,488	50,188	39,012	536,180
Operating equipment	225,276	20,636	8,624	4,611	249,925
Installations	676,310	58,452	13,802	5,763	742,801
Site development	290,025	27,001	-	-	317,026
Communications equipment	107,140	11,131	63,912	9,090	173,093
Other	72,339	3,542	-	350	75,531
	6,013,603	563,049	389,999	259,079	6,707,572

Exhibit 3

SOURCE OF FUNDS
DECEMBER 31, 1982

	US$	US$
CORE OPERATING GRANTS:		
Multi-purpose		
Danish International Development Agency	315,159	
Swiss Development Cooperation and Humanitarian Agency	381,554	
International Bank for Reconstruction and Development	400,000	
Netherlands Government	325,000	
	1,421,713	
Less:		
Applied to capital	563,049	
Applied to working funds	43,000	
	815,664	
Core unrestricted grants		
Swedish Agency for Research Cooperation with Developing Countries	745,342	
United Kingdom Overseas Development Administration	533,918	
Canadian International Development Agency	692,240	
Federal German Government	452,036	
Australian Development Assistance Agency	236,835	
Norwegian Government	135,731	
Government of Spain	25,000	
Philippine Government	50,000	
Belgian Government	71,909	
	2,943,011	
Plus:		
Balance from previous year	(42,581)	3,716,094
Core restricted grants		
U.S. Agency for International Development	2,200,000	
International Fund for Agricultural Development	600,000	
Japan Economic Cooperation Bureau	250,000	
Interamerican Development Bank	950,000	
Belgian Government	59,287	
European Economic Community	796,362	
French Government	122,302	
OPEC Fund for International Development	190,000	
DSE Germany	58,263	
	5,226,214	
Plus:		
Balance from previous year	45,387	5,271,601
Carried forward:		8,987,695

Exhibit 3
Page 2

	US$	US$
Brought forward:		
		8,987,695
SPECIAL PROJECT GRANTS:		
Government of Japan	200,000	
Government of Ireland	68,600	
Swiss Development Cooperation and Humanitarian Agency	99,771	
Federal German Government	10,000	
International Development Research Center	6,944	
Canadian International Development Agency	(230)	
United Nations Development Program	35,484	
Belgian Government	188,445	
W.K. Kellogg Foundation	56,000	
Australian Development Assistance Bureau	12,198	
	677,212	
Balance from previous year:		
Belgian Government	53,340	
Australian Development Assistance Bureau	(13,863)	
W.K. Kellogg Foundation	(5,017)	
Swiss Development Cooperation and Humanitarian Agency	66,705	
Canadian International Development Agency	(17,658)	
United Nations Development Program	117,366	
Federal German Government	79,010	
International Development Research Center	16,060	
Ford Foundation	(1,261)	
	294,682	971,894
CAPITAL GRANTS:		
Transferred from multi-purpose funds	563,049	563,049
WORKING FUNDS.		
Transferred from multi-purpose funds	43,000	
Balance from previous year	702,000	745,000
OTHER INCOME, net	124,253	124,253
		11,391,891
		==========

Exhibit 4

MOVEMENT OF SOURCE AND APPLICATION OF FUNDS OF SPECIAL PROJECTS
DECEMBER 31, 1982

Name of donors and projects
Ford Foundation -
Improve potato production
Training and research activities in Colombia and Ecuador
Federal German Government -
Potato Marketing
Electrophoresis technique
Regional seed production specialist
Lupine rotation system
Swiss Development Cooperation and Humanitarian Agency -
Training - Shakya
Potato improvement - Nepal (Second Phase)
Basic seed potato production training
PRECODEPA - Second Phase
Helvetas potato project - Bhutan
Seed project - Peru
Canadian International Development Agency -
Potato improvement - Tunisia
United Nations Development Program -
Technology transfer on root and tuber crops (First phase)
Technology transfer on root and tuber crops (Second phase)
International Development Research Center -
Agro-Economic research on potato production
Potato dehydration
W.K. Kellogg Foundation -
Develop training material
Australian Development Assistance Bureau -
Sapprad
Belgian Government -
Potato improvement - Burundi
Government of Ireland -
Other uses of potato starch
Government of Japan -
Irrigation system
Germplasm conservation facility
Payable to donors

	Funds provided US$	Disbursements: Prior years US$	Disbursements: This year US$	Disbursements: Total accumulated US$	Balance to date US$	
	127,300	129,067	(1,767)	127,300	-	
	54,607	54,101	506	54,607	-	
	181,907	183,168	(1,261)	181,907	-	
	42,214	17,733	25,732	43,465	(1,251)	
	40,815	-	40,815	40,815	-	
	149,391	135,677	-	135,677	13,714	(1)
	10,000	-	2,824	2,824	7,176	
	242,420	153,410	69,371	222,781	19,639	
	27,305	11,589	22,051	33,640	(6,335)	
	207,295	207,295	-	207,295	-	
	35,000	22,253	3,267	25,520	9,480	(1)
	25,000	16,750	792	17,542	7,458	(1)
	210,000	80,238	79,142	159,380	50,620	
	-	-	851	851	(851)	
	504,600	338,125	106,103	444,228	60,372	
	272,122	290,010	(17,888)	272,122	-	
	191,484	77,634	109,618	187,252	4,232	
	39,000	-	44,030	44,030	(5,030)	
	230,484	77,634	153,648	231,282	(798)	
	248,341	248,341	-	248,341	-	
	68,291	45,287	23,915	69,202	(911)	
	316,632	293,628	23,915	317,543	(911)	
	126,000	75,017	47,199	122,216	3,784	
	30,368	32,033	(1,665)	30,368	-	
	241,785	-	41,560	41,560	200,225	
	68,600	-	46,738	46,738	21,862	
	104,000	-	-	-	104,000	
	96,000	-	-	-	96,000	
	200,000	-	-	-	200,000	
	2,414,918	1,443,025	467,720	1,910,745	504,173	
	=========	=========	======	=========		
					(30,652)	(1)
					473,521	
					=======	

THE INTERNATIONAL POTATO CENTER

Schedule 1: FUNDS PROVIDED AND COSTS

For the year ended December 31,1982
(Expressed in thousand of U.S. dollars)

	Total Funds Available	Fixed Assets	Total Research
Unrestricted Core	(1) 3'783.4		1'596.5
Restricted Core			
USAID	2'200.0		859.0
IFAD	600.0		-
IDB	950.0		220.0
Belgium	(2) 104.7		-
E.E.C.	796.4		435.0
French	122.3		89.7
Japan	250.0		126.3
OPEC	190.0		10.2
DSE-Germany	58.2		-
Total Restricted Core	5'271.6		1'740.2
Total Operating Costs	9'055.0		3'336.7
Capital Grants			
Transferred from Earned Income	57.0	-	
Transferred from multi-purpose	563.0	563.0	
Total Capital	620.0	563.0	
Special Projects			
Ford Foundation	(1.2)		
Federal Germany	89.0		43.3
Swiss Dev. Cooperation	158.2		
Swiss-PRECODEPA	8.3		
CIDA	(17.9)		
UNDP	152.8	0.3	
IDRC	23.0	1.5	22.4
W.K. Kellogg Foundation	51.0		
ADAB - SAPPRAD	(1.7)		
Belgian Government	241.8	12.5	23.9
Ireland	68.6		
Japan	200.0		
Total Special Projects	971.9	14.3	89.6
Working Funds			
Transferred from multi-purpose	43.0		
Balance from previous years	702.0		
Total Working Funds	745.0		
TOTAL FUNDS AND COSTS	11'391.9	577.3	3'426.3

1) Includes $67,253 from earned income.
2) Net of $39.048 transferred to Special Projects and $9'077 adjusted of 1981 contribution.
3) Includes $254,000 of the TAC Review and Ten Years Symposium.

PROGRAM COSTS						
Reg.Res. & Training	Library Doc. & Inf.	General Administ.	General Operating	% of Gral. Adm.& Operat. to Direct	Unex-pended Balance	Payable to Donors
338.1	263.5	464.2	934.6 (3)	46.7	186.5	Ø
657.0	109.0	242.0	333.0	25.0	-	
541.1		28.2	30.7	15.0		
425.7	51.3	106.5	146.5	36.4		
117.0	-	-	-	-	(12.3)	
144.2		88.6	122.0	36.4	6.6	
-	-	13.7	18.9	36.4	-	
123.7	-	-	-	-		
145.6	-	23.4	-	15.0	10.8	
57.1	-	1.1	-	-	-	
2'211.4	160.3	503.5	651.1		5.1	
2'549.5	423.8	967.7	1'585.7		191.6	
					57.0	
					Ø	
					57.0	
(1.2)					-	
22.4			3.7	15.0	5.9	13.7
92.9			12.4	15.0	43.4	9.5
0.8			-	-	-	7.5
(17.9)			-	-	-	
145.1			8.2	6.0	(0.8)	
-			-	-	(0.9)	
47.2			-	-	3.8	
(1.7)			-	-	-	
-			5.2	15.0	200.2	
46.7			-	-	21.9	
			-	-	200.0	
334.3			29.5		473.5	30.7
					745.0	
2'883.8	423.8	967.7	1'615.2		1'467.1	30.7

THE INTERNATIONAL POTATO CENTER

Schedule 3: COMPARATIVE STATEMENT OF ACTUAL EXPENSES AND APPROVED BUDGET FOR THE YEAR ENDED DECEMBER 31, 1982

(Expressed in thousand of U.S.dollars)

Programs

- Potato Research
- Regional Research & Training
- Library, Doc. & Info. Services
- General Administration
- General Operating Costs
- TAC Review and Symposium

Capital

- Operating Equipment
- Research Equipment
- Vehicles & Aircraft
- Furniture, Fixtures & Off. Equip.
- Installation & Utilities
- Constructions & Buildings
- Site Development
- Communication Equipment
- Other Equipment

Analysis of Variances

Budget Surpluses
- (Minor) or Additional earned income
- Grant (shortfall) or additions
- Transferred to Capital
- Net surplus

Deficits
- Net deficit

TOTAL BUDGET VS EXPENSES AND APPLICATION OF VARIANCES

Operating Unrestricted		Operating Restricted		Capital	
Budget	Actual	Budget	Actual	Budget	Actual
	1'596.5		1'740.2		
	338.1		2'211.4		
	263.5		160.3		
	464.2		503.5		
	680.6		651.1		
	254.0		-		
4'217.4	3'596.9	5'201.4	5'266.5		
				56.0	20.6
				77.0	57.9
				51.0	84.4
				53.0	66.5
				10.0	58.5
				70.0	233.5
				19.0	27.0
				13.0	11.1
				7.0	3.5
				356.0	563.0
(82.7)				57.0	
(144.3)		70.2			
(207.0)				207.0	
	186.5		5.1		57.0
3'783.4	3'783.4	5'271.6	5'271.6	620.0	620.0

THE INTERNATIONAL POTATO CENTER

Schedule 2: EARNED INCOME AND APPLICATIONS

For the year ended December 31, 1982

(Expressed in thousand of U.S.dollars)

	Approved Budget	Actual
Sources of Earned Income		
Interest on Deposits	80	112.3
Sale of Crops & Materials	10	8.8
Sale of Fixed Assets	40	36.8
Indirect Costs charges on Special Projects & Current Accounts	60	47.7
Adjustment prior year	-	(1.0)
Rate of Exchange adjustment	(20)	(49.1)
Other	-	3.3
Sub-Total	170	158.8
Less: Auxiliary Services Deficit	(20)	(34.5)
TOTAL	150	124.3
Application of Earned Income		
Applied to Core Operations	150	67.3
Applied to Capital	-	57.0
	150	124.3