ANNUAL REPORT CIP 1983

International Potato Center

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

1984

The International Potato Center (CIP) is a nonprofit, autonomous scientific institution established in 1972 by agreement with the Government of Peru for developing and disseminating knowledge for greater use of the potato as a basic food in the developing world. CIP is one of 13 nonprofit international research and training centers supported by the Consultative Group for International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the United Nations Development Programme (UNDP), and the International Bank for Reconstruction and Development (World Bank), and comprises more than 45 countries, international and regional organizations, and private foundations.

CIP received funding in 1983, through the CGIAR, from the following donors: the governments of Australia, Belgium, France, Germany, Ireland, Japan, Netherlands, Norway, Philippines, Spain, and Switzerland; the Canadian International Development Agency (CIDA); the Danish International Development Agency (DANIDA); the European Economic Community (EEC); the Inter-American Development Bank (IDB); the International Fund for Agricultural Development (IFAD); the Swedish Agency for Research Cooperation with Developing Countries (SAREC); the United Kingdom Overseas Development Administration (UKODA); the United States Agency for International Development (USAID); the OPEC Fund for International Development; and the German Foundation for International Development (DSE).

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Foreword

Exciting things are happening worldwide in potato production. The dynamic relationships that have evolved between CIP and national research programs over the past 12 years are producing a steady flow of technological progress from the research scientist to the growers' fields.

To try and capture in one annual report what has been happening in CIP's collaborative research work with countries around the world is a difficult task. As national programs progress in developing technologies—improved germplasm and potato production techniques—appropriate to their own growing conditions, it becomes almost impossible to differentiate between what has been contributed by national programs and by CIP directly. What is clear is that capable manpower must first exist within national research systems before technology transfer can take place. After all, it is the national researcher, the extensionist, the educator, and the agri-businessman who have the responsibility and ability to reach growers and affect changes in potato production.

Any report written about CIP is really a report about national programs. Through their participation and involvement in CIP's regional network system, international research contracts, and research planning conferences, CIP has become part of more than 80 national potato programs worldwide.

The 1983 Annual Report highlights manpower development through training and emphasizes contributions made by national programs. From the beginning, CIP has recognized that the transfer of technology to growers' fields depends more on the ability of national programs to make use of a technology than on the technology alone. We have deliberately focused on enhancing the capability of national programs to conduct research relevant to specific growing conditions and to transfer the results to farmers' fields. These efforts are beginning to bear fruit and are evident throughout this 1983 report.

The content of this year's report has been changed to incorporate a new Thrust. The 1982-1983 external reviews of CIP's research organization recommended a modification to better depict the concentration of existing research priorities. As such, Thrust X, "Potatoes in Developing Country Food Systems," was created. This addition will better reflect the role of the social scientists at CIP, as well as the participation and contribution of biological scientists involved in this new Thrust. This holistic approach to research has allowed us to focus our energies on priority, real-world issues that relate to potato production in the Third World.

Special attention is given in this report to country network programs—groups of countries that have combined efforts and scientific expertise for the benefit of all members in the group. While CIP has been instrumental in identifying funding sources for joint ventures within these networks, the successes being enjoyed are due to the hard work and willingness of national scientists to collaborate with each other on mutual problems.

As in previous years, we continue to present the latest advancements made within each Thrust. As improved clones become available, there is a corresponding increase in their movement to developing countries. True potato seed research continues to make headway and is demonstrating more clearly than ever the value of this approach to potato production in developing countries. Appropriate agronomical practices, using traditional methods for production in warm climates, are having wide acceptability; and the use of diffused-light stores for seed tubers became a reality quite some time ago. Basic research at CIP headquarters and through research contracts continues to add to the wealth of information that is permitting the potato to become a staple food in a wide range of environments around the globe.

As this report goes to press, we will have just completed an introspective and retrospective examination of our work over the past 12 years. The results will be published in a document entitled *Potato Improvement in the Developing World, A Collaborative Experience*. In this publication one can see why the successes we are now enjoying with potato improvement in developing countries can be attributed to the collaboration between CIP and national research and extension systems. This collaborative effort has been the force behind all progress made by CIP, and it is this force that will continue to be essential to CIP's progress in the future.

Richard L. Sawyer

Richard L. Sawyer
Director General

CIP'S 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 accumulated by CIP provides ample opportunity for research breakthroughs through the exploitation of this large quantity of previously unavailable genetic resources.

IN MEMORIAM
Dr. Werner Hunnius
1929 – 1983

It is with deep regret that we report the death of Dr. Werner Hunnius, on 3 August 1983 after a serious illness. Dr. Hunnius served on CIP's Board of Trustees from 1977 to 1980 as a member of the Program Committee.

Dr. Hunnius was born on January 16, 1929 at Hildburghausen, Thüringen. He received his Ph.D. in Agriculture in 1954 and joined the Bavarian Institute for Soil Science and Plant Production in 1957. He was a dedicated member of the European Association for Potato Research (EAPR) for more than 20 years, and served as its president from 1978-1981. He served as a member of the Committee for Potato Breeding and Improvement of the German Agricultural Association, and his services were recognized by the presentation of the Max Eyth Memorial Silver Medal. In 1979, Dr. Hunnius was appointed head of the Plant Protection Division of his Institute and quickly achieved a position of high esteem.

During the three years he served on the Board, Dr. Hunnius gave strong technical leadership based on his scientific knowledge of the potato. His contribution to the work of the Program Committee was invaluable in critically appraising the research program during CIP's annual program reviews.

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List of Abbreviations and Acronyms

AARD	Agency for Agricultural Research and Development (Indonesia)
AMV	alfalfa mosaic virus
andigena	when not italicized in text refers to breeding materials with characteristics of *Solanum tuberosum* ssp. *andigena*
APLV	Andean potato latent virus
avg	average
BARI	Bangladesh Agricultural Research Institute
BW	bacterial wilt
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIP	Centro Internacional de la Papa (Peru)
CPE	centrally planned economy
CV	coefficient of variation
cv.	cultivar
d	day
DLS	diffused-light stores
DNA	deoxyribonucleic acid
DSE	Deutsche Stiftung für internationale Entwicklung (West Germany)
EB	early blight
ELISA	enzyme-linked immunosorbent assay
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria (Brazil)
FAO	Food and Agriculture Organization of the United Nations
FDR	first division restitution
GA	gibberellic acid
GCA	general combining ability
h	hour
ha	hectare
IADS	International Agricultural Development Service
ICA	Instituto Colombiano Agropecuario (Colombia)
IDIAP	Instituto de Investigación Agropecuaria de Panamá (Panama)
IITA	Institute of Tropical Agriculture (Nigeria)
INIA	Instituto de Investigaciones Agropecuarias (Chile)
INIAP	Instituto Nacional de Investigaciones Agropecuarias (Ecuador)
INIPA	Instituto Nacional de Investigación y Promoción Agropecuaria (Peru)
INTA	Instituto Nacional de Tecnología Agropecuaria (Argentina)
IPO	Research Institute for Plant Protection (Netherlands)
L	liter
LB	late blight
LER	land equivalent ratio
LSD	least significant difference
M	molar
min	minute

ml	milliliter
mm	millimeter
mo	month
ND	not determined
ns	not significant
NS	not studied
OP	open-pollinated
PCARRD	Philippine Council for Agriculture and Resources Research and Development
PDMV	potato deforming mosaic virus
Pf/Pi	final population/initial population
PLRV	potato leafroll virus
PNAP	Programme National de l'Amelioration de la Pomme de Terre (Rwanda)
PRACIPA	Programa Andino Cooperativo de Investigación en Papa (Andean region)
PRAPAC	Programme Regional d'Amelioration de la Culture de Pomme de Terre en Afrique Centrale (Central Africa)
PRECODEPA	Programa Regional Cooperativo de Papa (Central America-Caribbean)
PROCIPA	Programa Cooperativo de Investigaciones en Papa (southeast region of South America)
PSTV	potato spindle tuber viroid
PTM	potato tuber moth
PVA	potato virus A
PVM	potato virus M
PVS	potato virus S
PVT	potato virus T
PVX	potato virus X
PVY	potato virus Y
RH	relative humidity
RNA	ribonucleic acid
SAPPRAD	Southeast Asian Program for Potato Research and Development
SD	standard deviation
sec	second
TBRV	tomato black ringspot virus
TPS	true potato seed
TRSV	tobacco ringspot virus
tuberosum	when not italicized in text refers to breeding materials with characteristics of *Solanum tuberosum* ssp. *tuberosum*
UNA	Universidad Nacional Agraria (Peru)
UNDP	United Nations Development Programme
VAM	vesicular arbuscular mycorrhiza
var.	variety
vol	volume
vs.	versus
W	watts
wk	week
WP	wettable powder
wt	weight
w/v	percent "weight in volume"; number of grams in 100 cm^3 of solution
yr	year

Summary of Research

World Potato Collection

In the Andean region, native cultivars are being replaced, habitats of wild species are being destroyed, and poor maintenance and loss of accessions are constant problems in national gene pools. Breeding new resistant potatoes depends on access to genetic resources. Through many difficult collection expeditions in the Andes and donations, CIP has accumulated, over the past 12 years, 13,000 specimens of primitive cultivated potatoes.

From these 13,000 accessions, CIP's world potato collection has been reduced to 5000 classified cultivated accessions. Identical accessions were verified by electrophoretic pherograms of proteins and enzymes (fingerprint patterns) and converted to true seed before discarding. This approach to verifying duplicates is unique among world gene banks. By reducing quantity, the quality of the collection has been improved, also making in vitro and field maintenance more efficient.

Some 1500 accessions from 90 tuber-bearing wild species have been collected by CIP expeditions. Twelve new species have been discovered, and 24, which previously existed only in herbaria, have been rediscovered.

True seed from wild species are being stored for long-term preservation. Species that have no seed are being converted in vitro. During the last five years, genetic barriers preventing crossing and gene transfer between species have been overcome through tissue culture techniques.

A frequency of 2% to 10% resistant genotypes was observed when thousands of wild and cultivated potatoes were screened for specific resistance factors. An estimated 90% of the available genetic diversity of the gene pool await evaluation. Descriptors for computer management of morphological and other data have been developed. Data on each accession in the collection is now available through CIP's computerized data management system.

Breeding Advanced Clones

The general philosophy is

- to maintain wide genetic diversity for high yield and stability of performance
- to increase frequency of genes controlling desirable attributes
- to establish a population breeding strategy based on recurrent selection with progeny testing
- to stimulate recombination of desirable attributes within families and populations

- to use a multidisciplinary approach to maximize use of genetic resources

CIP's breeding program has direct access to the single most extensive potato germplasm collection in the world. Breeding for disease and pest resistance and environmental adaptation involves the cooperation of CIP's multidisciplinary *Thrusts* and the support of research contracts.

The breeding strategy is based on crossing superior parents, screening their progenies for desired genetic attributes, and making further crosses using those improved progenies with good combining ability as parents. This approach develops genetically diverse families of progenies bred for yield, along with specific combinations of resistances to diseases, pests, and environmental stress.

It is necessary to have advanced clones adapted to diverse climates. Three broad populations, containing progenies with various combinations of characters, have been the source of advanced clones sent to developing countries:

- *Highland tropics*—yield, frost tolerance, and resistance to late blight, cyst nematodes, wart disease, and potato virus Y (PVY).
- *Lowland tropics*—yield, heat tolerance, earliness, and resistance to late blight, bacterial wilt and PVY.
- *Subtropical*—yield, and resistance to early blight, late blight, and potato viruses X and Y. This population developed from temperate climate sources including material from contract research.

The successful impact made by these advanced clones from CIP and contract breeding programs can be best judged by the varieties that have been evaluated and named by developing country programs. Two new varieties were added to the list of varieties named or released by 22 countries. A bacterial wilt-resistant clone has been selected in Kenya, while Argentina has identified 23 clones with resistance to potato leafroll virus.

Success in Virus Research

Of major importance are potato leafroll virus (PLRV), and potato viruses X and Y (PVX and PVY). These viruses are spread by aphid vectors, by plant-to-plant contact, and through infected tubers from one cropping season to the next.

Quarantine control and seed tuber certification are enforced in the international trade of potato seed tubers. Seed tubers exported by CIP are accompanied by a phytosanitary statement detailing the tests used to ensure their pathogen-free status.

> As quoted in the *Journal of Applied Biology*: Various International Organizations and commercial firms have a particular role to play in setting and maintaining health standards of the type now enforced by the International Potato Center when distributing breeding stocks around the world.

CIP is a leader in developing modifications of various virus detection techniques. Sensitive methods such as the latex test, enzyme-linked immunosorbent assay (ELISA), various serological procedures, and indicator hosts are used routinely at CIP.

For virus detection, large amounts of antisera are prepared and distributed to national programs. An ELISA kit for use in developing countries has been designed at CIP, while adaptations of standard detection measures have been devised for the convenient use of national programs.

The potato spindle tuber viroid (PSTV), a virus-like infectious agent, is of special quarantine significance in the international export of potatoes. A simplified electrophoretic detection system for this viroid has been developed, as well as an ultrasensitive spot-hybridization test that can detect PSTV even in a single minute true seed. The spot test was developed by CIP in collaboration with the United States Department of Agriculture.

CIP is leading the way in the use of heat therapy and tissue culture 1) to ensure virus-free condition of breeding stocks and 2) to export advanced tuber lines to national programs. World knowledge on viral pathogens of potatoes has been advanced by CIP's identification of eight previously undescribed viruses.

Through increased reliability of health status and rapid production of pathogen-tested clones, CIP has made substantial contributions to improving international standards for export of potato seed tubers and true potato seed.

Biological Control of Pests

Breeding resistant clones is one of the components necessary for an integrated pest management program. The addition of each new resistance factor in a breeding program results in an exponential increase in the number of seedlings to be screened.

Extreme selectivity must be exercised in choosing which of the 128 insect and 67 nematode species require priority. CIP has focused on cyst and root-knot nematodes and potato tuber moth (PTM), all of worldwide interest.

• A high frequency of clones resistant to cyst nematodes has been selected through breeding. Hybrids have been bred with resistance to root galling and egg mass production by *Meloidogyne* root-knot nematodes.

• From over 40 primitive cultivars and wild species with resistance to PTM, crosses are now being made to breed potatoes that are high-yielding, resistant to PTM, and adapted to lowland tropics.

Renewed interest in the biological control of nematodes has been stimulated by CIP's discovery of a parasitic fungus, *Paecilomyces lilacinus*, that attacks and destroys egg masses of root-knot nematodes. Through cooperation with North Carolina State University's International Meloidogyne Project, trials on the fungus are being carried out in 46 countries. In field trials, the fungus has proved superior to a widely used nematicide. *P. lilacinus*, which persisted in field plots during a three-year study, is non-pathogenic to crops, spreads rapidly in the soil, and also shows promise in controlling other crops.

Insecticides often fail to prevent PTM infection of tubers – a pest which shows increased insecticide resistance. Commercial potato varieties are highly susceptible to PTM. CIP has developed a simple procedure to impregnate small rubber caps with PTM sex pheromone. Pheromones are used to lure male moths into traps, thereby reducing PTM populations and tuber damage in the field and stores. Pheromone traps are also used to monitor PTM populations so that insecticide treatments can be regulated more economically or even omitted.

In stores, biological insecticide dust, the use of insect-repellent weeds layered over tubers, and wire screening are effective in controlling PTM. Other research on biological control of PTM has identified parasites that may be potentially effective against this pest. Mixed cropping with onion, maize, and soybean has also consistently reduced PTM damage.

Fourteen developing countries are involved in further testing of various biocontrol components – particularly PTM sex pheromones.

- Leaf miner fly, *Liriomyza huidobrensis*, is readily attracted to and trapped by yellow-green surfaces with sticky coatings.

- CIP has cosponsored and cooperated in research on insect-trapping glandular trichomes. This approach has reached the advanced clonal stage in breeding and is of considerable interest in both developing and developed countries.

By combining host resistance, effective biological controls, and judicious use of insecticides, CIP can provide a practical and acceptable control package for pest management in developing countries.

Warm Climate Potato Production

Active research on potato production in warm climates is being conducted in nine countries. Both breeding and agronomic management are the keys to developing heat-tolerant potatoes that can be produced in warm climate conditions. CIP has made steady progress in breeding potatoes for heat stress conditions. A succession of advanced clones, particularly the high-yielding LT series, has clearly demonstrated the potato's adaptability to warm climates. CIP heat-tolerant clones DTO-33 and LT-2 are yielding well in El Salvador, the Dominican Republic, and Cuba.

The first step in selection was to develop, through contract research, a seedling screening technique for early identification of potential heat-tolerant clones. A computer model to predict field behavior under tropical conditions has been developed. Resistances to warm-climate pathogens, including resistance to bacterial wilt, root-knot nematodes, and PVY have been combined and incorporated into breeding lines.

Agronomic management practices have been developed to modify heat stress:

- High quality seed tubers of correct physiological age permit vigorous emergence that is further accelerated by correct planting depth, closer spacing, and mulching.
- Soil temperature can be modified by interplanting with maize, planting on the cool-facing side of slopes, and row orientation.
- Rotation and no hilling reduce the incidence of bacterial wilt.
- Genotype selection and methods that maximize radiation interception by potato crops during the growing season improve total dry matter yield – photosynthetic efficiency tends to be reduced in warm climates.

Seed Technology

Use of true potato seed (TPS), initiated at CIP in 1977, is a viable alternative to traditional seed tuber propagation and offers major advantages under many agroeconomic situations. Adoption of TPS technology is being followed closely in Peru, Sri Lanka, Bangladesh, India, South Korea, and Rwanda.

TPS is cheaper, eliminates storage and transportation problems, and overcomes transfer of major degenerative viruses and the need for complicated seed certification schemes. TPS makes available 1.5 to 2 t/ha of seed tubers as food and also frees land previously used to produce seed tubers.

Tuber uniformity of plants grown from TPS, equivalent to varietal uniformity, has been achieved. Production by seedling transplants or seedling tubers is generally superior to direct field seeding.

Hybrid TPS has consistently outproduced open-pollinated (OP) progenies. The productivity of OP, produced by farmers, is being gradually improved.

- In 1982, 23% of improved progenies gave a tuber yield of more than 2 kg/plant.
- Average yield of OP progenies in three developed and three developing countries under experimental field conditions was 37 t/ha.
- In on-farm trials in Peru, directed by farmers, yields from TPS were equal or superior to those produced by farmers' seed tubers.

Postharvest Technology

In diffused-light stores (DLS), seed tubers exposed to indirect light produce short, stout sprouts in contrast to the spindly, elongated sprouts produced in the dark. Since 1979, thousands of farmers have adopted low-cost DLS, ranging in size from 200 kg capacity to 100 tons. Twenty-four of 28 comparisons revealed that potatoes stored in DLS exceeded the yield of cold-stored seed tubers.

Pests in DLS have been effectively controlled by repellent weeds, sex pheromone traps, and biological insecticides. Tuber greening and ventilation of tubers stored in shallow layers suppressed anaerobic soft-rot bacteria.

Sprout suppressants used in naturally ventilated stores permitted successful storage of consumer potatoes for six months with storage losses under 2% per month. At the farm level, average storage losses were reduced from 26% to 8% over six months by using improved DLS technology.

In potato processing, solar drying, "black box" dehydrators, and a low-cost pilot plant demonstrated the feasibility of village-scale *papa seca* (form of dehydrated potato) and starch. Emphasis has now shifted to processed food mixes, which are cost-effective and have enhanced nutrition through potato-cereal-legume combinations.

- One mix, M6, containing 30% dried potato with flours of rice, bean, oats, barley, and maize, had good product acceptability in Peru after being sampled by more than 1000 individuals, plus an eight-month trial with a community kitchen where more than 100 children are fed daily.

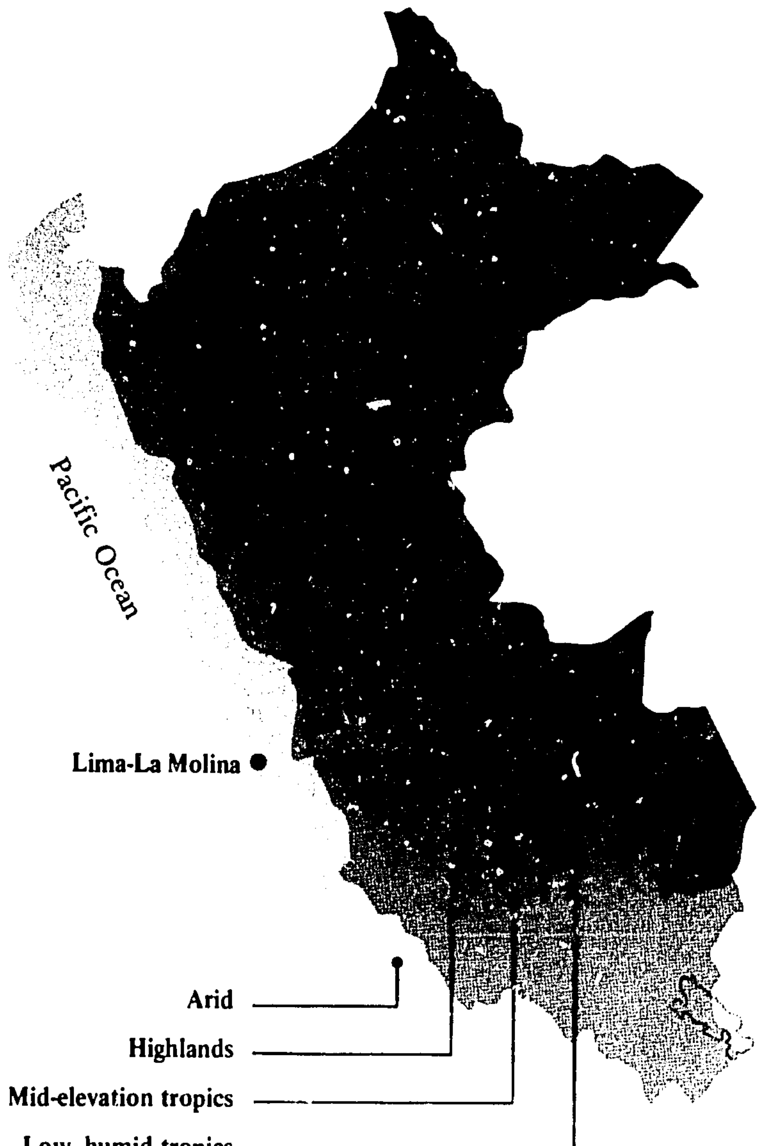
- The mixes are easily reconstituted with water and boiled for 25 minutes to ensure sterility–one kilogram provides 50 standard food portions (250 ml).

- CIP's low-cost pilot plant and solar drying facilities are now being used to produce dried potato mixes as well as potato mash and dehydrated french fries.

Practical postharvest technologies for storing consumer and seed potatoes and for processing potato-based foods are undergoing continuous evaluation and improvement to meet the needs of developing countries.

International Networks

Networking, in which country programs pool their resources to establish an integrated research program, has been pioneered by CIP. The organization PRECODEPA was established in Central America in 1978 and has proved to be a dynamic, productive research network. Two other operational works are SAPPRAD in Southeast Asia and PRACIPA in the Andean zone of South America.



Pacific Ocean
Lima-La Molina
Arid
Highlands
Mid-elevation tropics
Low, humid tropics

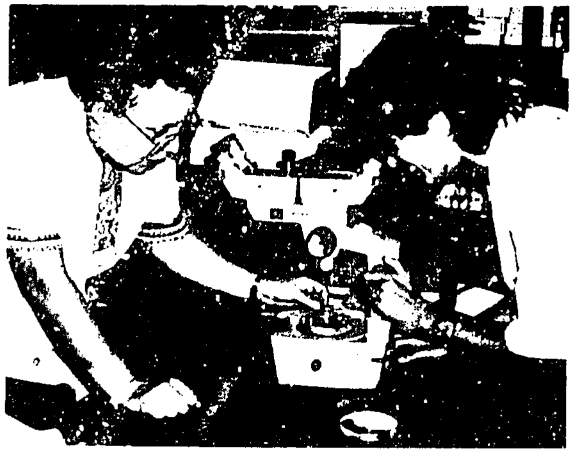
Agroecological Zones of Peru

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

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

CIP research sites in Peru and potato-growing seasons, with meteorological data for 1983.

Site	Latitude Altitude	Growing season (mo)	Average temperature		Rainfall (total mm)
			Air max (°C)	Air min (°C)	
Lima/La Molina	12°05'S 240 m	Jan - Mar 83 May - Nov 83	30.2 21.6	22.1 16.1	6 5
Huancayo	12°07'S 3280 m	Oct 82 - May 83	21.8	6.9	662
San Ramon	11°08'S 800 m	Nov 82 - Mar 83 May - Aug 83	31.2 31.1	20.4 18.6	1390 305
Yurimaguas	5°41'S 180 m	May - Aug 83	31.3	20.6	336



Research Organization

Research at CIP is organized administratively by six departments in which scientists are grouped according to their particular field of research. 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. Within each Thrust, individual projects change according to annual progress evaluations and analyses of priority problem areas. Each Thrust has a coordinator responsible for integrating the various project activities. Long-term planning for each Thrust is guided by recommendations from international planning conferences, which address specific priority topics. CIP has established research contracts with leading institutions in both developed and developing countries to augment its research base and to provide support for various Thrust projects.

As research progresses and results are produced, technologies emerge that require development and evaluation. Early in its formation, 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. CIP's seven regions are headquartered in Colombia (I), Brazil (II), Kenya (III), Egypt (IV), Tunisia (V), India (VI), and the Philippines (VII).

THRUST I

Maintenance and Utilization of Unexploited Genetic Resources

In previous years research concentrated on collecting and classifying tuber-bearing *Solanums*. These activities have been reduced, and emphasis has shifted to the maintenance and use of CIP's largely unexploited germplasm. The fertility and crossability of 30 species in five taxonomic series were studied to determine evolutionary relationships and compatibilities. The coastal species of Peru exhibited strong crossability barriers in contrast to the mountain species in the series Tuberosa.

About 200 clones were transferred to in vitro, long-term storage conditions; from this group, 51 were propagated to replace damaged material. Proembryos arrested in an early stage of development have been successfully cultivated on a sucrose osmoticum.

The Andean cultivar collection was increased by adding 1866 accessions from Bolivia, Chile, and Peru. More than 100 genetically different Andean cultivars have been added to the in vitro collection to widen CIP's germplasm distribution and to avoid genetic losses due to crop failure. A book dealing with taxonomy of the tuber-bearing *Solanums* is in progress. The first volume will focus on the potatoes of Bolivia and should be ready for publication in the near future. A new facility for tissue culture and true seed storage is being constructed at CIP headquarters in Lima and will be ready for use in early 1984.

FERTILITY AND CROSSABILITY OF WILD SPECIES

To use germplasm efficiently, it is necessary to understand its biosystematic status; therefore, studies concentrated on interspecific and interseries crossability behavior of a group of selected materials. This group is of special interest because of its resistances and adaptation to extreme ecological conditions. Thirty species were studied from five taxonomic series: Olmosiana, Ingaefolia, Circaeifolia, Conicibaccata, and Tuberosa. In total, 7000 pollinations representing 400 crosses were made and about 175,000 seeds were obtained. Some of these crosses will be used for morphological analysis in F_2 populations.

The two closely related series Ingaefolia and Olmosiana were investigated to establish the crossability of the species *Solanum jalcae*, whose taxonomic position has been uncertain. The results demonstrated that *S. jalcae* should be grouped with series Ingaefolia to which it is most closely related. The results obtained from crosses between members of the series Conicibaccata and Circaeifolia demonstrated that these two should not be fused into one series. The crossability barriers that exist between them are such that this position could not be justified.

The species *S. capsicibaccatum* from series Circaeifolia, whose members are particularly difficult to cross with species from other series, has been successfully hybridized with the frost-resistant, high mountain species *S. bukasovii* from the series Tuberosa. The *S. capsicibaccatum* x *S. bukasovii* hybrids crossed easily with diploid cultivated and *tuberosum* haploid material; whereas *S. capsicibaccatum* did not cross with cultivated potatoes directly. In this way, strong resistance to various pathotypes of *Globodera pallida* (potato cyst nematode), which is found in some clones of *S. capsicibaccatum*, may be transferred to cultivated parental material.

Crosses between members of the series Tuberosa and Conicibaccata have also been successful. The two species *S. leptophyes* and *S. sparsipilum* from series Tuberosa, with resistance to *G. pallida*, hybridized with the frost- and late blight-resistant species *S. chomatophilum* (Fig. I-1) from the series Conicibaccata. Although more work is needed on interspecific and interseries crossability behavior, crossability barriers are no longer an obstacle to using many of the wild species in breeding programs.

One of the crossability barriers that was unknown until recently is the endosperm balance number (EBN) a theory proposed by Johnston and Hanneman in 1980. In this theory, the genome of each species is assigned an "effective ploidy" (or EBN) with respect to endosperm function by crossing to a species used as a standard. It is the EBNs that must be in a 2:1 maternal:paternal chromosome ratio for normal endosperm development. As the EBN of more species is determined, interspecific hybridizations become easier. Embryo culture has also proved useful in obtaining vigorous hybrids from crosses that have been previously unsuccessful.

In addition to the interseries crossability studies that were carried out during 1983, a set of crosses within the series Tuberosa was also made. This study confirmed the field observation that strong crossability barriers exist between many species on the Pacific Coast of Peru and that no such barriers exist between the mountain species of the same series. A series of crosses including all known species from the Pacific Coast of South America, with the exception of *S. maglia*, clearly demonstrated that strong crossability barriers exist between some of the coastal species. The species *S. mochicense* and *S.*

Figure I-1. *Solanum chomatophilum* 2n = 2x = 24 chromosomes. Frost and late blight resistant.

chancayense, native to the central Peruvian coast, are the two most closely related and can be crossed without any problems.

The species *S. wittmackii* and *S. hypacrarthrum* also hybridize with relative ease although they are markedly different morphologically. *S. hypacrarthrum*, however, is not a true coastal species, as it is found mostly in the central Andean region of Peru (around 2500-3500 m). Species *S. wittmackii* occurs primarily in the areas surrounding Lima, near the Pacific Ocean (300-400 m), and occasionally at 3000 m to 3500 m near the natural habitat of *S. hypacrarthrum*. These two species are as isolated from each other as some of the other Peruvian coastal species.

In contrast to the coastal species from series Tuberosa, there are no crossability barriers between the mountain species even if they are separated by more than 1000 km.

The reasons for these differences are not yet clear. It is possible, however, that the Peruvian coast, which is one of the driest deserts in the world, prevented any kind of gene exchange between geographically isolated coastal species, and that genetic barriers evolved as a result of complete geographic isolation. This is not the only possible explanation, since crossability barriers also exist between sympatric species.

TRANSFER OF WORLD POTATO COLLECTION TO IN VITRO

During 1983, CIP started transferring the accessions of CIP's world potato collection to in vitro. Experiments were conducted to reduce virus concentration in the plants by applying the nucleoside analogue Virazole to the plants before shoot tips were excised. In a second set of experiments, shoot tips were cultured for two weeks in a culture medium that contained Virazole. The results of these experiments were positive.

About 200 clones have been transferred to in vitro storage and are being maintained under long-term conditions. Fifty-one clones were propagated to replace material that was lost due to lack of tuberization under extremely high temperature conditions.

Rescue of early stage embryos. Proembryos arrested in an early stage of development were cultivated and exposed to an osmotic gradient in which sucrose or mannitol was used as an osmoticum. The osmotic gradient helps the development of early stage embryos if sucrose is used as the osmoticum. Other media additions had no positive effect on the rate of germination.

MANAGEMENT, DISTRIBUTION, AND USE OF GERMPLASM

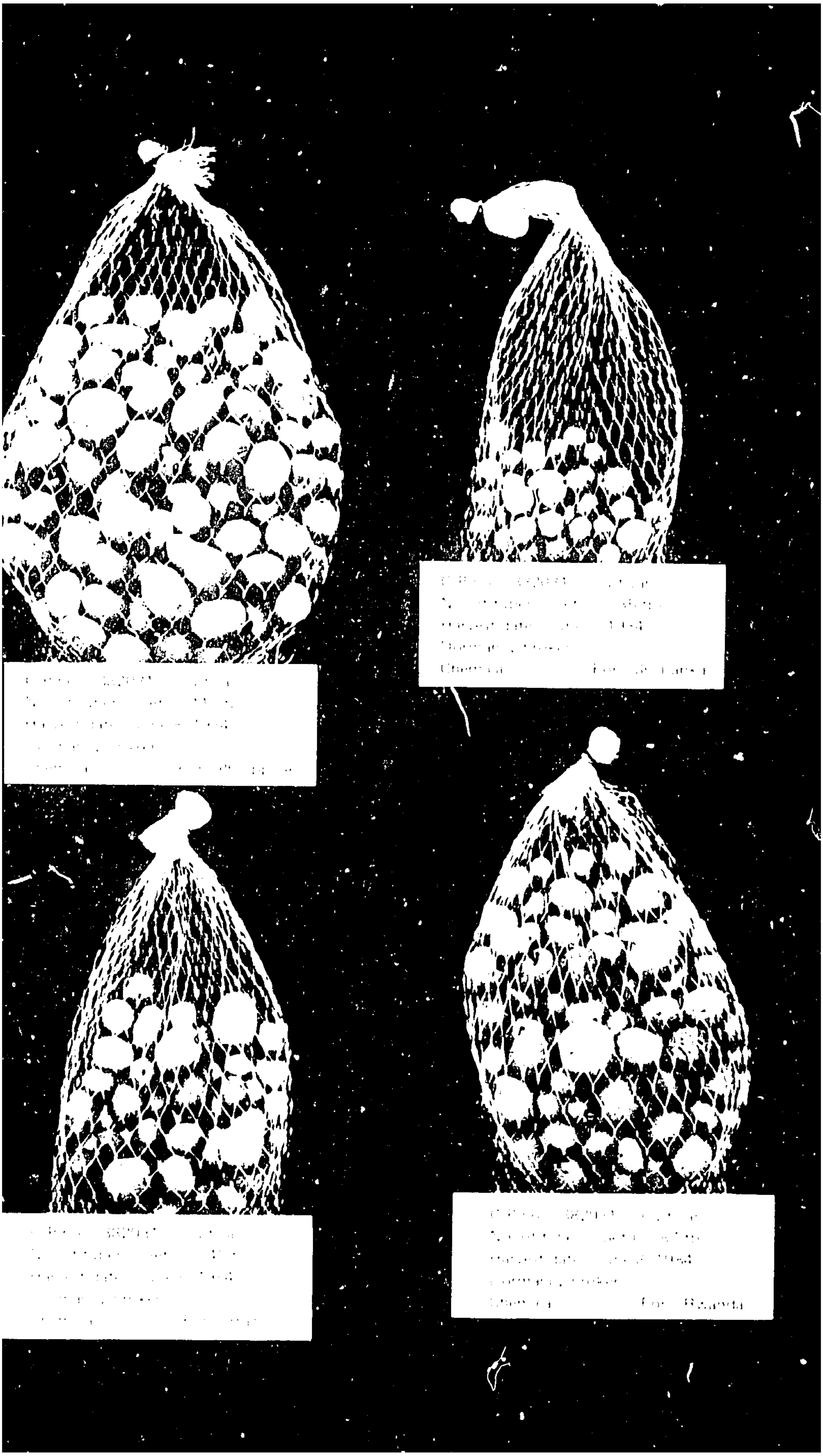
A new Genetic Resources Laboratory is being added to CIP's facilities, which will include space to process and store true potato seed (TPS) and in vitro cultures from the world potato collection.

CIP's collection of Andean cultivars, maintained in the field at Huancayo, has been increased with the introduction of 1866 accessions from Bolivia, Chile, and Peru. These new accessions appear to contain several new cultivars not previously included in the collection. Also, 765 duplicate accessions have been converted into true seed for storage and their tubers eliminated.

To broaden the distribution of CIP materials and also to avoid genetic losses due to crop failure in the field, 101 genetically different Andean cultivars, comprising 86 diploid and 15 triploid cultivars, were added to the in vitro collection. Furthermore, seed samples of 43 accessions were tested in a 10% seed sample and found to be negative for PSTV infection. A total of 230 seed lots and 1835 tuber samples were screened at CIP for several pests and diseases.

In ongoing contract research at the Federal Biological Institute in Braunschweig, Germany, an additional 1500 accessions of CIP's germplasm collection were investigated for duplicates, about 2800 pherograms were evaluated. The number of duplicates thought to be different by morphological criteria, but found to be identical after being checked by electrophoresis (pH 8.9 and pH 7.9), remained as previously determined (1974-1978). This means that about one fifth of the collected samples are genetically different.

Steady progress is being made on a book dealing with the taxonomy of tuber-bearing *Solanums*. Instead of being released in a single volume, which would take many years to complete, the work is being prepared in parts, the first of which should be ready in the near future. This volume will deal with the potatoes of Bolivia, one of the least known Andean regions from the standpoint of potato taxonomy. The germplasm from this country offers, at the present time, great potential as a source of germplasm for breeding purposes.



THRUST II

Production and Distribution of Advanced Breeding Material

Research activities centered on three general areas: genetic research on specific traits; breeding methods and use of germplasm; and the pathogen-tested collection and international distribution of germplasm. Genetic studies revealed significant advances in breeding for earliness and high yield. Advances were also made in clarifying the inheritance of resistance to root-knot nematode. A study on the inheritance of heat tolerance indicated that more progress can be expected in this particular program.

Heritability estimates indicated that large genetic gains can be made for foliage maturity, average tuber weight, and resistance to root-knot nematode. Work on ploidy manipulation continued and several diploid populations were developed with combined specific resistances to biotic and abiotic stresses. An extensive 4x-2x crossing program to transfer these resistances to the tetraploid level is in progress. CIP's breeding program for combining heat tolerance and bacterial wilt resistance has enabled countries such as Sri Lanka, Fiji, Kenya, and Rwanda to select advanced material and name varieties.

Thirty-five clones were added to the pathogen-tested collection, which now contains 189 clones--145 (about 77%) of these have been requested by national potato programs. During 1983, more than 30,000 plantlets were propagated in vitro and handed over to CIP's seed program for worldwide distribution. The list of pathogen-tested clones has been revised and distributed to collaborating scientists in national programs. A total of 138 advanced and 51 wild and primitive cultivars are now available for international distribution.

GENETIC RESEARCH ON SPECIFIC TRAITS

In a random sample of 11 tetraploid clones crossed in a diallel mating design, estimates of narrow sense heritability (h^2) were .70 for inheritance of foliage maturity, .17 for average yield per plant, and .35 for average tuber weight at various dates of harvesting. These estimates demonstrated the significant potential for improvement achieved at CIP in breeding for earliness. Among the clones used, CIP clone 800169 proved to be an outstanding parent in breeding for earliness and high yield.

A study was completed on determining the inheritance of resistance to root-knot nematode. A sample of seven progenitors was crossed in a diallel mating design including reciprocals. A heritability estimate of $h^2 = .75$ was determined and significant reciprocal effects were found. Cytoplasm from resistant clones increased the expected frequency of resistant individuals in the progeny.

A random sample of 13 male clones from a population adapted to the lowland tropics was crossed to a random sample of 4 females from the same population. The genetic variability for heat tolerance was estimated, using the North Carolina Mating Design I. Heritability for yield under the hot summer environments of San Ramon and La Molina was estimated to be $h^2 = .23$, which indicates that further advances are possible in breeding for heat tolerance. Uniformity trials were done to determine the optimum plot size for evaluating seedlings from the lowland tropic populations. The optimum size ranged between 20 and 60 seedlings per plot and was found to be a function of the within-plot variances.

BREEDING METHODS AND GERMPLASM UTILIZATION

In contract research carried out at Cornell University, New York, 24 clones selected in 1982 from the 7th cycle neotuberosum (andigena) population were crossed with a tuberosum tester clone, NY66. The seedlings were transplanted to the field and evaluated for yield, uniformity, and tuber appearance. Five crosses produced seedlings that yielded about the same as

Table II-1. Diploid groups selected for specific resistance: their genetic background and identification of 2n pollen production.

Selected resistance	Genetic background[a]	Production of 2n pollen
Bacterial wilt	chc, spl, phu, stn, tbr, adg	Yes
Soft rot	phu, stn	Yes
Late blight	tbr, adg	Yes
Early blight (*A. solani*)	phu, stn	Yes
Potato viruses X and Y	tbr, adg	NS[b]
Potato leafroll virus	tbr, adg	NS
Root-knot nematodes	chc, spl, mcd, phu, stn, tbr, adg	Yes
Cyst nematodes	spl, chc, phu, stn, tbr	Yes
Potato tuber moth	spl, phu, stn, tbr, adg	Yes
Heat	stn, phu, chc, tbr	Yes

[a] chc = *S. chacoense*; spl = *S. sparsipilum*; mcd = *S. microdontum*; phu = *S. phureja*; stn = *S. stenotomum*; tbr = haploids of *S. tuberosum* subsp. *tuberosum*; adg = haploids of *S. tuberosum* subsp. *andigena*.

[b] NS = not studied.

the variety Katahdin, planted from tubers that had good appearance and uniformity. In 1983, 23 neotuberosums were crossed with 5 tuberosum tester males (a total of about 115 families) to estimate the general combining ability of the neotuberosum females for yield, uniformity, heat tolerance, and potato virus Y (PVY) and late blight resistances.

PLOIDY MANIPULATION

Work on ploidy manipulations continued at CIP headquarters. Haploids (2n=2x= 24) were extracted from highly selected tetraploids and then crossed to tuber-bearing wild species and primitive cultivars in order to transfer disease and insect resistances and to increase genetic variability. Selection for 2n pollen production (pollen with the unreduced chromosome number) was carried out to facilitate the transfer of the combination of traits achieved at the diploid level to the tetraploid level through 4x-2x crosses. Results obtained so far indicate that 2n pollen formed by First Division Restitution (FDR) transfers 80% of the genotype of the diploids intact to their tetraploid progeny in 4x-2x crosses. Several diploid populations with specific resistances to major abiotic and biotic stresses have been developed (Table II-1). Crosses are being made between selected tetraploid females and resistant diploids that produce 2n pollen.

In contract research on 4x-2x hybrids at the University of Wisconsin, 11 cultivars (4x) were crossed to 25 2x-clones that produced 2n pollen by either parallel spindles (the gene *ps*) or an impairment of synapsis (*sy3*) combined with parallel spindles (i.e., *sy3* plus *ps*). This was done to determine the parental effects on vine maturity, tuber appearance and yield. Significant differences in vine maturity were observed in the 4x and 2x parents, and in the 4x families. The maturity of the 4x families was highly correlated with the 2x parent, but not the 4x parent. This indicated that selection for maturity, based on parent phenotype among 2x clones that produce 2n pollen, would be effective in determining 4x family maturities. Similar results were obtained for tuber appearance. Thus, highly heterozygous 2x hybrids with smooth tubers can be selected.

The correlations between the yields of the 2x parents and the 4x progenies were low. This indicated that selection of 2x parents to increase total yield in 4x progeny from 4x-2x crosses should be based on progeny testing. The families obtained from several new 4x-2x crosses outyielded the best cultivar.

More than 100 tuberosum haploids were crossed with *Solanum chacoense* (chc) introductions selected for the production of 2n gametes. Haploid *S. chacoei* hybrids (HC) vary widely for tuber yield; certain haploids when crossed with chc gave high-yielding HC segregants. Use of selected haploids is an excellent method for transferring wild species germplasm into cultivated germplasm.

Contract work at the Plant Breeding Department of the Agricultural University, Wageningen, Netherlands, has developed fertile diploid clones with a desynapsis gene in which only 2n-FDR gametes are functional. F_1 populations from diploid x diploid matings consisted of tetraploid progeny only. The genotypes obtained were about equal to those resulting from somatic hybridizations of diploid parents. The desynapsis gene occurring in the material under study was observed to be expressed in micro- as well as megasporogenesis. The goal is to develop near-apomictic potatoes that produce true seed with the maternal genotype.

SPECIAL SELECTION METHOD

A study of selection for tuberosum-like tubers and vines within the neotuberosum population has been completed at Cornell University. Selection for vine-type alone resulted in a 161% improvement in the vine type and a 24% improvement in tuber type. Selection for tuber type alone resulted in a 39% increase in tuber score and a 62% increase in vine score. Simultaneous selection for vine and tuber type produced a 117% increase in vine score and a 37% increase in tuber score. The results of this study indicated that 1) there is a correlated response to selection for vine and tuber type, and that 2) the neotuberosum population has reached the stage where it is very usable in hybridizations with tuberosum. Even without crossing neotuberosum with tuberosum, tuberosum-like clones with regard to tuber appearance and vine type can be obtained.

NEW CYTOLOGICAL TECHNIQUE

A stain-clearing technique for observations within whole ovules was developed under contract at the University of Wisconsin. With this technique, megasporogenesis and megagametogenesis can be observed with speed and accuracy. Whole ovaries are stained with Mayer's hemalum and then cleared with methyl salicylate. Clarity, resolution, and contrast within ovules dissected from ovaries were as good as those obtained from paraffin sections; however, the stain-clearing technique was much easier and faster. The new method made it possible to detect 2n eggs and to determine their frequency and mode of formation. Most 2n eggs were formed through the failure of the second meiotic division; the frequency of this failure varied from 10% to 50%. Female sterility, previously difficult to investigate, can now be studied using this new cytological technique.

VARIOUS BREEDING PROGRAMS

Breeding to combine bacterial wilt, late blight, and other resistances was continued at CIP-Lima and in the regions. In evaluations made in Peru, the highest performers among the clones selected for high yield, resistance to bacterial wilt, late blight, and viruses are listed in Table II-2.

At North Carolina State University, a diploid breeding program, supported by CIP, evaluated 83 clones for resistance to *Alternaria solani* (early blight) in a replicated trial. Three replications of the 83 clones were inoculated twice with a spore suspension of *A. solani* and subsequently evaluated for number of lesions and percent of defoliation (Horsfall-Barrett rating). Under severe environmental stress conditions, all previously resistant clones were still resistant, but many clones exhibited less resistance than in previous years. Thirty-eight clones were still highly resistant even under these conditions. In addition, 86 clones, selected from 1982 single-hill seedlings, were inoculated with *A. solani* and tested in single-row plots. Twenty clones were highly resistant.

COLLABORATION WITH CIP'S REGIONAL RESEARCH CENTERS

CIP regional staff in cooperation with national programs conducted extensive field trials to evaluate CIP clonal introductions for adaptability to local conditions. In Table II-3, up-to-date information is provided on the selection stages of clones introduced by CIP into developing countries.

CIP's Region III germplasm bank, located in the Plant Quarantine Station in Kenya, now contains 260 pathogen-free

Table II-2. CIP clones from the pathogen-tested program, resistant to bacterial wilt, late blight, and viruses, Huanuco, Peru.

Clone	Yield (kg/plant)	Bacterial wilt (%)	Late blight (1-9)	Other characteristics
800928	2.0	0	2	
800941	1.3	50	1	
800942	1.3	0	7	Resistant to PLRV
720118	1.2	47	1	
800927	1.1	50	2	
800934	1.1	100	3	Resistant to PVY
800936	1.0	0	1	
800212	1.0	0	6	Resistant to PVX
800937	1.0	17	5	Resistant to PVX
800935	1.0	73	4	High dry matter
800951	0.9	0	3	
800224	0.9	0	3	Resistant to PVY
Molinera	1.2	20	4	Resistant to PLRV
Ticahuasi	1.0	100	9	

PLRV = potato leafroll virus; PVY = potato virus Y; PVX = potato virus X.

Table II-3. Main resistances of clones introduced by CIP under various phases of selection in developing countries.

CIP regions	Selection stage: Selected clones		Highly advanced clones		Clones released or named	
I	4[a] (88)[b]	Frost, cyst, LB, BW, PLRV, PVY, early	1 (4)	LB, BW, PLRV	4 (7)	LB, BW, PLRV
II	4 (119)	BW, PLRV, early			2 (3)	LB, BW, PLRV
III	8 (51)	LB, BW	3 (10)	LB, BW, PLRV	9 (31)	LB, BW, PVY, HT°, early
IV			1 (3)	PLRV, PVY	1 (2)	PLRV, PVY
V	2 (15)	LB, BW, HT°			2 (2)	LB, BW, HT°, early
VI	4 (34)	LB, BW, PLRV, PVY, HT°	3 (7)	LB, BW, HT°, early	2 (6)	LB, PLRV, PVY, HT°, early
VII	7 (23)	LB, BW, HT°	2 (3)	LB, PLRV	2 (4)	LB, BW, PLRV

[a] No. of countries.
[b] No. of clones.
LB = late blight; BW = bacterial wilt; PLRV = potato leafroll virus; PVY = potato virus Y; HT° = heat tolerant.

clones available for export as requests are received from national programs in that region. In 1983 the Plant Quarantine Station received 70 in vitro plantlets for checking disease status before being released. CIP clone 800224, proven to be high yielding (31 t/ha) and resistant to bacterial wilt and late blight, is being considered for release as a variety by Kenya.

In Rwanda, three clones introduced by CIP (720118, 800935, and 377831.1) showed lower incidence of bacterial wilt and higher yields than the standard local variety. In Burundi, located south of Rwanda, the first priority is for combined bacterial wilt and late blight resistance. The variety Montsama and clones 720088 and 720118 have shown good potential. More than 27,000 new clones were received in Burundi during 1983 and will be evaluated in the field during 1984.

Germplasm released from quarantine in India was multiplied and tested during 1982-1983, and six superior clones were selected for further trials in Region VI. In Sri Lanka, clones 379418.40, 379420.15, 379420.40, and 379421.75 were found to be completely resistant to bacterial wilt. Eleven bacterial wilt-resistant clones with heat tolerance were retested during 1982-1983 in this island country.

In Region VII, the multiplication and testing site in Santa Lucia, Philippines, has had a successful year in germplasm evaluation. Of the 126 clones and cultivars from CIP and other sources that were tested in five trials, the varieties Cosima, Arka, and Piratini were superior. By means of a rapid multiplication procedure using sprout cuttings, approximately 5000 tubers of LT-2 and various quantities of DTO-33 and other cultivars were produced at Santa Lucia. Most of this germplasm has been supplied to Indonesia and Vietnam for local evaluation. The Argentine variety Serrana, introduced by CIP into Vietnam, gave excellent yields in the north; while in the south at Dalat, Atzimba, CFK 69-1, and B-71-240.2 were the best performers.

In Thailand, where the potato-growing area is relatively cool, the varieties currently grown are Kennebec and Spunta. Among the new clones introduced there by CIP, DTO-2, BR-69-84, and B71-240.2, and Sequoia appear to be excellent, high-yielding alternatives to the present varieties. Fiji, also served by the Santa Lucia station, has released CIP clone 800226 as the variety Domoni. Following its release, 47 other clones were tested: four out-yielded Domoni in both yield and tuber weight, were earlier, and showed good potential as new varieties. They will be reevaluated in 1984 for bacterial wilt resistance.

In South America, the Brazilian organization EMBRAPA (Region II) selected from previously introduced germplasm, 23 clones with resistance to viruses and 17 clones with bacterial wilt resistance. Nine clones specifically selected for adaptation to the aluminum toxic and phosphate-deficient *cerrado* soils are being multiplied for further evaluation and for recurrent breeding and selection in Lima.

In the international program for testing and selecting late blight-resistant material, a population of 3343 clones from 79 families was sent to Rio Negro, Colombia, in Region I. Due to climatic disturbances caused by El Niño, late blight incidence was low, although there was severe damage to susceptible commercial varieties. About 80% of the population tested appeared to be resistant. At harvest time, after 120 days, 318 clones were selected for earliness and other agronomic characters (Table II-4). Of the 318 clones, 111 were suitable for non-Andean tropical and subtropical countries with regard to maturity (90-120 days), skin color, eye depth, and tuber shape.

Duplicates of these clones are being increased under quarantine conditions and will be evaluated further at the Toluca Valley site in Mexico for late blight resistance. The third group to enter the international testing program was grown and harvested under quarantine conditions at CIP's Huancayo site in Peru. Two tubers

Table II-4. Performance of the best families selected for desirable agronomic traits and earliness a Rio Negro, Colombia.

Family no.	Pedigree	Selections			
		No.	%[a]	Yield (kg/plant)	Yield rang (kg/plant)
381148	378498.204 x LB bk	5	18.5	1.4	0.8 - 1.9
381154	378508.276 x LB bk	7	20.0	1.4	0.9 - 2.4
381162	378508.291 x LB bk	7	14.6	1.7	0.6 - 2.7
381163	378508.295 x LB bk	7	16.7	2.1	1.5 - 2.6
381173	378979.440 x LB bk	8	22.2	1.8	0.6 - 2.9
381185	378971.748 x LB bk	7	14.9	2.6	1.0 - 5.0
381376	794 x LLT early bk	6	14.3	2.4	1.8 - 3.0
381377	814 x LLT early bk	10	18.9	2.6	1.4 - 4.1
381378	833 x LLT early bk	13	26.5	2.2	1.1 - 4.5
381397	721 x Mex LB bk	11	21.6	1.9	0.6 - 4.9

[a] Percent of families selected.

each from a population of 3331 clones representing 125 families were shipped to Colombia; duplicates were stored in Lima.

In CIP's Region IV, new breeding lines from CIP are being supplied to Turkey's national program under a contract that was established when the regional headquarters was transferred from Turkey to Egypt in 1983.

INTERNATIONAL RESEARCH COLLABORATION

Argentina. Contract research at the National Institute of Agricultural Technology (INTA), Balcarce, Argentina, carried out some 10,000 pollinations to produce botanical seed of about 100 successful parental combinations. These crosses were planned to combine virus resistance with yield under relatively long days and warm weather. From crosses made in previous years, 13,000 seedlings were raised and tubers produced. The genotypes raised from these tubers will undergo selection in future seasons. In a search for haploids, 2023 seeds without embryo spot were found—the absence of embryo spot indicates that this seed might be haploid. Also, 3860 4x-2x pollinations were pei formed to identify new diploid pollinator adapted to local conditions in Argentina.

Eleven hectares were planted at Bal carce with material that survived selectioı in previous years; this included 20,50‹ individual plants from crosses in 1981 and 6017 clones from previous years Twenty-nine clones representing advancec selections from a collaborative agricultur program were sent to Lima for broadeı evaluations and for use as parents ir crosses.

Australia. At the Department of Agri culture Station, Victoria, Australia, 1(advanced clones were grown in insect proof cages and in the field under CII contract during 1982-1983. Sets of tuber for each clone and also for six varietie were distributed to Fiji, New Caledonia Tahiti, Kingdom of Tonga, Guam, and the Republic of Vanuatu. Two additional sets of tubers were held for Vanuatu and one each for Papua New Guinea, Sri Lanka, and Thailand. Other pathogen-free samples were sent to Bangladesh, Bhutan, Burma, Indonesia, Papua New Guinea, and Sri Lanka. Ten CIP clones and six Indonesian cultivars were heat-treated, cultured in vitro, indexed for virus, and multiplied prior to shipment.

Canada. At CIP it is necessary to be able to predict with better efficiency how advanced clones will perform in the different environments found in developing countries. A research contract was established with Agriculture Canada, Fredericton, New Brunswick, which has international leadership in developing a biometrical model to predict the response of tuberosum genotypes to environmental stress. During 1983, trials were conducted in Bangladesh, Canada, Philippines, Peru, Brazil, Tunisia, Turkey, Rwanda, and Ethiopia. This year 800 lbs of Elite II seed have been produced and will be tested in five countries in 1984.

Training. Twenty scientists from Southeast Asia attended a production and germplasm management course in the Philippines so that procedures for evaluation of the material distributed from Australia could be standardized. The only other course on germplasm was conducted in Colombia, where staff from the breeding programs of eight Central and South American countries were trained. Six scientists were trained, four at CIP-Lima and two in Australia, in tissue culture and rapid multiplication techniques to improve the handling of pathogen-tested in vitro plantlets. Six scientists, nominated by CIP, attended a joint CIAT/IITA/CIP global workshop on root and tuber crop propagation in Colombia.

THE PATHOGEN-TESTED COLLECTION AND GERMPLASM DISTRIBUTION

Thirty-five new clones were added to the pathogen-tested collection at CIP: 30 had been freed of viruses at IPO, Wageningen, and 5 at Lima. Presently, the CIP collection contains 189 clones of which 145 (77%) were requested by various programs. In total, 30,853 plantlets were propagated in vitro at CIP and handed over to the seed program. Repeated cycles of shake culture incubation of stem pieces with two to four nodes made such mass propagation possible. Single nodes from these plantlets were then transferred to a soft agar medium in sterile plastic boxes. In three weeks the buds developed

Table II-5. Distribution of CIP germplasm, 1983.

CIP regions	Countries (no.)	Clones	Tuber families	Genotypes	True seed	Genotypes	In vitro (no. genotypes)	True seed progenies	Seeds (no.)
I	5	196	119	5,479	105	13,709	4	3	7,000
II	10	208	263	12,371	65	3,695	5	10	35,000
III	12	354	339	7,915	–	–	18	5	18,000
IV	4	35	69	4,209	22	6,644	9	18	224,428
V	4	19	27	786	–	–	–	5	16,000
VI	6	46	9	64	–	–	8	6	21,645
VII	12	167	82	5,528	5	8,000	33	11	34,000
Subtotal	53	1,025	908	36,352	197	32,048	77	58	356,073
Others[a]	17	32	42	5,900	60	6,700	167	10	23,000
Total	70	1,057	950	42,252	257	38,748	244	68	379,073

[a] Others = developed market economies and centrally planned economies.

into plantlets 5-10 cm high with good root systems. After an adaptation period, the plantlets were transferred directly to pots or seedbeds.

CIP's list of pathogen-tested cultivars was revised during 1983 and distributed to cooperating scientists. By the end of September, 138 advanced cultivars and 51 wild and primitive cultivars were available for international distribution. All materials distributed (Table II-5) were tested by indicator hosts, latex or ELISA serology, and electron microscopy and found free of potato leafroll virus, potato viruses A, M, S, T, V, X, Y, Andean potato latent virus, Andean potato mottle virus, tomato black ring virus, and tobacco ringspot virus. Potato spindle tuber viroid was tested by the tomato test and electrophoresis.

Although all of these tests are used routinely at CIP, research is still continuing on how to increase their precision and efficiency. The accelerated rate at which germplasm developed by Thrust II is now being distributed to the regions is an indication of a threshold reached in CIP's breeding program, and more and better material should be leaving CIP at the request of national programs in 1984.

THRUST III

Bacterial and Fungal Diseases

In breeding and screening for bacterial wilt resistance, additional tetraploid groups of genetically variable tuber families were developed. Diploid populations with different sources of resistance (e.g., *Solanum phureja* and *Solanum sparsipilum*) were crossed with agronomically advanced diploids and the resulting progenies evaluated for agronomic characteristics. Growth studies were concluded on different isolates of *Pseudomonas solanacearum* through a temperature range of 10° to 14°C. The isolate collection now contains 228 bacterial isolates, including recent acquisitions from Chile, Argentina, Brazil, Indonesia, Rwanda, and Sri Lanka.

Breeding for late blight resistance continued to broaden the source population and number of parental lines and to introduce earliness and improved agronomic characters. Despite droughts at two test sites in Rio Negro, Colombia, and Huanuco, Peru, late blight-resistant clones with excellent agronomic characters were selected at both sites. Experiments at Rio Negro on the interaction between fungicidal spraying and different levels of resistance showed that 1) yield was correlated with spray frequency, 2) resistance and fungicide response exhibited a strong interaction, and 3) yielding ability and resistance were clearly independent traits. Screening for late blight resistance in tubers was initiated at Lima; the first results have indicated that good levels of resistance are present in both the germplasm collection and in advanced genetic material.

Various chemical and cultural control experiments on several soil-borne fungal diseases were evaluated. Combined application of Basamid+Ridomil 5G was still the best chemical control for potato smut and pink rot. Studies on occurrence and distribution of Verticillium wilt on the coast and central highlands of Peru showed that the problem of early dying is more frequent than previously suspected. *Verticillium dahliae* has been the only species so far identified on potatoes. A technique for Verticillium wilt tolerance was developed for use in the greenhouse. Research on screening for resistance to gangrene (*Phoma exigua* var. *foveata*) indicated low levels of resistance in different types of genetic material at CIP.

BACTERIAL DISEASES

Breeding for resistance to bacterial wilt (*Pseudomonas solanacearum*). Breeding for bacterial wilt (BW) resistance concentrated on two major goals. The first was to generate a further tetraploid group of genetically variable tuber families for export (Group V). Twenty-six families totaling 2725 seedlings were grown and tested against isolate 181 from Indonesia and isolate 235 from Brazil. Of all the seedlings tested, 47% were resistant to the Indonesia isolate and 60% to the Brazilian. These figures reflect the high levels of resistance attained in this genetic population. This cycle of selection, which also contained a high proportion of material adapted to warm climates, is now available for export to Indonesia and Brazil. Experience has shown that material with known resistance to specific isolates may also be resistant to other pathogenic isolates of *P. solanacearum*.

The second goal was to develop a diploid population whose resistance to BW was based on new sources of resistance different from *Solanum phureja* (MBN population). A population of highly resistant diploids derived from *Solanum sparsipilum* were combined with a population of agronomically advanced diploids from a North Carolina State University project. Of this population, about 10,000 hybrid seedlings were grown in the field in Huancayo and selected for agronomic characters. From 50 families, 628 clones were selected and will be tested for resistance to various strains of *P. solanacearum* and for resistance to potato tuber moth in stores. This population will be used in tetraploid-diploid crosses to generate a highly variable tetraploid population that combines resistance from various specific sources (Fig. III-1).

Breeding for resistance to bacterial wilt and late blight. Over the past six years, hundreds of clones bred by the University of Wisconsin program and later by CIP have been screened in Peru for bacterial wilt and late blight (LB) resistance. The most promising clones were also tested in other countries and then entered into CIP's pathogen-tested program (Table III-1) for distribution.

Table III-1. Clones selected for bacterial wilt and late blight resistance that are ready for regional distribution.

Clone	Yield (g/plant) Lima (350 m)	Yield (g/plant) Huanuco (2000 m)	Disease ratings Bacterial wilt % (latency[a])	Disease ratings Late blight (1-9)
800212 (BR63.5)	950	–	0 (–)	6
800224 (BR63.76)	1415	867	0 (–)	3
800935 (MS1C-2)[3]	1618	990	73 (+)	4
800928 (MS42.3)	1514	2000	0 (+)	2
800941 (MS82.60)	1500	1300	50 (+)	1
800927 (MS91.18)	1323	1120	50 (+)	2
800936 (PSP30.10)	1713	–	0 (–)	1
720118 (cr.148)	1340	–	47 (–)	1
800951 (R593.10)	1150	–	0 (+)	3
MB56.10	1638	–	0 (–)	8
800222 (Molinera)	1737	300	20 (–)	4

[a] Latency of disease expression: + = tubers infected; – = tubers symptomless.

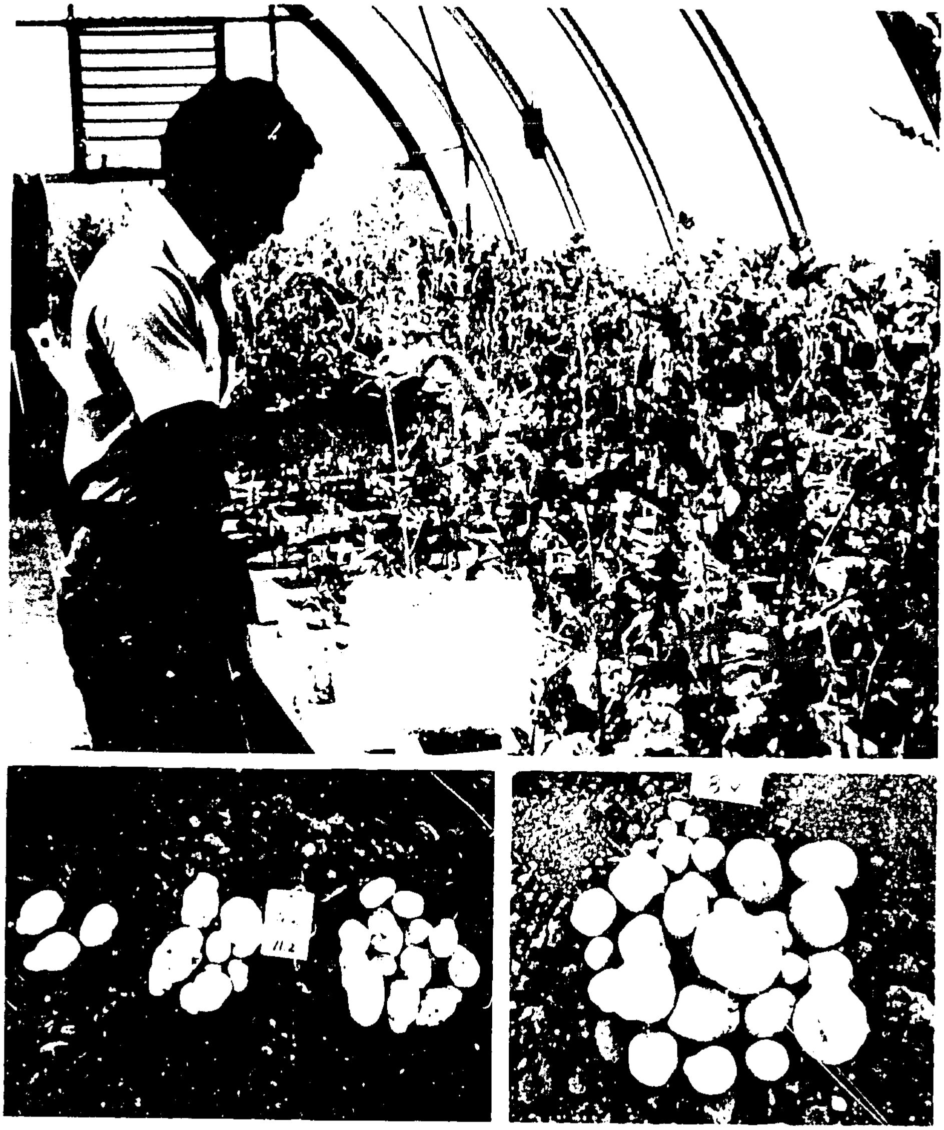


Figure III-1. Screening a bacterial-wilt resistant diploid population with one set of chromosomes from *Solanum sparsipilum*, and two of the selected resistant clones from this population.

Drastic selection procedures are being applied with recently developed clones from the 1981 crosses. From 111 clones screened in the greenhouse at Lima and transplanted to the field, 53 were selected for testing at Huanuco, Peru. These were planted at three Huanuco sites: Umari for BW, Molinos for LB resistance and yield, and at the University of Huanuco, at a lower elevation, for heat-adaptation yield trials. After the first two tests were completed, five clones (3810A46.502, A46.503, A47.505, A65.503, A71.501) were selected that were BW resistant, had moderate LB resistance, and gave good yields.

It is important to note that breeding for bacterial wilt resistance has been conducted on the basis of limited information about races and strains of *P. solanacearum*, since most studies have so far only been done in the Americas. CIP's expanding collection of isolates, including those from Africa and Asia, now totals 228. The most recent acquisitions are from Chile, Argentina, Brazil, Indonesia, Rwanda, and Sri Lanka. A duplicate collection is being maintained by the Plant Disease Division Culture Collection, Department of Scientific and Industrial Research, Auckland, New Zealand. This duplicate collection will permit mapping studies on the geographical distribution of pathogenic strains, which will aid in predicting the performance of resistances being developed for any location.

Studies on *P. solanacearum* isolates. Growth studies on the isolate collection were conducted in a temperature gradient incubator calibrated with a range of 10°-40°C. Twenty-four isolates of both race 1 (biovar I) and race 3 (biovar II) from cool and warm locations were used. Isolates from the highest latitudes came from Sweden and Argentina; those from warm and cool locations in the tropics came from Peru – Yurimaguas (180 m) and Chocon (3500 m, near Huancayo). Growth temperature curves were similar for all isolates, with the average very close to the maximum. The minimum temperatures were variable due to lack of precise spectrophotometric readings at low concentrations of the bacteria.

In Sri Lanka, biovar II is typically found in the cool upland regions. In collaborative work between CIP and the Sri Lanka national program, four soil types from different locations were artificially inoculated with biovar II and planted with BW-resistant clone 800224. Bacterial wilt was first observed 14 days after planting, and all plants developed symptoms by the 26th day under the high temperature conditions prevailing at the test site. The survival of biovar II under hot, coastal conditions at Jaffna (10°N) was observed following an outbreak of BW resulting from infected seed. Sixteen of 22 isolates were biovar II and 6 were biovar III. The foregoing and other observations suggested a ready accommodation of so-called "cool temperature" isolates of *P. solanacearum* to "warm temperature" conditions.

Biological control of bacterial wilt. Contract research at the University of Wisconsin has contributed valuable insight into the basic biology of *P. solanacearum*. In the biological control of BW, studies are testing the potential chemical inducers of resistance and also the potential of cross protection by avirulent strains of the bacterium. None of the various compounds tested provided a satisfactory level of protection, although a proteinase inhibitor-inducing factor delayed wilt symptoms in Kennebec potatoes. When seed pieces were treated with three different avirulent strains of *Pseudomonas*, only the avirulent isolate B-82 from Colombia caused a significant and prolonged reduction in disease severity after being challenged with a virulent bacterial suspension. At high temperatures, however, the same treatment caused only a delay in symptom expression. Recently, work has started on genetically transferring bacteriocins from two *P. solanacearum* isolates into isolate B-82. Tissue culture will be used for in vivo production of bacteriocins.

Investigators are continuing work on developing an antiserum, specific for race 3 of *P. solanacearum*, to develop a practical method for field detection of this race. There are, however, several subserotypes that require many cross-absorption tests for identification and data compilation.

A research contract with the National Agricultural Laboratories in Nairobi, Kenya, is developing a method for screening germplasm for BW resistance under local conditions. In spite of inducing a high inoculum potential in the field by repeated cropping with susceptible hosts, infection of test plants was random and unreliable. However, when plants were artificially inoculated by bacterial suspension around their bases, infection ranged from 12.5% to 69.0%. Tests made at various dilutions of the bacteria concluded that this method did not overcome the genetic resistance to BW in test clones at the dilutions being used.

In contrast, artificial inoculation did not permit useful discrimination of genetic resistance in experiments at Bukidnon, Mindanao, conducted by CIP and the Philippine national program. In a field trial, the var. Red Pontiac – a known susceptible – was planted in alternate rows with test varieties, and all plants were root-inoculated with a suspension of *P. solanacearum*. The ten imported German varieties exhibited more than 75% infection. Only the var. Nordsterm gave a moderate yield (13 t/ha), in spite of almost total BW infection ten weeks after planting. In a second trial using seed tubers harvested from a wilt-infected field, even var. Greta and clone 720057 were infected. Both of these had previously proved to be fairly resistant in other parts of the Philippines. Under very warm conditions, artificial inoculations should be used with caution.

In Rwanda, bacterial wilt is controlled during the dry season when the soil dries out and apparently reduces the level of bacterial inoculum. In a collaborative project with the Rwanda national program (PNAP), crop rotations, now in the sixth season, showed that one season of rotation with a different crop reduced the incidence of BW in the next potato crop. Cutting seed tubers, a practice sometimes used in Rwanda, increased the number of plants affected by bacterial wilt.

Control of bacterial soft rot. Other contract research at the University of Wisconsin confirmed the positive correlation between tuber calcium content and resistance to bacterial soft rot caused by *Erwinia carotovora* pv *atroseptica* (ECA). When whole tubers were injected with pectic enzyme from ECA and incubated under low oxygen levels, tissue maceration was greater in the low-calcium tubers than in those with high calcium. In commercial cultivars grown in the field at the same level of calcium fertilization, there were wide differences in tuber calcium content, which reflected differences in cultivar calcium assimilation. The three large-scale field trials carried out in 1983 are expected to confirm the influence of soil calcium levels on disease severity as was determined in 1981 and 1982.

At North Carolina State University, a contract project selected diploid subpopulations for soft rot-resistant clones that produced unreduced gametes. Eight clones were identified that produced tetraploid offspring in tetraploid x diploid crosses involving unreduced gametes. From 80 advanced tetraploids from 4x-2x crosses, 20 were selected for trials with commercial clones. From 1600 segregates, 82 clones were selected for further trials. An additional 20 clones with tuber resistance to soft rot were used to produce plants that were evaluated for blackleg resistance by stab-inoculation. Two clones exhibited high resistance to both soft rot and blackleg.

FUNGAL DISEASES

Late blight (*Phytophthora infestans*). For testing late blight (LB) resistance, three localities have been established by CIP in collaboration with university and national programs: Huanuco, Peru; Rio Negro, Colombia; and Toluca, Mexico. The source population of LB-resistant clones is maintained at Lima where it is being improved for earliness. Progenies from selected advanced clones are introduced to the international testing program (see Thrust II) for evaluation, selection, and distribution to CIP regions. Other sources of resistance are also tested and selected under local conditions at Huanuco in cooperation with the Peruvian national potato program of INIPA and the University of Huanuco.

At Huanuco, a total of 169 clones selected for agronomic type were tested for LB resistance in a lattice experiment. A second group of 280 advanced clones was retested at the same location in 10-hill plots, in addition to 258 new clones from 1982 single-hill selections. Because the season was unusually dry, most of the material had blight scores within the range of resistance. Selection for agronomic type and tuber yield, however, was carried out at Huanuco and on duplicates at Huancayo. Additionally, 58 clones from the 1982 selection (239) were selected as potential varieties under the CIP-University of Huanuco contract. These clones will be retested for LB resistance at Huanuco and the duplicates will be given to INIPA.

At Huancayo, 196 of the 427 duplicate clones tested at Huanuco were selected from 10-hill plots at 120 days for agronomic type and yield. An additional 121 advanced clones with resistance to LB, previously evaluated at Huanuco, were tested for yield in an 11 x 11 lattice experiment. Fifteen of the highest yielding clones produced an average of 2.0 kg/plant despite damage from two hail storms.

Fungicide spraying and levels of resistance. At Rio Negro, Colombia, the interaction between fungicidal spraying and different levels of LB resistance was studied. The tests were to determine if lower levels of resistance may be acceptable if selection occurs in an environment where LB pressure is attenuated by using low levels of fungicide application. Six commercial potato varieties with different levels of resistance were used with three application frequencies (each 7, 14, and 28 days) of Bravo-500 (Chlorathalonil 70%). Part of the results are shown in Figure III-2.

The weather at Rio Negro was exceptionally dry during the major part of the growing season, especially in mid-season; nevertheless, Monserrate was the most resistant, followed by Tequendama; and Guantiva was clearly the most susceptible. These preliminary results supported observations 1) that yield was correlated with spray frequency for each individual cultivar; 2) that resistance and fungicide response showed a strong interaction; and 3) that yielding ability and resistance were clearly independent traits.

In 1983, four new clones with late blight resistance and good yielding ability were introduced to CIP's seed program for cleanup and export: 377369.7, 378143.5, 380496.2, and 380496.6.

Late blight resistance in tubers. CIP started screening procedures for general resistance to late blight in tubers by testing 1043 clones from nine breeding projects in 1983. Of the clones tested, 37% were resistant, 36% moderately resistant, and 27% susceptible. The most promising was material 8308 (Landeo) with more than 60% resistant clones. The most resistant clones will be retested during 1984.

Advanced clone testing in on-farm trials. Advanced clones were tested by a collaborative project between CIP and ICA, Colombia's national program. Six

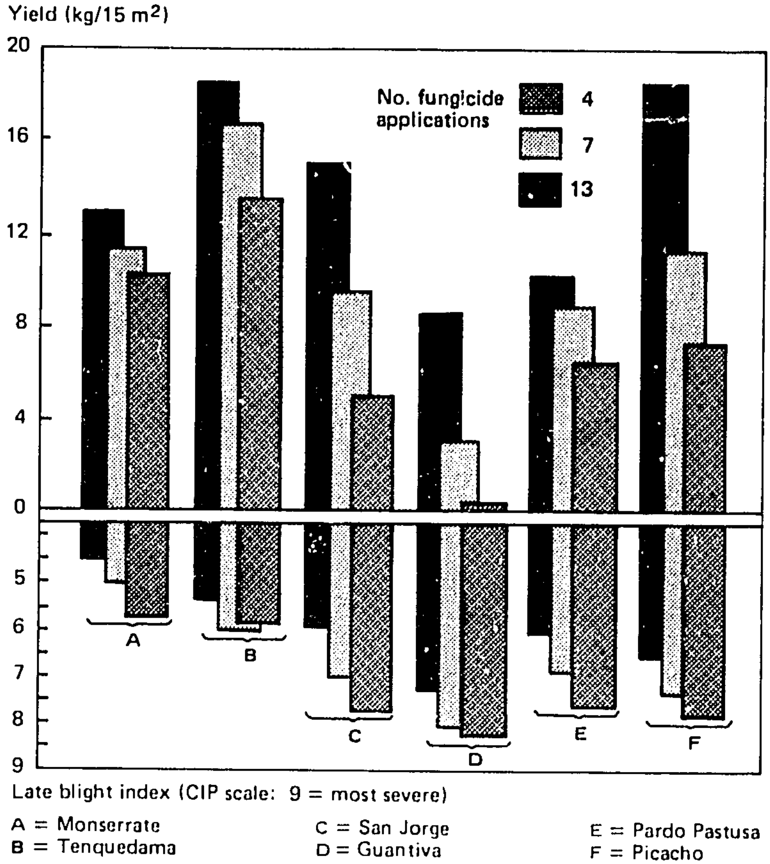


Figure III-2. Relation between yield and late blight index under three levels of fungicide treatments for six commercial potato cultivars.

on-farm trials in the Department of Antioquia, Colombia, gave the following results during two seasons: CIP's advanced clones were superior in yield and LB resistant when compared to a local cultivar (Fig. III-3). All CIP clones were LB resistant and had a growing period of 120 days, while the local cultivar was susceptible and matured at 135 days.

SOIL-BORNE DISEASES

Verticillium wilt (*Verticillium dahliae*). Studies on the occurrence, incidence, and distribution of Verticillium wilt in Peru began in late 1982 as a new project on fungal potato wilt. Data was collected in the Mantaro Valley of Peru, including Huancayo (highlands), and in three coastal valleys (Cañete, Barranca, and Huacho). A total of 552 stem samples from plants showing early senescence were collected from the germplasm collection at Huancayo. Of the samples collected, an average of 60% were infected, and in most cases *Verticillium* sp. was the only wilt organism isolated. Two other Mantaro Valley surveys in farmers' fields indicated a relatively high infection by *Verticillium* sp. Coastal valley surveys showed that a high proportion of plants with early senescence were infected by *Verticillium* sp. It is interesting to note that 62% of true potato seed (TPS) transplants at

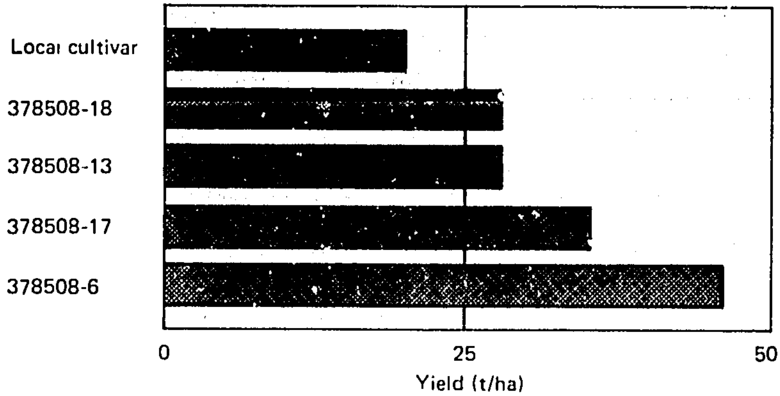


Figure III-3. Mean yield of a local cultivar and CIP advanced clones. Average of six on-farm trials in Antioquia, Colombia.

Huancayo were also infected. In the Mantaro Valley and in the coastal valleys of central Peru, only *V. dahliae* has been isolated (Fig. III-4).

A screening method used routinely at the Research Institute for Plant Protection, Wageningen, Netherlands, to evaluate tolerance to Verticillium wilt was adapted for use at CIP and tested on 26 clones from the pathogen-tested list. Only one clone, Cruza 148, was found to have intermediate levels of tolerance; however, the inoculum concentration in the first trial was considerably high (1.7×10^7 propagules/ml).

Pink rot (***Phytophthora erythroseptica***). In fungicide trials to control pink rot, Ridomil 5G applications at planting were again the most effective (Table III-2). All treatments that included Ridomil yielded

Table III-2. Average yield of healthy and diseased tubers treated with different chemical products to control pink rot (*P. erythroseptica*), Huancayo, 1983.

Treatment	Avg yield of healthy tubers (kg/6 m²)	Diseased tubers (%)
Basamid + Ridomil 5G[a] (300 kg + 30 kg/ha)	34.94	6.73
Ridomil 5G (30 kg/ha)	34.08	5.28
Fujione + Ridomil 5G (30 kg + 30 kg/ha)	32.48	9.78
Ditrapex + Ridomil 5G (500 L/ha) + (30 kg/ha)	30.90	2.46
Terrazole + Ridomil 5G (14.2 kg + 30 kg/ha)	29.98	6.19
Plastic cover + Ridomil 5G (30 kg/ha)	23.84	11.37
Fujione (30 kg/ha)	14.96	13.12
Ditrapex (500 L/ha)	11.14	16.24
Plastic soil cover	11.06	19.27
Terrazole (14.2 kg/ha)	9.64	15.73
Untreated control	10.78	17.20
Dunnet Test (LSD)	5.25	–

[a] Used as a check treatment.

Figure III-4. Verticillium wilt in the highlands and the coastal valleys of Peru is caused by *Verticillium dahliae. Top*: verticilliate conidiphore. *Bottom*: microsclerotia of *V. dahliae.*

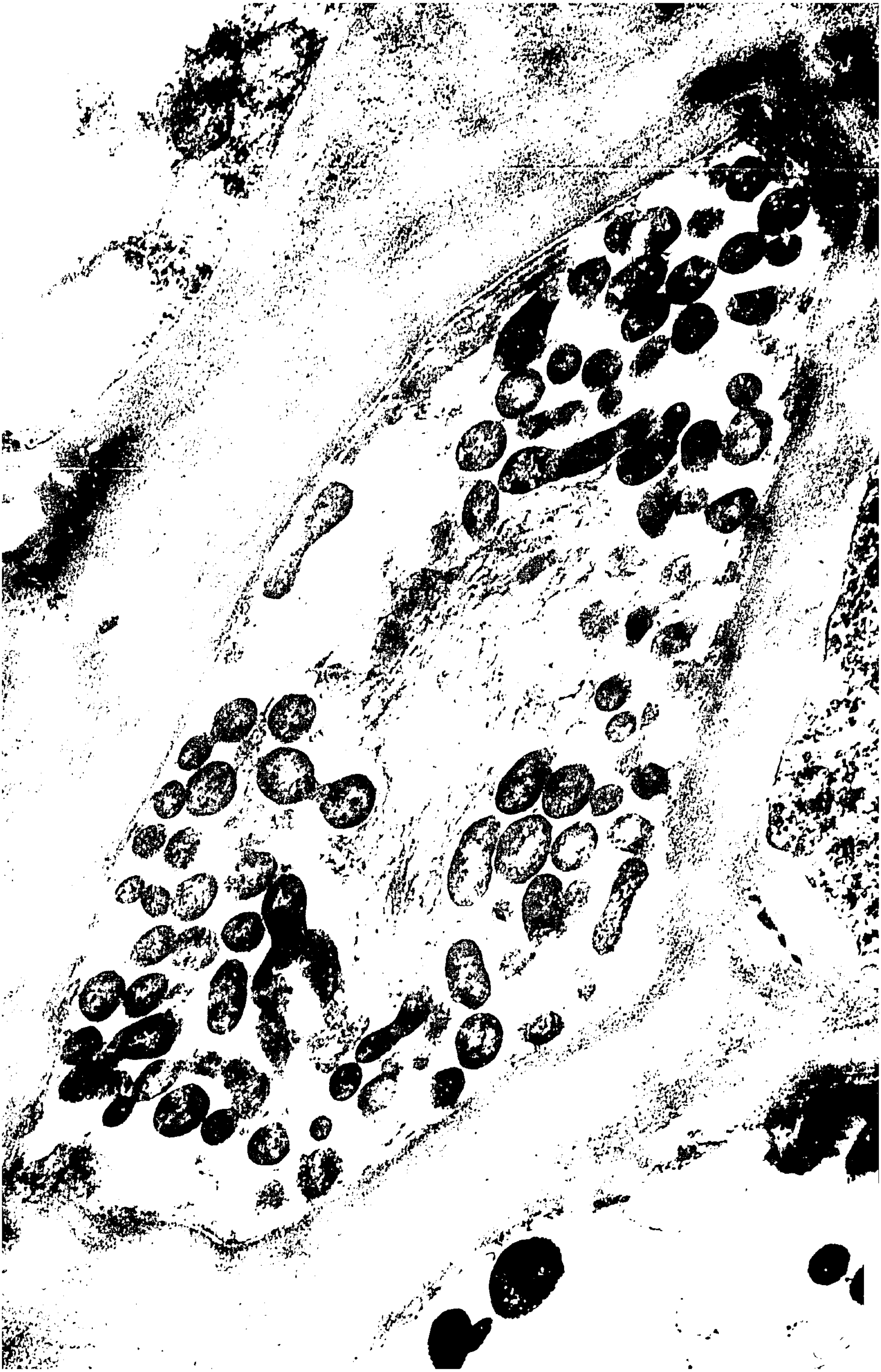
significantly higher than those without Ridomil. Studies on the residual action of Basamid+Ridomil applications are still in progress. Preliminary observations have indicated that after two years this treatment is still effectively controlling pink rot.

Gangrene (*Phoma exigua* var. *foveata*). Many clones from CIP's germplasm collection were screened for tuber resistance to gangrene. Whole tubers were superficially wounded by rolling them over ten nail points (4 mm high) and then brushing inoculum over the wounded areas. Tubers were maintained at 9° to 10°C for six weeks and then evaluated externally as well as internally. From a total of 526 clones evaluated, only 3 were found to be resistant, as compared to 211 clones found to be moderately resistant, and 312 susceptible. This work was done at CIP by a scientist from Norway as part of his sabbatical and will be continued in Norway upon his return.

Potato smut (*Angiosorus solani*). A total of 77 clones were evaluated in a heavily infested field near Huancayo for resistance to potato smut. Twenty-three clones showed no infection and are being retested. In different field plots at Huancayo previously treated with Basamid+ Ridomil 5G, smut was adequately controlled by the fungicides' residual effect during a second growing season.

Southern wilt (*Sclerotium rolfsii*). The method of crop rotation has been reported as an alternative to control *S. rolfsii* incidence and to reduce the number of viable sclerotia in the soil. Most of the research reported has been done in areas other than the humid tropics and on other crops. A rotation study was started in 1980 at San Ramon and included four rotation sequences (two crops/yr) of rice-beans-corn-potatoes to be compared with consecutive potato crops. Each rotation included subtreatments with and without crop residue incorporation. Prior to establishing the rotations, the entire field was planted to potato and then inoculated plant-by-plant with *S. rolfsii*.

The study, which concluded in 1983, showed that the number of viable sclerotia was much higher in plots with incorporated residue, but that percent infection was almost equal in plots with or without residue incorporated. Treatments including incorporation of residues had a reduction in percent of tubers infected with *S. rolfsii* and other pathogens, and therefore an increase in percent of healthy tubers.



THRUST IV

Potato Virus Research

Emphasis was placed on studies to combine resistance to potato leafroll virus (PLRV) and potato virus Y (PVY) in the same genotype. Selection of resistant genotypes to PLRV and confirmation of potato virus Y (PVY) immunity were performed under controlled conditions. An extremely high level of resistance to PLRV from *Solanum acaule* was successfully incorporated into tetraploid cultivars via resistant hexaploids. Resistance to PLRV present in *S. acaule* appeared to be a combination of resistance to infection and to multiplication of the virus; whereas in *Solanum etuberosum* x *Solanum pinnatisectum* (EP), only resistance to multiplication was found. Inheritance of immunity to PVX_{HB}, the resistance-breaking strain of potato virus X (PVX), and to PVX_{cp} in *Solanum sucrense* (OCH 11926), is concordant with a monogenic tetrasomic model. Immunity to PVX_{cp} (Group 2), also found in *S. sucrense*, is controlled in a monogenic fashion at a separate locus.

The enzyme-linked immunosorbent assay (ELISA) was simplified and test kits were developed for use in developing countries where laboratory resources are scarce. Efforts were also directed toward helping national programs produce large quantities of high-quality virus antisera.

Sensitivity of potato spindle tuber viroid (PSTV) detection was substantially improved by using a silver-based stain in polyacrylamide gels. A new method is being studied for detecting PSTV by means of nucleic acid hybridization combined with enzymatic detection of hybrids.

VIRUS RESISTANCE AT THE CULTIVAR LEVEL

Resistance to potato leafroll virus (PLRV) in clones. Clones with resistance to PLRV were tested for general combining ability (GCA) for resistance to PLRV infection by inoculating progenies from PLRV-resistant parents crossed in a top-cross fashion. The GCA of parents selected for resistance to PLRV in repeated field exposures was 114% higher than parents that had not passed through such a process. This shows the progress in both phenotypic and genotypic terms. Efforts are now concentrating on the selection of potato virus Y (PVY) + PLRV combined resistance. Field exposure trials and testing by enzyme-linked immunosorbent assay (ELISA) have led to the selection of 82 clones that are PLRV-resistant.

In Argentina, CIP collaborates annually with the national potato program of INTA to evaluate PLRV-resistant material. In 1983, INTA received 2242 new clones and selected 302 for further evaluation. Twenty-three previously introduced clones continue to retain PLRV resistance after three years of testing. Uruguay has also proved to be an excellent screening site for PLRV resistance. Even though disease intensity is high in Uruguay, collaborative studies are underway to reduce aphid populations and achieve the infection pressure found in other parts of the world. From 23 families tested, 140 clones were selected and reexposed to PLRV infection.

Trials on yield performance were conducted in Huancayo and Lima (Table IV-1). In both sites, virus-resistant clones were among the top yielders. The clone 78C11.5 (V-3), which is being multiplied in the pathogen-tested program, is characterized by immunity to potato viruses Y, X, and A, a moderate resistance to PLRV, broad adaptation, heavy set of medium-sized tubers, and long dormancy (4 months at 20°C, average ambient temperature). In Turkey, CIP virus-resistant clones selected during the last two seasons considerably outyielded local varieties, which have always given high yields.

Resistance to potato virus X in clones. Advanced clones from CIP's pathogen-tested seed program were evaluated for their reaction to PVX_{cp} (Cockerham's

Table IV-1. Yield performance and virus resistance of clones and cultivars tested at Lima (June-September 1983).

Clone or cultivar	Virus resistance	Yield (t/ha)	Specific gravity
Revolución	Susceptible	27.8 a*	1.070
Rosita	Susceptible	26.7 a	
78C11.5	PVY + PVX immune, PLRV resistant	23.3 ab	1.082
78A15.6	PLRV resistant	22.6 ab	1.076
Serrana	PLRV resistant	21.8 ab	1.071
G5264.1	PLRV resistant, PVY immune	21.2 ab	
B71.240.2	PLRV resistant	17.2 b	
DTO-2	Susceptible	17.1 b	
Pirola	PVY immune, PLRV resistant	17.1 b	1.084
DTO-28	Susceptible	16.9 b	
Desirée	Susceptible	15.8 b	1.069

CV = 26%; $S\bar{x}$ = 1.8.

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

PVX strain Group 2) and to PVY^O. Relative resistance to PVX was found in Loman, Piritani, DTO-33, and BR-63.5, and a high level of hypersensitivity was found in AJU-69.1 (573272). The latter clone is expected to behave as "field immune" in potato-growing areas where PVX_{cp} (Group 2) or similar strains are prevalent.

Resistance to potato virus Y in clones. Relative resistance to PVY was found in cv. Santo Amor (720109) and in clones BR-63.76 (800224), and MS-35.22 (800-926). Immunity to PVY was found in two clones, I-1039 (676008) and LT-4 (377319.7). Immunity in I-1039 probably derives from *Solanum stoloniferum* and in LT-4 from *Solanum tuberosum* spp. *andigena*. Similarly, graft inoculation followed by ELISA confirmed immunity to PVY in 126 clones (Table IV-2).

Table IV-2. Present CIP inventory of 126 selected clones confirmed as immune to potato virus Y by graft testing.

Crossing series	Attributes	Immune clones (no.)
79D	Highland adapted	11
TTY	Late blight resistant	15
79S	Late blight resistant	1
377 series	Good combiners with tuberosum	15
80JA	High yielders	24
379 series	Early	15
81B	Early	31
81C	Early	8

Although sources of resistance to PVY (immunity) and PLRV (resistance to infection) have not yet been thoroughly exposed to natural infection in a wide range of environments, immunity to PVY seems to be stable. Graft inoculations with a wide range of PVY isolates from the Andean region (Chile, Argentina, Peru, and Ecuador) were continued during 1983 under controlled greenhouse conditions. Results indicated that immunity to PVY was not overcome by any of the isolates used (Table IV-3). The clones 78C11.5

Table IV-3. Reaction of selected clones to a wide range of Andean potato virus Y (PVY) isolates and to potato virus A (PVA).

Clone	PVY		PVA	
	No. of isolates	Reaction[a]	No. of isolates	Reaction[a]
Stoloniferum source				
78C 11.5	8	I	2	I
PG 285	21	I	2	I
PG 295	22	I	3	I
BL 61.74.167	16	I	1	I
Andigena source				
14 XY 4	11	I	3	h
XY 2.4	11	I	2	h
	7	H	–[b]	–
XY 12.1	22	I	2	h
XY 13.14	15	I	2	h
XY 13.15	22	I	2	h
XY 14.7	13	I	–	–

[a]h = hypersensitivity, systemic infection detected; H = hypersensitivity, no systemic infection detected; I = immunity.

[b]Dash (–) indicates not tested.

(V-3), PG285, PG295 (800953), and BL-61.74.167, all having the gene for immunity from *S. stoloniferum*, were also immune to PVA. The other clones with immunity from *S. tuberosum* ssp. *andigena*, however, showed hypersensitivity to PVA. Both groups of clones were also immune to PVX_{cp} but not to PVX_{HB}. No resistance-breaking strains of PVX and PVY have been detected after several field exposures at three agroecologically distinct locations in Peru.

A research priority was to study factors affecting seedling screening for resistance to PVY by means of a mass inoculation technique with a spray gun (MITS). Seedlings from open-pollinated (OP) progenies of susceptible cultivars such as Atzimba, Molinera, and BR-69.84 were inoculated and incubated at a temperature range of 16° to 28°C. Inoculum was used at a concentration of 2% (w/v), carborundum at 0.5%, and the period of seedling exposure to spraying at 0.5 sec/seedling. Under these conditions, 99% of the seedlings became infected, thus making a second sap inoculation of symptomless seedlings unnecessary.

The ELISA is now routinely used at CIP to detect PLRV and PVY infections in screening trials for resistance. This technique permits greater accuracy in all steps of selection and consequently allows more rapid testing of a large number of samples.

Wild species as sources of virus resistance. Although known sources of resistance to viruses are used for developing resistant populations at the cultivar level, studies are underway 1) to identify better sources of resistance among wild species and 2) to understand the mechanisms of virus and viroid resistance. A stronger type of resistance to potato leafroll virus than that now available is highly desirable.

Resistance to PLRV in *Solanum acaule*. Clones developed from *S. acaule* accessions OCH 13824 and OCH 13823, resistant to PLRV by aphid inoculation, were retested by graft inoculation with PLRV-infected potato scions. All 12 inoculated plants were negative to ELISA after 45 days; however, symptoms were observed and virus was detected in five *Datura stramonium* plants grafted with scions from these plants. This finding suggested that plants of OCH 13824 and OCH 13823 carried the virus below the level of detection by ELISA. Stem cuttings and tubers from these PLRV-infected plants were planted, and PLRV infection was retested by graft inoculation to *D. stramonium*. Surprisingly, not a single tuber carried the virus, and only two of five stem cuttings now contained PLRV. These results suggested the presence of a new type of resistance to PLRV, which was tentatively called "resistance to virus multiplication." This type of resistance differs from the well known "resistance to infection" in which plants are not easily infected, but once infected, the virus reaches relatively high concentration levels. Experiments are in progress to confirm this new type of resistance.

In other experiments, the same *S. acaule* (OCH 13823), resistant to PLRV, was crossed to hybrids of *S. phureja* x *S. stenotomum*, resulting in triploid progenies. These were doubled by a colchicine treatment to produce hexaploids. The hexaploids were then tested for resistance to PLRV by grafting, and resistant and susceptible phenotypes were crossed to susceptible tetraploid cultivars. The pentaploid progenies derived from the graft-resistant hexaploid parent (T3.1.33) showed virtually no infection after aphid inoculation (Table IV-4); whereas those derived from graft-susceptible hexaploids were completely susceptible. These results

Table IV-4. Infection by potato leafroll virus (PLRV) in pentaploid progenies and tetraploid parents after inoculation with 20 viruliferous aphids per plant.

Cross or clone	Ploidy	No. of progenies or plants[a] Infected	Healthy
CGN-69.1 x T 3.1.33[b]	5x	2	17
DTO-28 x T 3.1.33	5x	1	19
CGN-69.1 x T 2.17[c]	5x	20	0
DTO-28 x T 2.17	5x	19	1
DTO-28 (clone)	4x	10	0
CGN-69.1 (clone)	4x	10	0

[a] Virus detected by ELISA 30 days after inoculation.
[b] Graft-immune hexaploid.
[c] Graft-susceptible hexaploid.

indicated that the resistance in *S. acaule* can be transferred into commercial tetraploid cultivars.

Resistance to PLRV in *Solanum etuberosum*. Materials deriving resistance from *S. etuberosum* x *S. pinnatisectum* (EP) were highly susceptible to PLRV by aphid inoculation, but were resistant to virus multiplication.

In contract research at the Agricultural University, Wageningen, Netherlands, the breeding barriers between *S. etuberosum* and potato cultivars have been successfully broken by using *S. pinnatisectum* and *S. verrucosum* as bridging species—both are highly resistant to late blight. The material obtained can easily be crossed with cultivars, but it has to be determined whether PLRV resistance is still present in this advanced material. In order to broaden the basis of the PLRV program, three accessions of *S. brevidens* and three accessions of *S. etuberosum* were successfully crossed with *S. jamesii*, *S. pinnatisectum*, and to a lesser extent with *S. verrucosum*. In 1983, the F_1 hybrids were doubled to restore fertility.

Resistance to PVX_{HB} in *Solanum sucrense*. Resistance to the virus strain PVX_{HB}, a strain that breaks the previously well-known resistance to PVX, was found in *S. sucrense* accession OCH 11926. When the resistance to PVX_{HB} in OCH 11926 was retested by graft inoculation of the original clones, an immune response was found. Although a few plants developed top necrosis (hypersensitivity), the virus was not recovered. The segregation pattern of two progenies of OCH 11926 x Maria Tropical against PVX_{HB} and PVX_{cp} is concordant with monogenic tetrasomic control. The gene Rx_{HB} controls immunity to PVX_{HB} and the gene Rx_c to PVX_{cp}. Both of the clones that were progeny-tested were duplex at both loci.

Resistance to PSTV in *Solanum acaule*. The same scheme used with PLRV resistance from *S. acaule* was used when PSTV-resistant *S. acaule* (OCH 11603) was crossed to *phureja-stenotomum* hybrids and the triploid progeny was colchicine treated. Before the pollen was checked for doubling, cuttings from each progeny were inoculated with sap from PSTV-infected potato. Thirty days after inoculation, plants were tested for PSTV infection. Out of the many hexaploids identified, two resistors and one susceptible were crossed to tetraploid cultivars.

ANTISERA PRODUCTION AND DETECTION OF VIRUSES

Antisera production. Antisera suitable for virus detection by means of ELISA were produced at CIP for PVY, PVX, and PVS. Diagnosis of PLRV at CIP has been performed with antisera produced through a research contract with the Swiss Federal Research Station at Nyon. An antisera to PLRV is now being produced at CIP headquarters. Recently, the use of the enzyme Driselase in virus extraction was found to increase the release of particles from infected tissue, which assists in virus purification for immunization purposes. Because this enzyme is costly, combinations with other enzymes such as pectinase and cellulase are being investigated.

Other research at Nyon has produced antibodies to PLRV in hen eggs. Such antibodies, together with rabbit antibodies, can now be used in indirect ELISA for detecting PLRV. The indirect techniques of ELISA allowed a preparation of single enzyme-conjugated antibody to be used for detecting nonrelated viruses. Distantly related serotypes of a particular virus can also be better detected, since the second antibody concentration can be increased without inducing additional background reaction due to higher enzyme input.

The number of countries establishing their own seed tuber programs is increasing; consequently, more requests are being received for antisera for virus detection. In 1983, CIP distributed sensitized latex and whole antisera to 18 countries. As distribution increases so does the need for more training in serological techniques for virus identification. During the year, nine scientists were individually trained in these techniques at CIP. Training in latex sensitization in conjugation with enzymes and antisera production was provided this year in Lima and in the regions. This is part of CIP's effort to transfer technology and to allow countries to produce enough antisera for their own use. In 1983, CIP initiated support for antisera production in Colombia and Brazil to supply sufficient antisera for Regions I and II.

Detection of virus. Studies were done on developing ELISA kits that contained the basic chemical or reagents in concentrated form and on using other available materials in any developing country or field station. These studies are important in promoting wider use of a sensitive serological test. For example, rain water can successfully substitute for distilled or deionized water for preparing buffers; similarly, the common phosphate buffered saline (PBS) used in the test can be replaced by 0.85% NaCl if only tap or well water is available.

Reagent stability was also studied under room temperature (20°-25° C) conditions, since it is an important factor during transportation of ELISA kits or for their storage by national programs lacking laboratory facilities. Antibody-precoated plates kept their activity after storage for two months; whereas PLRV gamma globulin or its enzyme conjugate remained active after three months. Substrate buffer remained stable when stored for three months, but substrate tablets kept their activity for only one month at room temperature and six months at 4° C.

Since the plates are one of the most expensive items in ELISA, the dissociation of viruses, antibodies, or both from used plates was investigated. Two alternatives seem possible: 1) enzyme-linked antibodies and virus antigens can be removed, leaving the coating antibodies attached to the plate (partial dissociation); and 2) a drastic treatment is used to remove even the coating antibodies, leaving the plate clean (complete dissociation). Successful partial dissociation was performed by washing plates with 0.2 M glycine pH 1.8 to 2.2. This system worked well with PVX and PLRV and permitted savings also in antisera, since coating antibodies were no longer needed for the next test.

Complete dissociation can be done with a mixture of ethanol:NaOH (pH above 13) and was found effective only with plates used for PVY and PVX. Washed (dissociated) plates can be used again to assay either PVX or PVY.

DETECTION OF POTATO SPINDLE TUBER VIROID

Nucleic acid hybridization. Previous studies have demonstrated higher sensitivity of the nucleic acid hybridization (dot blot test) over other methods for detecting PSTV. The dot blot test so far developed requires the use of a highly radioactive (^{32}p)-labeled PSTVcDNA to detect, by autoradiography, the hybrids formed with PSTV. However, ^{32}p has a short half-life (only 14 days), which limits its use to countries where it is produced or available. The application of this technique at CIP or in developing countries is therefore restricted by the availability of the label.

To obviate this problem, studies were initiated to replace ^{32}p by a more versatile and stable label. This seemed possible if the PSTVcDNA molecule could be modified by incorporating a molecule that can be detected by its specific linkage to an enzyme- or fluorescent dye-labeled affinity molecule. Based on this principle, biotin (vitamin H) was incorporated into the PSTVcDNA. Its presence after hybridization to PSTV was detected by biotin antibodies, or by its specific coupling to avidin (protein) molecules previously conjugated to enzyme horseradish peroxidase (HRP) or alkaline phosphatase (AP).

PSTV immobilized in nitrocellulose membranes or in modified nitrocellulose-coated microtiter plates was assayed through a protocol similar to that used on ELISA. It seems, however, that nonspecific retention of enzymes on the nitrocellulose membranes increased the background reaction and obscured positive results. This was more pronounced with HRP-labeled than with AP-labeled avidin (Fig. IV-1). Results with AP-labeled avidin are encouraging, however, and work is

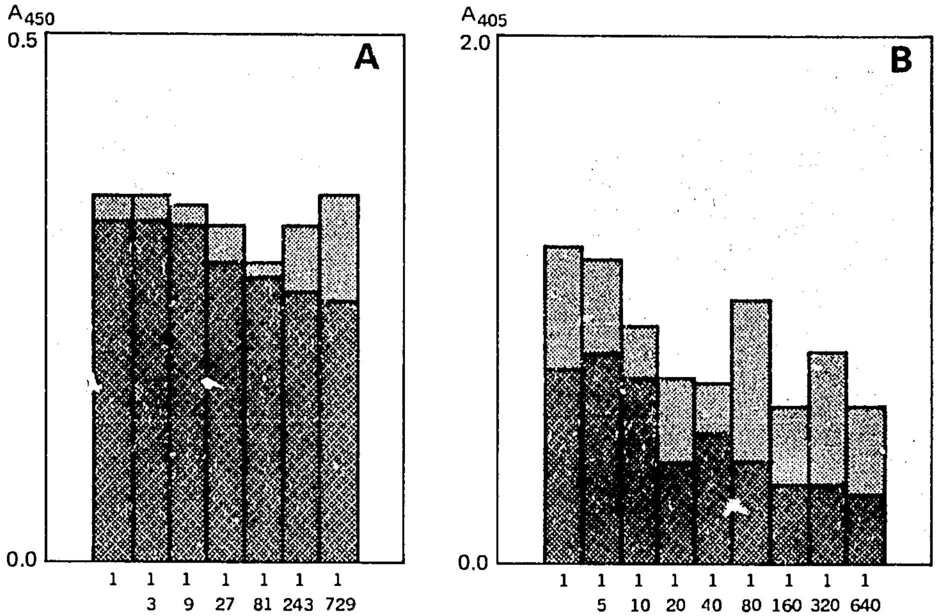


Figure IV-1. Absorbance values of hybridization experiments with PSTV-infected (□) and healthy tomato sap (■) using (A) avidin-horseradish peroxidase, and (B) avidin-alkaline phosphatase conjugates. A biotinylated PSTVcDNA probe at a concentration of about 5 μg/ml was used over potato spindle tuber viroid (PSTV) and healthy samples dried on nitrocellulose membranes.

now directed to find conditions that will reduce background reactions and increase sensitivity. Rapid improvement in purification of plasmid DNA research is essential for application of the dot blot test. Birnboim's procedure using alkaline degradation of bacterial cells allowed purification of large quantities of plasmid DNA (Fig. IV-2).

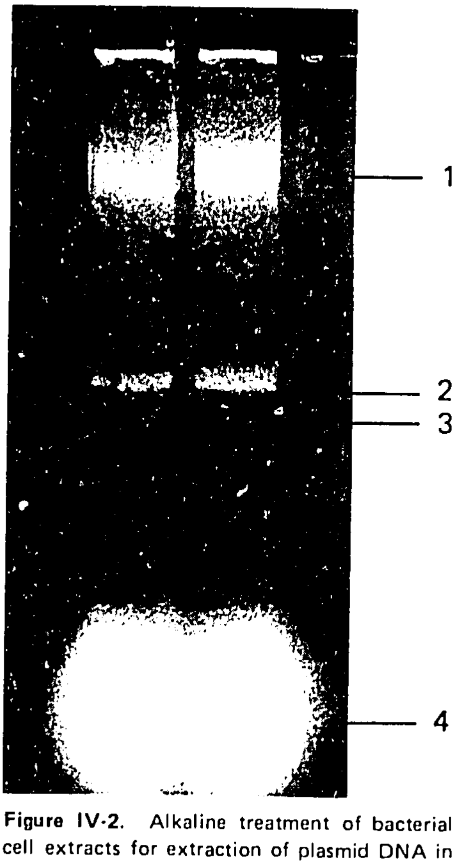


Figure IV-2. Alkaline treatment of bacterial cell extracts for extraction of plasmid DNA in agarose gel electrophoresis after Birnboim and Doly (Nuc. Acid Res. 7:1513, 1979). Plasmid DNA eluted from corresponding gel section is essentially free of contaminant nucleic acids. The numbers refer to: 1 = chromosomal DNA; 2 = plasmid DNA (PV6); 3 = irreversibly denatured form of plasmid DNA; 4 = low molecular weight RNA.

Improvement in sensitivity of electrophoresis. Sensitivity of electrophoresis was improved by staining polyacrylamide gels with a simple procedure based on silver nitrate. Comparisons between toluidine blue O and silver nitrate showed that PSTV can be detected in nucleic acid of low molecular weight extracted from 125-250 mg of tomato leaves with toluidine blue O, whereas silver nitrate allowed detection in only 7 mg of tomato leaves. These figures represent an increase of more than 16-fold in the sensitivity of electrophoresis by using silver nitrate. In addition, silver nitrate staining is simple to perform and usually requires less time than the previous method.

IDENTIFICATION OF OTHER VIRUS DISEASES

Physalis floridana was confirmed as a susceptible host of potato deforming mosaic virus that can be infected only by grafting. Back-inoculations from *P. floridana* to potato cv. Renacimiento and DTO-33 reproduced the disease symptoms originally found in cv. Serrana. In tissue sections from infected Serrana plants, virus particles inside a tubule were observed that were apparently associated with the plasmalemma of some phloem parenchyma cells (Fig. IV-3). Light microscopy suggested that the virus was associated with phloem tissue and was more concentrated in leaf petioles.

In a collaborative project with the national potato program in Brazil, Andean potato mottle virus (APMV) was found in a seed field at Canoinhas, in the state of Santa Catarina. This isolate, APMV-B, is serologically distinct to strains C and H previously reported from the Andean region. In addition, APMV-B is more virulent and seems to be related to a virus reported many years ago that caused mosaic

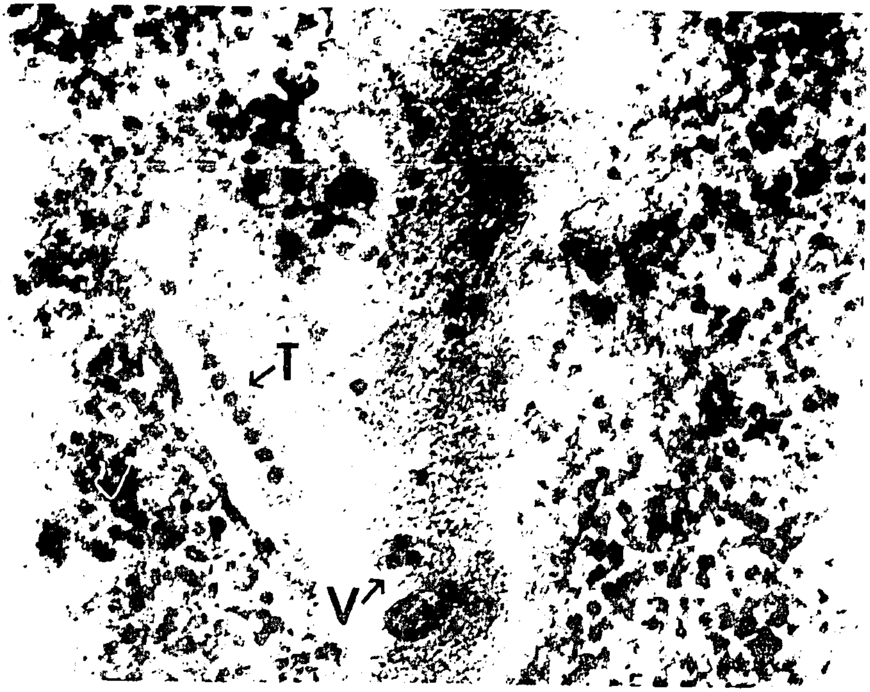


Figure IV-3. Particles of potato deforming mosaic virus (PDMV) in a tubule (T) and apparently loose particles (V) associated to the plasmalemma of a phloem parenchyma cell of potato cv. Serrana.

of eggplant in Brazil. An antiserum was produced and sent to Brazil for inclusion in their testing program.

In the highlands of Peru, symptoms of yellow blotching were observed in several potato fields. In these samples, alfalfa mosaic virus (AMV) was identified for the first time in Peru. Because potato virus M (PVM) is an important virus worldwide, an extensive survey was conducted in Peru using ELISA to assess the presence and degree of PVM dissemination. In more than 1000 samples tested, no PVM was found, which suggested that PVM is not common in Peru.

The national potato program of ICA in Colombia conducted surveys on virus incidence to determine the rate of degeneration of seed stock. This information will help to identify the best areas for seed production in Colombia. Additional seed samples from three other areas have been collected for confirmation tests; potato virus S was detected in several areas of the country.

In Tunisia, collaborative studies with the national program were initiated to correlate aphid epidemiology and virus spread as part of a further development of the Tunisian seed multiplication program. Trapping of aphids was recorded 3x week from January, and plant leaf samples were collected on March 21, April 11, and May 10. ELISA tests on 300 samples detected no PVY and only 1% PLRV, thus explaining the low number of plants removed by roguing. This seed will be planted to check for virus incidence.

THRUST V

Integrated Pest Management

Breeding and screening for resistance to major nematode and insect pests were priority activities during 1983. Biological, cultural, and chemical control components were studied as part of CIP's integrated pest management program.

Of 273 families developed in a breeding program, 38 showed a high frequency of resistance to *Globodera pallida* pathotypes P_4A and P_5A, while 46 showed a high frequency of resistance to P_5A and 34 to pathotype P_4A. Clones with resistance to a single pathotype had higher yields than clones with resistance to two pathotypes. Twenty-six clones selected in Peru were also resistant to local populations of *G. pallida* in Ecuador. Of 13,347 genotypes tested for resistance to *Meloidogyne incognita*, 1089 were selected for high levels of resistance. When soil was covered with transparent polyethylene (solarization), seedbed temperatures were raised 12°C higher than bare soil temperatures. This treatment was as effective as the nematicide phenamiphos in controlling *M. incognita* in potato seedling nurseries.

The fungus *Paecilomyces lilacinus* continued to perform well in controlling the cyst nematodes *Globodera rostochiensis* and *M. incognita*. This fungus has now been recommended to control *G. rostochiensis* in the Philippines.

Seven clones were classed resistant to potato tuber moth, *Phthorimaea operculella*, after field and laboratory screening. After two storage tests, 10 clones were selected from 11 families involving mainly (*Solanum sparsipilum* x *S. phureja*) x *S. sparsipilum*. In studies on the integrated control of *P. operculella*, the most efficient treatments were Fenvalerate+*Lantana* sp., and Dipel+*Lantana* sp. Thirty-five of 896 clones from Cornell University had less than 10% foliar damage by the spider mite *Tetranychus cinnabarinus* and were classed resistant. The larval pupal parasite *Halticoptera patellana* was the most predominant natural enemy of leafminer fly, *Liriomyza huidobrensis*.

Infestation due to green peach aphid, *Myzus persicae*, was significantly less in potato+tomato crop associations when compared with potato alone. Intercropping potatoes with onions significantly increased the number of *M. persicae* predators, predominantly *Chrysopa* sp., when compared with other crop mixtures and with potato alone. In chemical control studies, the insecticides chlorfenvinphos and acephate were the most efficient in controlling the tuber moth *Scrobipalpula absoluta*. Insecticides dicofol and quinomethionate were highly effective in controlling the broad mite *Polyphagotarsonemus latus*.

Screening for resistance. Two tests (pot test and petri dish test) were used for classifying reaction to potato cyst nematode (*Globodera pallida*). The pot test used two criteria: root ball and nematode multiplication rate (Pf/Pi), which were highly correlated ($r = 0.95$) (Fig. V-1A). When the pot test was correlated with the petri dish test, a correlation coefficient (r) of 0.77 was found (Fig. V-1B). The clones (•) represented in both graphs indicate different levels of resistance. These levels do not fit the classical definition of resistance, where the ratio of final population/initial population (Pf/Pi) is equal to or less than 1 ($Pf/Pi < 1$), or the female formation is zero ($\% f = 0$).

Two types of resistance (total and partial) with three levels were proposed. These levels were based on a correlation of female formation and nematode multiplication rate. *Total* resistance resulted from a failure of new female development (cyst $Pf/pi \leq 1$). Two levels of *partial* resistance, where new female development occurred, were distinguished by the egg multiplication rate: egg $Pf/Pi < 1.0$ and 1.0 to 5.

Mass screening using the flat tray technique is now a routine method at CIP for classifying *G. pallida* resistance. In earlier trials, mass screening with this technique was limited because counting the total number of females on the root tray surface was laborious, and errors resulted from the desiccation of infected roots after unnecessarily long exposure. To solve this problem, a new approach was found by using a photograph of 16 predetermined grids of the root tray to count the females. Live root count and photograph count were highly correlated ($r = 0.98$). This correlation was demonstrated when immature females among some segregating families were tested (Table V-1).

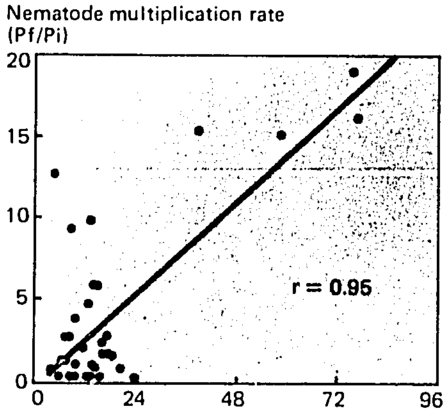


Figure V-1A. Relationships between the number of females (root-ball reading) and the nematode multiplication rate (Pf/Pi) in the pot test technique for evaluating resistance to *G. pallida* (P_4A).

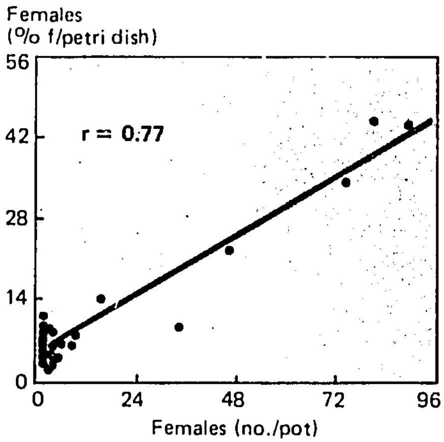


Figure V-1B. Relationships between the pot test and petri dish techniques and for evaluating resistance to *G. pallida* (P_4A) in clones.

Heritability studies on resistance. In studies testing progenies from different types of crosses, the highest frequency of resistance was obtained by intercrossing resistant clones; the lowest frequency was obtained when susceptible clones were crossed with pollen bulk collected from five resistant clones (Table V-2). Different genes incorporated for resistance from

Table V-1. Correlation (r=0.98) between number of females in live root and photographic root-tray counts (n=16 grids) in mass seedling screening.

Family	Number of females/root tray		
	Live root count (total no.)	Photograph count	
		Sample size[a]	Pf/Pi
AG-001	124	93	5.5
AG-002	70	94	4.2
AG-003	736	358	9.6
AG-004	1123	601	21.5
AG-005	950	370	16.9
AG-006	2216	728	24.3
AG-007	3560	1727	40.5

[a]Optimum sample size=16 grids.

diploid *S. vernei* through 4x-2x crosses to six advanced P_4A-resistant tetraploid clones resulted in low heritability, poor yields, and poor tuber shape. Several breeding cycles will be required to bring the resistance, yield, and tuber shape to desired levels.

Use of resistant material. Comparison of clonal reaction in three geographical locations of Peru indicated that all clones found resistant to P_5A in greenhouse tests were also resistant in field tests in the north where P_5A is the predominant pathotype. In contrast, clones found resistant to P_4A in greenhouse tests had only 80% field resistance in central Peru, and 89% in the south where P_4A is the predominant pathotype. Clones with single resistance had higher yields than double-resistant clones when grown in *G. pallida*-infested fields at the three locations.

Thirty-six clones previously tested for *G. pallida* resistance were sent to the national programs of INIAP in Ecuador and ICA in Colombia during 1983 for testing. Twenty-six of the clones sent to Ecuador were found resistant against two local Ecuadorian nematode populations. The clones sent to Colombia were first multiplied in the field and 13 were selected for further field observation as well as for resistance tests to the local nematode populations.

Clones from a previous shipment to Ecuador, already tested for resistance, were grown in infested plots at the INIAP Santa Cata'ina site in Quito, Ecuador. The yields of the best clones in this group are reported in Figure V-2.

ROOT-KNOT NEMATODE

Diploid hybrid progenies from the third and fourth cycles of recurrent selection for resistance to root-knot nematode, *M. incognita*, were tested at North Carolina State University for resistance to four major species and eight different races of *Meloidogyne*. The resistant diploid clones were crossed with four groups of diploids

Table V-2. Percent segregation of resistance to *G. pallida* and several types of crosses in which five double-resistant clones were used as resistant parents.

Type of cross	Genotypes tested (no.)	% segregation (resistant)		
		P_4A	P_5A	P_4A+P_5A
Resistant x resistant	85	37.5	51.7	21
Resistant x susceptible	271	38.0	36.0	15
Susceptible x resistant (bulk)	163	22.0	18.0	4
Resistant x susceptible (Glob)[a]	104	66.0	27.0	18

[a]Susceptible segregant from a *G. pallida* cross.

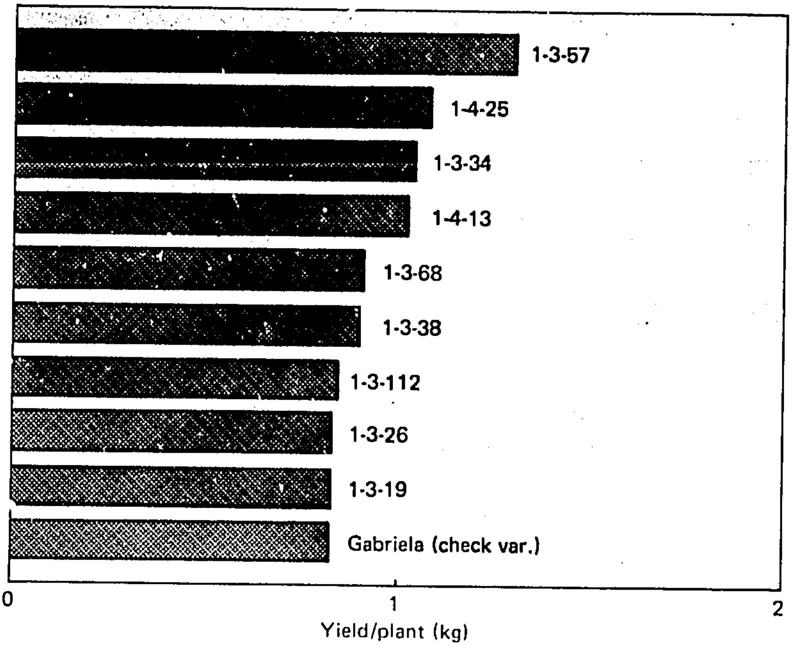


Figure V-2. Yields of the best *G. pallida*-resistant clones and the Ecuadorian var. Gabriela, Quito, Ecuador, 1983.

resistant to *Pseudomonas solanacearum*, *Phytophthora infestans*, potato virus Y (PVY) and potato leafroll virus (PLRV). Combined resistances are essential for potato production in warm environments.

A total of 13,437 genotypes, representing 293 hybrid families developed from these crosses, were tested for resistance to *M. incognita*. A total of 1089 genotypes with high levels of resistance were selected and will be evaluated for other desirable characters such as resistance to other organisms and the production of 2n pollen. Resistant clones producing 2n pollen will be used in 4x-2x crosses for transferring the resistance to 4x progenies.

Control by solarization. A solarization experiment in San Ramon used solar heating of soil to control *M. incognita* and compared it with the nematicide phenamiphos. Solar heating uses heat as a lethal agent for pest control by using traps like plastic soil mulches or tarpaulins for capturing solar energy (Fig. V-3).

Transparent polyethylene was the most effective in heating the soil and raised the temperature to 12°C higher than the temperature of the nontreated control or bare soil. An almost equal reduction in rootknot nematode damage was found on plots covered with transparent plastic and the phenamiphos-treated plots. Damage by nematodes, expressed as percent infected seedlings, was significantly less on these two types of plots (13% and 12%, respectively), when compared with 21% damage on bare soil.

BIOLOGICAL CONTROL OF NEMATODES

***Paecilomyces lilacinus*.** In the Philippines, the use of the fungus *P. lilacinus* to control cyst nematode *G. rostochiensis* on potatoes has been recommended by investigators at the University of the Philippines in Los Baños. The fungus almost completely controlled *M. incognita* in cotton, which is also a susceptible host. In a collaborative study by CIP and IDIAP in Panama, *P. lilacinus* effectively controlled *G. rostochiensis* in infested potato fields. Encouraging results have also been obtained in using *P. lilacinus* to control nematodes on sugar cane in Panama and citrus in Peru.

The efficacy of *P. lilacinus* as a method of controlling *M. incognita* was evaluated on tomato, okra, and eggplant in CIP contract research at North Carolina State University. Preliminary data showed that plots treated with *P. lilacinus* yielded 20% to 30% more okra than untreated plots. Tomato and eggplant yields also increased by 10% to 15%.

Plots treated with *P. lilacinus* during the previous growing season had significantly lower ($P < 0.05$) population densities of *M. incognita* than untreated plots. There were no significant differences in population densities at the beginning of the previous growing season (before treatment), which indicated that *P. lilacinus* was controlling population levels of *M. incognita*.

Newly isolated fungi. Collaborative work between CIP and the national program of IDIAP in Panama isolated a new fungus from potato fields in Cerro Punta. This fungus appeared to be parasitizing the eggs of *G. rostochiensis* and *G. pallida*, particularly when they were in the embryonic stages. Studies will continue on identifying the specific mode of action of this new fungus as well as a similar fungus found in Peru.

Figure V-3. Solarization (solar heating) uses heat as a lethal agent for pest control. Traps made from transparent polyethylene soil mulches (tarps) are used to capture solar energy. These plastic mulches can be applied manually (photo) or mechanically.

POTATO TUBER MOTH

Screening for resistance. More that 680 clones were screened for resistance to potato tuber moth (PTM), *Phthorimaea operculella*, in the laboratory and field under high PTM-population pressure. Seven clones had an average of less than one pupa per tuber when inoculated with PTM larvae in the laboratory. These clones are now being multiplied to confirm resistance.

The low selection rate in seedlings derived from tuberosum crosses prompted intercrossing of tetraploids generated from *Solanum sparsipilum* and *Solanum andigena* as sources of resistance. Of 8000 seedlings representing 130 families from this population, 764 seedlings were selected for further resistance tests. As part of the continuing search for PTM resistance, 90 diploid genotypes from 11 families mainly involving (*S. sparsipilum* x *S. phureja*) x *S. sparsipilum* were retested under storage conditions in San Ramon. Ten clones were selected. Tubers from 2500 genotypes involving 32 crosses with *S. sparsipilum*, *S. commersonii*, *S. sucrense*, and *S. tarijense* were also tested under storage conditions. Of these, 135 clones were selected and are now being multiplied for laboratory tests.

Two parasitic biocontrol agents collected from the Mantaro Valley (3200 m) in Peru are being investigated for their efficiency to infect their hosts. One is the ectoparasite *Dibrachys cavus*, which infects *Symmetrischema plaesiosema* (tuber moth species); and the other is the polyembryonic parasite *Copidosoma roehleri*, which infects *P. operculella*.

Laboratory methods to impregnate rubber stoppers with PTM sex pheromone (PTM1 + PTM2) have been developed. During 1983, more than 2000 pheromone-impregnated stoppers were distributed by CIP to 13 national potato programs. Studies in San Ramon showed that pheromone formulations of PTM1 (0.7 mg)+ PTM2 (0.3 mg) or PTM1 (0.4 mg) + PTM2 (0.6 mg) were the most effective in capturing male PTM.

For controlling PTM in stored tubers, the foliage of *Lantana* sp. was the most effective (Fig. V-4). Fenvalerate 0.2%

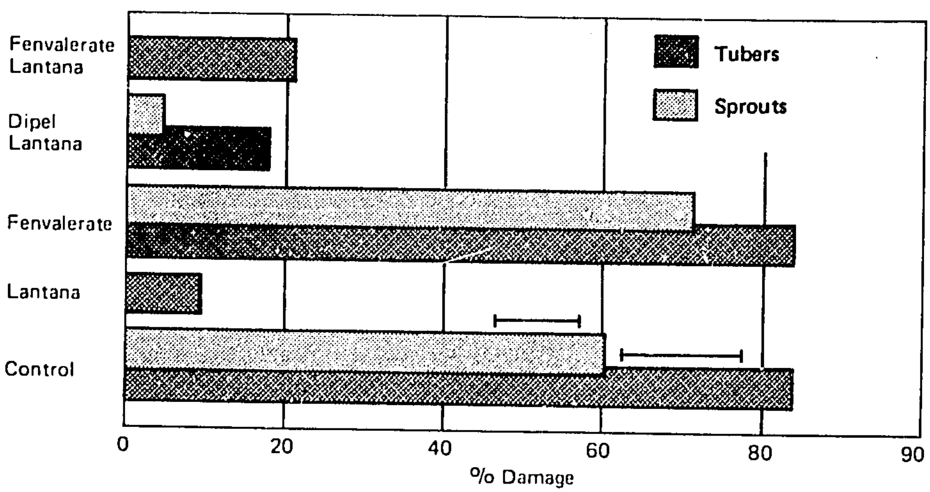


Figure V-4. Effects of different treatments in controlling potato tuber moth in storage on cv. Desirée. The tubers (cv. Desirée) used in this trial were produced in San Ramon, 1983.

spray alone was not effective as tuber damage exceeded 80%.

In Tunisia, two synthetic pyrethroid-based insecticides with low mammalian toxicity proved to be as effective as Parathion, which is commonly used by Tunisian farmers to control PTM in stores. A liquid application at harvest gave as good a control as spraying at the start of the storage period. Mesh screening was also used to prevent PTM entry into seed tuber stores. Only 5% tuber damage after 100 days of storage was reported. Potatoes harvested in late May or early June had lower PTM egg infestation than later harvests.

LEAFMINER FLY

Potato cultivars Revolución, Cuzco, and Tomasa Condemayta were field-tested to classify their reaction to leafminer fly, *Liriomyza huidobrensis*. All three cultivars were classed susceptible based on yield loss data. Revolución had the lowest yield loss of 27%.

A survey of leafminer-fly parasites was conducted on the coast of Peru in collaboration with the National Agrarian University, La Molina. The most predominant species was *Halticoptera patellana* (Pteromalidae). Other species included *Chrysocharis phytomyzae*, *Diglyphus* sp., *Chrysocharis* sp. (Eulophidae), *Ganaspidium* sp. (Cynipidae), and *Opius* sp. (Braconidae). *Diglyphus* sp. is an ectoparasite of leafminer larvae; all the other species are larval-pupal parasites of leafminer fly.

Of the several different-colored sticky traps tested for leafminer fly, the total fly capture was greatest (2740 flies/wk) by using a light-green trap. The yellow and green traps had total fly captures of 1379 and 1264, respectively (Table V-3).

Higher female to male ratios, corresponding to 1:1.4 and 1:2.8 respectively, were obtained on green and light-green traps compared with 1:10.6 for the yellow trap. The higher sex ratio signified that a higher proportion of female flies were being captured only the females flies cause damage to plants.

Table V-3. Evaluation of different-colored sticky traps at 60-cm height to capture leafminer fly, Lima, Peru, 1983.

Trap color	Total capture ($\bar{x}$/week)	Sex ratio (female:male)
Yellow (Pantone 11?C)	1379	1:10.6
Green (Pantone 358C)	1264	1:1.4
Light green (Pantone 375U)	2740	1:2.8
LSD (5%)	490	

POTENTIALLY DESTRUCTIVE POTATO PESTS

Sex pheromones of cutworms and armyworms from the Wolfson Unit of Chemical Entomology, University of Southampton, U.K., were field-tested in San Ramon using different traps. These sex pheromone have been newly synthesized and are being tested for the first time by CIP.

CHEMICAL CONTROL OF OTHER PESTS

The tuber moth *Scrobipalpula absoluta* is the most destructive foliar pest in CIP greenhouses at Lima and Huancayo. In chemical control studies, plants sprayed with the insecticides chlorfenvinphos and acephate had significantly less eggs and larvae of *S. absoluta* when compared with the nonsprayed control plants.

Potato plants infested with the broad mite *Polyphagotarsonemus latus* were treated with two chemicals dicofol and quinomethionate. The egg counts on plants treated with both chemicals were 0.70 and 1.13 eggs per cm^2, respectively, as compared with the control which had 2.4 eggs per cm^2.

CROP ASSOCIATION

A study was conducted in San Ramon to compare green peach aphid (*M. persicae*) infestation on plots of potato alone and on potato plots associated with other crops. The potato + tomato association had significantly less aphids (33 aphids/leaf) than potato alone. The potato + onion (89 aphids/leaf) and potato + corn associations also had less aphids (53 and 50 aphids/leaf respectively) than potato alone, but the differences were not significant.

GLANDULAR TRICHOMES

True potato seedlings of 896 clones derived from crosses between *Solanum berthaultii* and *Solanum tuberosum* obtained from Cornell University were screened at CIP for resistance to the red spider mite (*Tetranychus cinnabarinus*). Thirty-five clones having less than 10% foliar damage were selected.

In contract research at Cornell University, a quick-screening method was developed to predict aphid resistance of seedlings. This was based on the capacity of the exudate from the 4-lobed trichomes to harden around the mouthparts of the aphid. Three leaflets of each seedling were agitated in a 3-ml solution of P-phenylenediamine, phosphate buffer, and detergent. The degree of darkening of this solution, which may be estimated visually or measured colorimetrically, correlated with the hardening capacity of the trichome exudate. The degree of hardening has shown good correlation with actual aphid resistance in the field.

A population of insect-resistant plants is being improved at Cornell to incorporate PVY and PVX resistances, good tuber yield, and appearance into material with good levels of insect resistance through the mechanism of glandular trichomes. The 273 selections, made on the basis of tuber yield and appearance, were all grown in the field in the summer of 1983 to be evaluated for resistance to aphids and Colorado potato beetle. The 15,260 seedlings that formed the next generation are presently being grown in the greenhouse. The 15 clones selected during the winter were the first clones that combined the trichome density and quality of the diploid species with reasonable tuber production. This opens the door for yield trials in pest management studies.

THRUST VI

Warm Climate Potato Production

The knowledge on agronomic practices for potato cultivation in warm climates has been refined, taking into account the interaction of the practices with the environment. Intermediate planting depths (7 cm) resulted in greater yields at San Ramon (mid-elevation tropics). Yields per unit area and per plant were favored by hilling, particularly at shallow (2 cm) and intermediate (7 cm) planting depths. Mulch was necessary during the entire growing season to maximize yields. At Yurimaguas (Amazon basin), deep planting (15 cm) resulted in greater yields over shallow planting; however, hilling reduced the yield per unit area at deep plantings due to loss of plants from bacterial wilt. Effects of mulch were inconsistent and were probably related to the excessive conservation of soil heat during the night.

Planting on the coolest position in the ridge, i.e., facing away from the sun, led to quicker emergence and greater tuber yield. A growing maize crop, interplanted with potato clones, provided shade of differing intensity and duration, depending upon maize population and date of cutting. Shade intensity and duration were effective in hastening emergence, but shade duration had a greater overall effect than shade intensity. There was, however, a trend toward higher tuber yields at the closest plant spacings.

Estimates of intercepted radiation enabled energy balances to be calculated during crop growth. At Yurimaguas and Lima (summer), the conversion of radiation to total dry matter was approximately 40% less efficient than that reported for temperate climates. Studies on improvements of both genetic and agronomic components of this low efficiency are in progress. Research on mycorrhizae has improved potato yields in a pot experiment with *Glomus fasciculatus*, and preliminary results from field tests will be available in early 1984.

CROP MANAGEMENT IN THE WARM TROPICS

Due to restructuring of Thrust VI in mid-1983, only the results on agronomic and physiological manipulations to improve potato production in warm climates are reported. Research objectives are being redefined and new projects are being created to improve the multidisciplinary approach to data presentation. Nevertheless, progress has been made in developing practical agronomic measures, particularly with respect to modifying microenvironments.

Mulching. In San Ramon, mulching maintained its effectiveness on increasing yields; but with similar treatments in Yurimaguas, improved yields were inconsistent. This was probably due to heat retention in soil during the hot nights (>25°C) at Yurimaguas. Other field trials at San Ramon tested the possibility that mulch, by reducing soil temperature, might improve the effectiveness of soil-applied fungicides such as pentachloronitrobenzene (PCNB) against *Rhizoctonia solani*, as was shown in pot experiments. Although mulch reduced mean soil temperatures from 32.1° to 26.6°C, resulting in improved tuber yield (19.31 vs. 10.34 t/ha), no benefit was noted from the application of PCNB, either in mulched or nonmulched plots.

The interactions between mulch and depth of planting and hilling were studied at Yurimaguas. There was no interaction between planting depth and mulch for plant emergence; however, emergence was faster at 2-cm planting depth. Drought conditions in mid-season at Yurimaguas led to greater benefits of mulch at a 2-cm planting depth than at 15 cm in terms of tuber yield. The benefits of hilling on tuber yield per plant were also more appreciable at 2 and 7 cm rather than 15-cm planting depths. Hilling, however, reduced tuber yield per unit area through reduction of plant population due to bacterial wilt (BW). On a per plant basis, hilling increased yield when combined with mulch.

An identical experiment in San Ramon during the dry season gave different results with respect to emergence. Mulch had a marked beneficial effect, the effect being more notable at the shallower plantings (Table VI-1). Also, in contrast to Yurimaguas, emergence without mulch was faster at the deeper plantings (7 and 15 cm). It is possible that the higher daytime soil temperature at San Ramon delayed emergence at the shallower depths (33.2° vs. 31.4°C for San Ramon - Yurimaguas, respectively). Mulch improved yield (12.45 vs. 9.12 t/ha) as did hilling, which was free of pathological problems. The effect of the latter on yield was less marked at the deepest planting depth (Table VI-2). In contrast to Yurimaguas, the 7-cm

Table VI-1. The number of days to reach 50% emergence as influenced by depth of planting and mulch, San Ramon, dry season.

Depth of planting (cm)	With mulch	Without mulch
2	12.5	18.0
7	13.5	16.0
15	14.2	14.5

Table VI-2. Effect of planting depth and hilling on tuber yield (t/ha) at San Ramon, dry season.

Planting depth (cm)	With hilling	Without hilling
2	11.28	8.86
7	12.97	10.53
15	10.65	10.42
Mean	11.63	9.94

SE difference between any two means in body of table = 3.25.

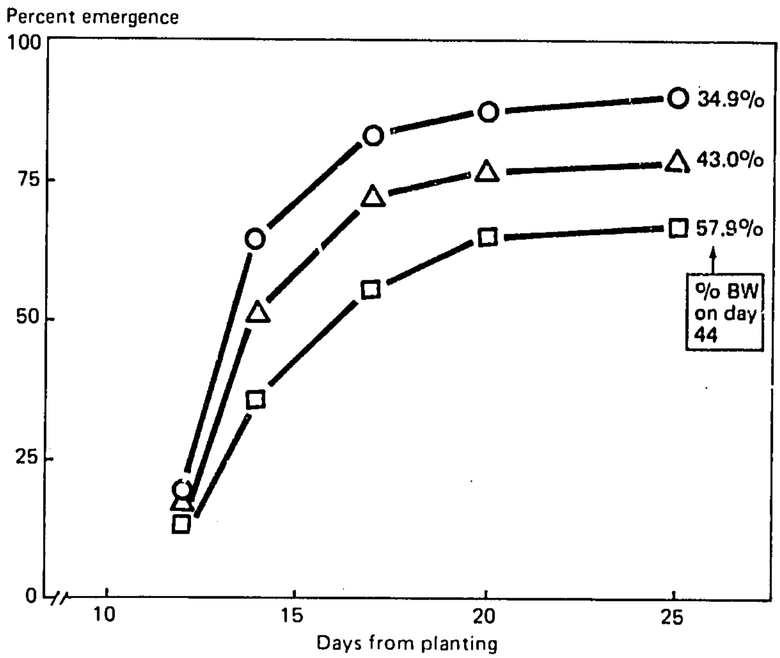


Figure VI-1. Emergence and bacterial wilt (BW) infection as influenced by seed tuber placement (○ = beds; △ = ridges; □ = on the flat), Yurimaguas, Peru.

planting depth gave highest yields, both on a per plant and per unit area basis.

Form of planting. Experiments comparing form of planting (flat, ridged, or in beds) and three periods of mulching (complete season, prior to hilling, or post-hilling) were carried out in Yurimaguas and San Ramon. In Yurimaguas, planting in beds resulted in faster emergence than in ridges or on the flat (Fig. VI-1). Bacterial wilt incidence was also proportionately less in beds.

In San Ramon, plants on the flat, in the absence of mulch, emerged earliest. The number of tuber-bearing plants per plot was least for bed plantings and in plots with mulch applied after hilling (Table VI-3). The same trend was evident for

Table VI-3. The number of tuber-bearing plants and tuber yield as affected by form of planting and duration of mulching, San Ramon, dry season.

Planting type	Plants with tubers (%)	Tuber yield (t/ha)	Duration of mulching	Plants with tubers (%)	Tuber yield (t/ha)
Ridges	94.7	14.28	Complete season	9 5.0	15.89
Beds	91.9	10.55	Prior to hilling	95.8	13.34
On the flat	93.6	15.70	Post-hilling	8 9.4	11.31
SE difference between any two means	1.5	0.95		0.7	4.10

final tuber yield per unit area. Mulch in San Ramon was necessary throughout the entire dry season to achieve maximum yields.

In temperate climates, potatoes and other crops for early production are planted on slopes facing the sun (e.g., on a north-facing slope in the southern hemisphere). For production in warm climates, however, potatoes should be planted on the cool-facing side of slopes to minimize soil heating. Similarly, row orientation and tuber placement in ridges can modify soil temperature, and subsequent plant emergence (Fig. VI-2) and plant yield.

Evaluation of mulching for potato production. In Rwanda, farmers regularly plant potatoes late in the rainy season to avoid the peak late-blight epidemic, even though yields are limited by low soil moisture. Collaborative CIP and national potato program (PNAP) experiments on reducing this loss were conducted on applying mulch treatments at the end of the 1983 growing season in Rwanda. The season (March-June) was relatively dry, late blight incidence was less, and as a result, the effect of mulch was highly effective in improving yield. Trials planted in May and June showed yield increases up to 50% when mulch was used. This seasonal use of mulching is now being tested in farmers' fields.

In the Philippines, agronomic research to improve potato production in warm climates has continued in a joint project between CIP and the Cagayan Integrated Agriculture Development Program in Luzon Province. Later planting (late November and early December) improved yields, but the effect of mulch on yields was not statistically significant. The main effect of mulch, apart from lowering soil temperatures, was the conservation of soil moisture toward the end of the growing season when dry periods occurred. At Laguna, Luzon, a mulch of rice husks applied to the cv. Cosima resulted in a crop of 14 t/ha in 60 days, compared to 6.3 t/ha in 60 days without mulch.

Similar mulch studies in Vietnam, near Hanoi in the north, where 80,000 ha of potatoes are grown, and further south near Ho Chi Minh City, gave promising results. Mulch improved yield whether or not supplementary irrigation was applied. As a result, mulch was recommended for commercial potato production in these areas.

Intercropping. At San Ramon, Peru, a growing maize crop interplanted with four potato clones provided over-the-ground cover of differing shade intensities and durations, depending on the maize population and date of cutting. Although the date that the maize was cut had a marked effect on maize yield, cutting dates had little effect on tuber yield. On the other hand, plant emergence was equally improved under all maize populations compared to the nonshaded control; there was a tendency for higher tuber yields at the closest plant spacings. In contrast to earlier experiments, there were no notable interactions between duration and intensity of shade; all four clones behaved similarly.

As an extension of shading experiments, and with the possible benefits of reduced insect damage, further mixed cropping experiments were undertaken in Yurimaguas and San Ramon. With respect to the land equivalent ratio (LER = the ratio of the mixture yield to the yield of separate components in monoculture), only one mixture at Yurimaguas – maize at 1 x 1.4 m spacing and DTO-33 – gave a significant increase (LER 1.63) over monocultured potato, although most crop mixtures (potato + rice, potato + soya, potato + maize) reduced insect damage to the potato. At San Ramon, all

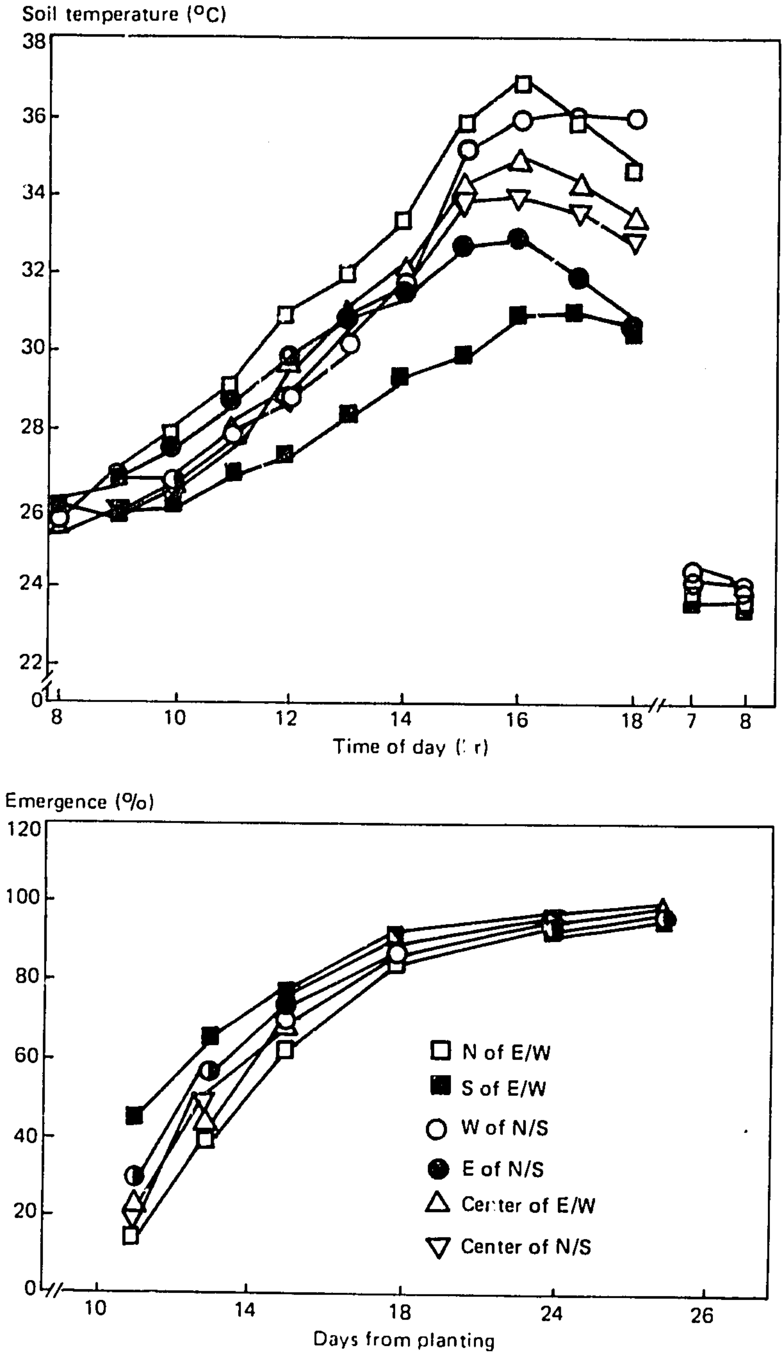


Figure VI-2. Effect of row orientation and planting position on soil temperature (7-cm depth) and plant emergence, Yurimaguas, 1983.

mixtures gave greater but not significant increases in productivity over the monocrops (LER ranging from 1.3 to 1.7). Further experiments on spatial distribution of component crops within the mixtures are in progress to improve the LER.

PLANT CHARACTERS FOR POTATO ADAPTATION TO WARM CLIMATES

The benefit of a quick foliage cover over the soil has been implicated from earlier Thrust VI physiological studies. An important consequence for the plant, however, is how it uses intercepted light energy. Measures of leaf area index (LAI) do not permit adequate comparisons between sites relative to the interception of light energy. For example, an LAI of 3 in Yurimaguas intercepts only 50% of incident radiation, compared to 75% by the same LAI in Lima (Fig. VI-3). More and smaller leaves, coupled with longer internodes—typical responses to high temperature stress at Yurimaguas—are responsible for this effect.

Estimates of intercepted radiation, using tuber solarimeters or quantitative visual estimates of crop cover (Fig. VI-4), made it possible for solar energy balances to be calculated during crop growth. These calculations indicated that radiation, not intercepted by the foliage, heated the soil.

Intercepted radiation was converted to dry matter following photosynthetic gains and respiratory losses (Fig. VI-5). The slope of Figure 5 gives an estimate of the efficiency of conversion of intercepted

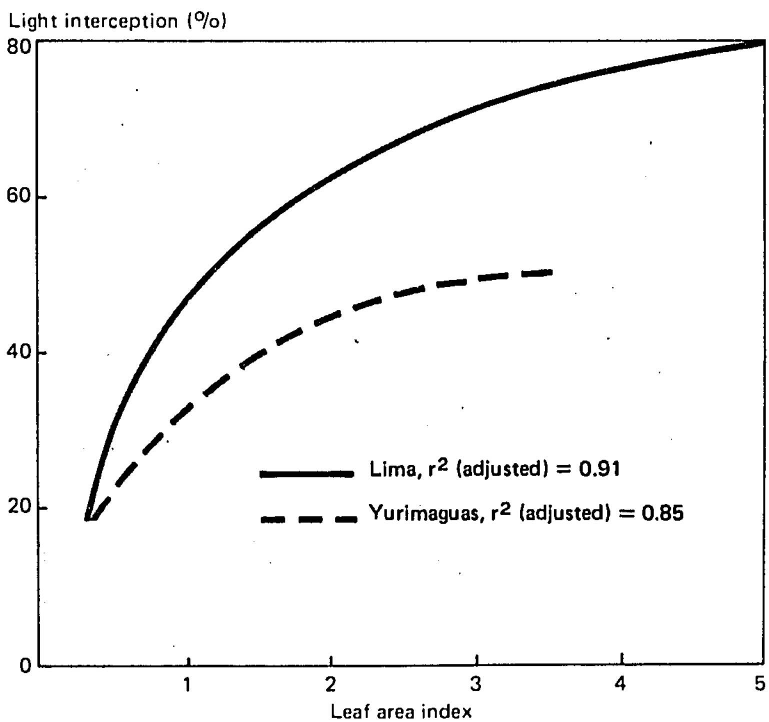


Figure VI-3. Relationship between leaf area index and percent light interception at two sites (cv. Desirée).

Figure VI-4. Quantitative visual estimation of foliage cover is taken by using a handmade grid.

radiation to dry matter in tubers or the whole plant. Comparisons of data from Yurimaguas and Lima (about 1.0 g/MJ) are up to 40% less efficient than those reported for temperate climates.

Radiation levels in the tropics are above light saturation for photosynthesis during longer periods of the day than in temperate environments, which leads to inefficient use of light energy by the plant. Similarly, respiratory losses in the plant system may be greater due to higher temperatures found in the warm tropics; hence, genetic selection for a more efficient net photosynthetic production may be appropriate. This efficiency approach is being used to quantify responses to environmental stresses, both in the search for tolerant genotypes and in the assessment of agronomic practices.

Preliminary results have indicated that mulch improved the efficiency of conversion of intercepted radiation to dry matter from 0.98 to 1.24 g/MJ - a result of lowering soil temperature and maintaining soil moisture. Studies are also underway to provide criteria for selecting clones with improved water use efficiency. Included are simple rapid measurements of relative leaf-water content and leaf-diffusive resistance at the seedling stage.

Studies continue on vesicular arbuscular mycorrhizae (VAM); *Glomus fasciculatus* showed 40% to 45% root infection and improved yields in pot experiments. In vitro studies suggested that the optimum pH for germination of *G. fasciculatus* was between pH 5 to 6.5, an ideal pH for the low phosphorous, acid soils included in this work. VAM inoculation of true potato seedlings is planned for the future.

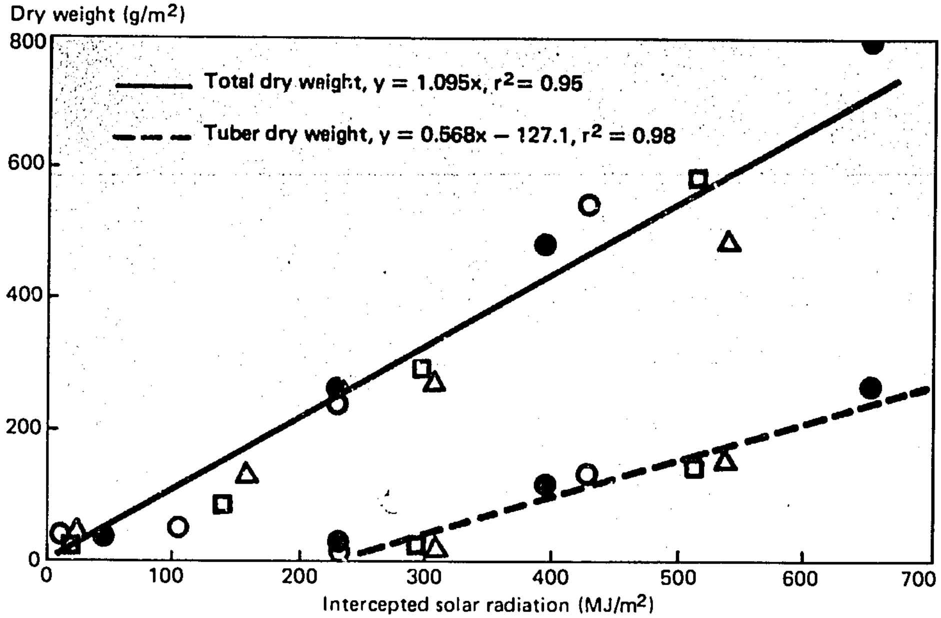


Figure VI-5. Total and tuber dry weights as functions of accumulated solar radiation interception, Lima (cv. Desirée). Row spacings: ● = 40 cm; △ = 50 cm; □ = 70 cm; ○ = 80 cm.

EXTENSION OF POTATO PRODUCTION IN WARM CLIMATES

The information gathered from four years of research at San Ramon and Yurimaguas formed the basis for the first international course on tropical agronomy held in Lima. The course was organized because of growing demand for information on how to extend potato production into warmer parts of the tropics. Seven of the eight participants came from Asian countries where research on tropical agronomy is already in progress.

A senior CIP scientist worked in Indonesia from August to November to assist the national potato program of the Agency for Agricultural Research and Development (AARD) in initiating a project on improving production. A two-day workshop was held in Lembang (W. Java) in August to inform researchers of recent findings and to identify cooperating scientists who would later receive on-the-job training. A workshop was also organized in the Philippines by the National Research Institute to stimulate research on developing agronomic techniques for local conditions.

In experiments conducted by national scientists at a mid-elevation site (800 m) in Cimangkok, Indonesia, Red Pontiac gave the best yields followed by Sequoia, Up-to-Date, BR-63.76, and N-565.1. Yields were promising, ranging from 10 to 19.9 t/ha. Other areas where CIP germplasm has recently been tested include the Pacific Islands of Guam, New Caledonia, and Vanuatu. From the above-mentioned and other results obtained throughout Southeast Asia, Red Pontiac and DTO-2 appear widely adapted, followed by Up-to-Date. In other trials in the Southeast Asian region, LT-2 has shown good adaptability to heat stress conditions.

In collaborative research with the Bangladesh Agricultural Research Institute (BARI), advanced trials using 22 heat-tolerant clones are in the final stages of selection. The basic seed of four introductions is being multiplied for multi-locational trials prior to being released as varieties. In Sri Lanka, scientists of the Department of Agriculture are including evaluation for heat tolerance in the later stages of clonal selection, mainly among selections with combined late blight and bacterial wilt resistance.

THRUST VII

Cool Climate Potato Production

Thrust VII was created during 1983 to develop appropriate technology for improving potato production in the cool climates of developing countries. Research is focusing on developing genetic material with tolerance to late blight and frost and with adaptability to tropical and subtropical cool climates. Another area of research will be to develop cultural practices that involve sources and levels of plant nutrient requirements and the control of pathogens affecting potato production.

Two potato populations, which combine earliness and frost resistance, are being developed for two target areas--the Andean highland tropics and the non-Andean highland tropics and subtropics. Rapid progress to combine earliness and frost resistance with high yield potential is being made. In addition, tolerance to hail and drought has been observed in these two populations.

A single leaf-node technique used to screen for long photoperiods has also proved useful for selecting clones adapted to subtropical daylengths. This technique will be used in the development of populations for the cool climates of the non-Andean tropical and subtropical highlands.

BREEDING FOR FROST TOLERANCE AND WIDE ADAPTABILITY

Two distinct geographical zones have been identified where frost is hazardous to potato crops in tropical and subtropical countries of the developing world: Zone 1 covers the high altitudes in the tropics, and Zone 2 the cool climates in the subtropics. In Zone 1, frost can occur anytime during the growing season, causing severe losses. In Zone 2, frost is usually limited to the early or late part of the season, particularly when the potato is growing under intermediate daylengths (15 h). The overall breeding strategy in this Thrust takes into account the resistance to frost, the effect of daylength on the crop, and the cropping patterns of the two zones. These patterns have enabled us to focus on and define two target areas for the development of better-adapted germplasm.

One target area is the Andean tropical highlands, where andigena germplasm has greatly influenced crop standards and crop maturity, which is usually late (180-210 days) in these regions. The varying skin and flesh colors of the native andigena germplasm are generally acceptable to farmers and consumers, who also show little concern for tuber shape and appearance.

The non-Andean highlands, the second target area, includes both the tropics and subtropics – regions where crop standards have been strongly influenced by improved tuberosum cultivars. In this area, early maturity is in demand (90-120 days), and tuber appearance such as skin and flesh color, depth of eyes, and tuber shape must conform to the features of a tuberosum cultivar. Consequently, two separate frost-resistant populations are being developed at CIP's research sites in Peru to meet the requirements of both target areas.

Frost-resistant clones improved for earliness (130 days) were tested in a replicated trial under natural frost conditions at a highland location in Usibamba, Peru (3800 m). The results at Usibamba indicated that rapid progress had been made in combining frost resistance, earliness, and high yield. This material performed well in spite of a hail storm and a three-week drought during the growing season (Table VII-1).

Another sample of clones with resistance to frost or late blight or both was evaluated at a lower elevation (Huancayo, 3200 m) without frost incidence. The results indicated the high yield potential of these clones even though there were severe hail storms at 61 and 90 days after planting (Table VII-2).

Genetic experiments to evaluate the parental value of a sample of clones through their progenies were carried out using the first clonal generation. The results helped us to select advanced clones with good general combining ability.

ADAPTATION TO INTERMEDIATE SUBTROPICAL DAYLENGTH

A single leaf-node cutting (Fig. VII-1) to screen for photoperiod was evaluated as a tool to help develop a population adaptable to intermediate daylengths. Results in 1983, obtained from two locations in Chile, established the comparison between clones that tuberized under intermediate daylengths and clones that failed to tuberize under the same conditions.

The field trials were conducted in collaboration with the national potato program of INIA in Chile to compare clones screened for tuberization under intermediate daylengths. This comparison included the measurement of five characters that may respond to changing daylengths (Table VII-3).

Table VII-1. Yield performance of the ten best clones tested under field frost, Usibamba, Peru (3800 m).

CIP no.	Pedigree	Yield/plant (kg)	Yield[a] (t/ha)	Frost[b] (−3°C)
379123.3	375585.11 x [(ajh x stn) x (adg x cur)]	1.5	50.9	1
375608.6	66-563-13 x 702267	1.3	43.4	2
375608.26	66-563-13 x 702267	1.1	36.9	1
377924.1	HJT-5711 x 702678	1.1	36.2	1
379114.6	375057.32 x [(acl x phu) x adg]	1.1	35.2	2
377744.3	M1266.14 (760015 x 701221)	1.0	34.0	3
365070.53	374023.12 x 373055.3	1.0	33.6	1
379111.10	Capiro x [(acl x phu) x adg]	1.0	33.2	2
379497.1A	(Caronora x cur) x Mu.III 80	1.0	32.9	3
377427.1	I-832 (tub) x 702449	1.0	32.9	1
Yungay	Control	0.9	29.7	3
Renacimiento	Control	0.7	24.0	2
CV (%)		26.4		
SD = 201.9				

[a] Estimated plant density (33,000 plants/ha).
[b] Frost scores from 1 to 9 (1 = 0-10%, 2 = 11-20%, 3 = 21-30% damage).

Table VII-2. Yield performance of some selected clones with resistance to frost and late blight evaluated under highland conditions in Huancayo, Peru (3200 m).

CIP no.	Pedigree	Wt/plant (kg)	Market-able wt (kg)	Avg tuber wt (gr)	Estimated t/ha[a]
376180.3	3730.76.10 x 702047	2.1	1.9	96	70.6 a*
374080.1	I-1058 x 700764	2.1	1.9	98	68.9 ab
378143.5	700947 x I-1058	1.8	1.6	82	61.0 ab
377427.1	India 832 (tub) x 702449	1.8	1.6	104	59.4 abc
377924.1	WRF 1919.2 x (HJT-5711 x 702678)	1.7	1.6	104	57.1 bc
375608.6	66-563-13 x 702267	1.7	1.5	98	56.8 bcd
377744.1	M 1266.14 x (760015 x 701221)	1.6	1.4	72	52.5 cd
377744.3	M 1266.14 x (760015 x 701221)	1.6	1.4	80	51.8 cd
376180.5	373076.10 x 702047	1.6	1.4	102	51.5 cd
379440.2	374080.5 x Neo tub. bk.	1.5	1.3	80	49.5 cd
Revolución	Control	1.5	1.4	94	49.2 cd
377369.7	I-832 x 700947	1.5	1.3	96	48.8 cd
377744.2	M 1266.14 x (760015 x 701221)	1.4	1.2	64	47.9 cd
374080.5	I-1058 x 700764	1.4	1.2	90	45.5 d
Renacimiento	Control	0.96	0.72	46	31.7 e
CV (%)		20.9	22.6	15.3	

[a] Estimated plant density (33,000 plants/ha).
*Means followed by the same letter are not significantly different at 5% level.

A randomized complete analysis on the variance of the characters measured indicated that the treatment means were highly significant. The LSD comparisons between Group 1 and Group 2 for average clonal performance of the five characters

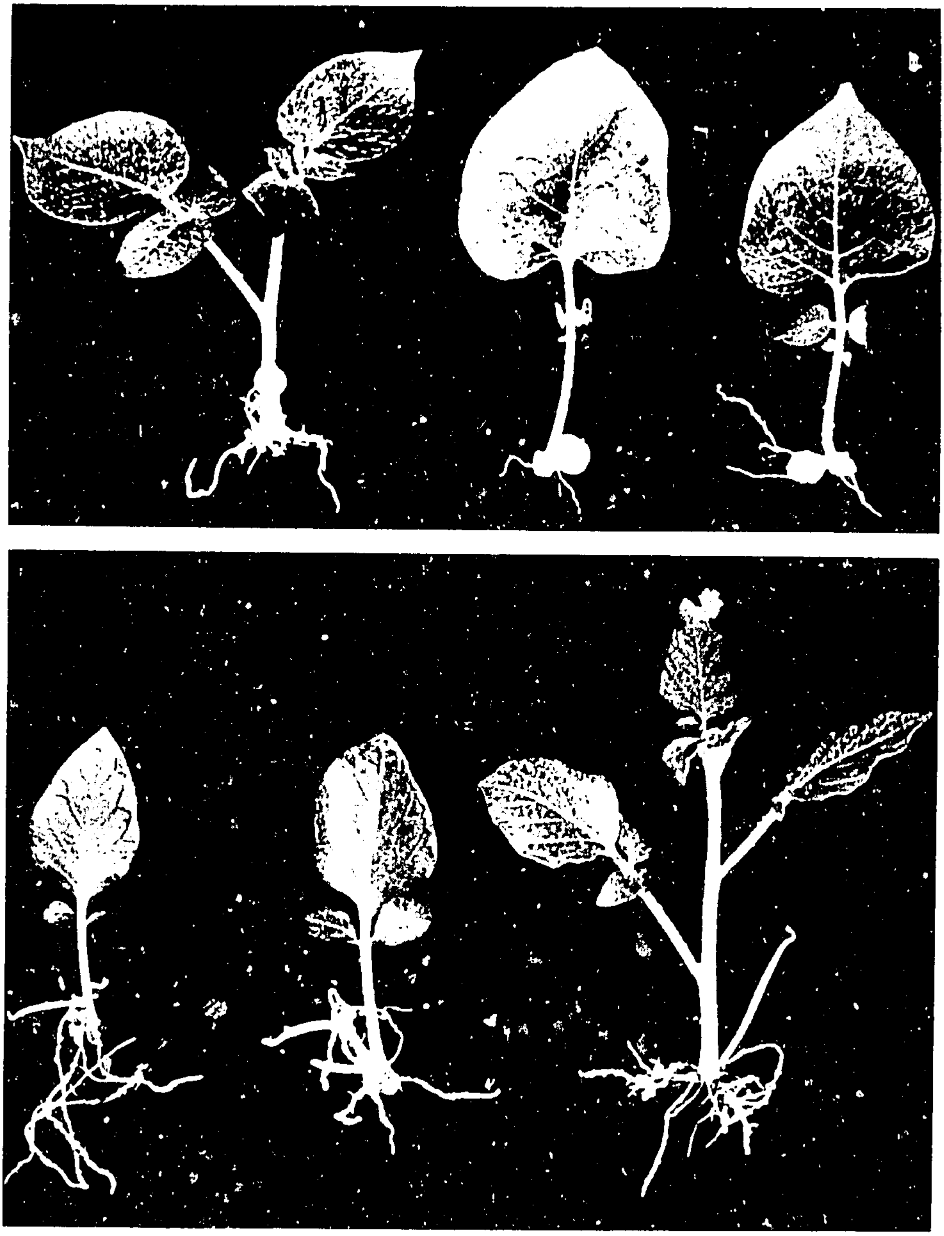


Figure VII-1. Single leaf-node cuttings showing contrasting response of different genotypes to photoperiod. *Top*: tuberization response of long-day genotype to 15-hour daylength. *Bottom*: negative response to tuberization of short-day genotype to 15-hour daylength.

indicated that Group I was superior for all characters at both locations in Chile. These results confirmed that the single leaf-node technique can be used to identify, at an early stage in the breeding program, genotypes in segregating families that are able to perform well under intermediate and long daylengths. This tech-

Table VII-3. Comparisons for five characters of potatoes in response to intermediate (Santiago) and long (Osorno) daylengths (Chile, 1983).

Characters	Santiago 33°S		Osorno 40°S	
	Group 1[a]	Group 2[b]	Group 1[a]	Group 2[b]
Senescence	1.50 (120)[c]	1.28 (133)**	1.46 (144)	1.11 (131)**
Tuber initiation	1.62 (120)	1.41 (133)**	1.31 (144)	0.77 (131)**
Tuber wt/plant	795.80 (120)	649.80 (133)**	850.70 (144)	678.20 (131)*
Avg tuber wt	109.50 (120)	74.90 (133)**	61.80 (144)	43.90 (131)**
Marketable wt/plant	742.00 (120)	585.40 (133)**	769.80 (143)	576.40 (131)**

[a] Group 1 = tuberization at 16-h daylength.
[b] Group 2 = no tuberization at 16-h daylength.
[c] Numbers parentheses represent number of clones.
*, ** Means followed by the same letter are not significantly different at 5%, 1% level, respectively.

nique will be useful in speeding up germplasm selection for subtropical countries with intermediate daylengths and in eliminating unadapted material for export.

PROJECTS ON CULTURAL PRACTICES

From a collaborative project established between CIP and the national potato program of ICA in Colombia, 30 clones with frost resistance were selected out of 100 clones selected from tuber families sent during previous years. Of 20,000 seedlings grown in a greenhouse, approximately 200 clones were selected for further evaluation; 20 of these are being distributed for local evaluation to other ICA research sites in Colombia, and to the national potato programs of Ecuador and Bolivia.

Projects on cultural practices were initiated in late 1983 and will address relevant problems in the cool climate areas. Three current projects are 1) the nutrient uptake efficiency of cool climate potatoes, 2) the use of Potash (K_2O) in avoiding frost damage, and 3) the control of economically important fungal pathogens.

THRUST VIII

Postharvest Technology

The use of natural diffused light for storing potato seed tubers continued to expand with more than 3000 farmers adopting this technology in 1983. A study on adopters in Sri Lanka showed that the impact of such improved and appropriate seed storage technologies was considerable and variable. The extensive buildup of aphid-transmitted viruses in stored seed tubers has been confirmed and the need to develop adequate control measures for inclusion in seed production programs is stressed. Such control measures should be integrated with those already developed to control other important pests and diseases of stored seed tubers. Tubers stored in diffused light have again proved to be more resistant to infection by *Erwinia* spp. than dark-stored tubers.

The storability of consumer tubers and problems of potato tuber moth damage and *Erwinia* soft rot have been identified as major limiting factors to storage under warm, humid conditions. On-farm trials in the Mantaro Valley of Peru demonstrated that farmers' storage practices can be improved with a reduction in storage losses of consumer potatoes. Further research is needed to adapt the technologies used to specific farmer needs.

In potato processing, emphasis was placed on developing a methodology for identifying and using the potato in dehydrated food products that are consumer-acceptable. Processing provides a potential alternative to the frequently difficult storage of fresh tubers and can simultaneously increase the overall demand for potatoes. Dehydrated mixes were produced and tested, which contained up to 50% potato with the remainder made up of locally produced dried grains and legumes. Several of these mixes have already found good consumer acceptability in several test sites in Peru.

STORAGE OF SEED TUBERS

The number of countries either testing (24) or adopting (11) diffused-light storage (DLS) technology continued to grow. An estimate of the number of adopters showed a sharp increase during 1983 (Fig. VIII-1 and Table VIII-1) as countries researched, tested, and adapted DLS technology.

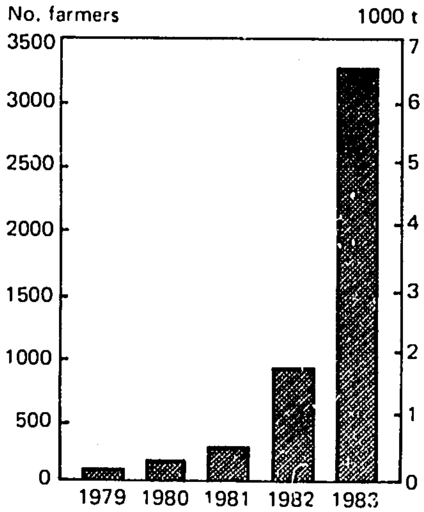


Figure VIII-1. Estimated number of farmer adopters and total capacity (tons) of diffused-light seed stores, 1979-1983.

Table VIII-1. Estimated number of farmers worldwide adopting diffused-light seed storage technology in 1983.

Countries	Adopters (est. no.)
Sri Lanka	1200
Guatemala	700
Philippines	593
Peru	400
East African countries	105
Colombia	90
Ecuador	65
Other Central American countries	50
Chile	20
Bolivia	15
Total	3238

In Colombia, 35 simple seed stores were built in Santander Province, 25 each in Boyaca and Cundinamarca, and 15 in Nariño. A rural development project in Colombia has budgeted for a further 200 stores to be built on supervised credit. Fifty very small stores, attached to farmers houses, were counted in the Santander Province alone. In Pamplona, yield increases from seed stored in diffused light, compared with traditional dark storage in farmers homes, ranged from 3.2 to 8.2 ha. The major part of this yield increase was in marketable consumer potatoes, thus the profit from this technology was maximized.

During 1983, seed tubers were successfully stored in India (Region VI) for eight months in DLS. Trials using the stored seed have been planted in farmers' fields to test the agroeconomic advantages of this method. Potato storage practices surveyed in the Mountain Province of the Philippines (Region VII) indicated that 42% of 1412 farmers had adopted DLS technology. A specific type of store design may not itself have been adopted, but the general principle was incorporated by farmers into existing stores by some suitable modification.

The rapid increase in adoption of DLS is a result of the intensive training courses regularly organized at regional and national levels for scientists and extension workers. CIP sponsored regional storage courses in Colombia and Sri Lanka in 1983 and a regional workshop in Chile—all courses were supported by funds from the United Nations Development Programme (UNDP). Individual training was given to a Venezuelan scientist at CIP headquarters to accelerate the transfer of skills in DLS technology available in the Colombian national program. The scientist later assisted in a course in Colombia funded by UNDP.

To further assist in understanding the transfer phase and impact of improved seed tuber storage, CIP conducted a collaborative study with the national program in Sri Lanka. A follow-up study on DLS selected a 10% sample of 400 early DLS adopters for interviews. An estimated 1200 Sri Lankan farmers had made at least one technological change in DLS as a result of national program efforts.

Sri Lanka is the first country adopting DLS where its potential impact can be documented. For example, in the Badulla District two importations of foreign seed were traditionally required: 1) *maha* planting in the upland zone for seed production, and 2) *yala* planting in the paddy zone for consumer potatoes. In 1979, however, foreign seed importation for the *yala* (paddy) planting was banned, forcing farmers to expand production in the upland zone to overcome seed deficits in the paddy zone. Traditionally stored seed had losses of approximately 25%. When DLS technology was introduced in 1980 by a national scientist trained in this technology, a new postharvest system and seed flows were eventually created (Fig. VIII-2). When longer storage periods became possible, farmers could keep seed from the *maha* harvest (Feb.-Mar.) to the *maha* planting (Oct.-Dec.).

The adoption of DLS in Sri Lanka allowed timely planting when climatic conditions were appropriate. For example, instead of the 1 to 3 multiplication rate farmers reported from imported seed that had arrived late or in poor physiological condition, survey farmers reported a 1 to 7 multiplication rate. This rate reflected a 133% increase in yield due to availability of seed in the proper planting condition. Storage losses were also reduced substantially. The government of Sri Lanka has now officially recognized the importance of postharvest activity in improving potato production by making credit available for constructing DLS.

Pest and disease control in diffused-light stores. Research continued on the control of major pests and diseases found in DLS. Results confirmed findings from previous years that tuber greening, following exposure to diffused light, influenced resistance to infection and spread of *Erwinia* spp. The cv. Yungay showed higher levels of *Erwinia* resistance than the cv. Ticahuasi, and resistance increased with increased storage time. Similarly, when healthy tubers were stored adjacent to tubers inoculated with three subspecies of *Erwinia*, resistance in healthy tubers to the spread of *Erwinia* increased slightly with more storage time. The trend was most pronounced with *Erwinia carotovora* subsp. *atroseptica*.

Control of potato tuber moth (PTM) in DLS was tested in Egypt (Region V). Large storage boxes with insect-proof screening were placed inside a traditional (*nawala*) seed store, which provided protection from direct heat while allowing diffused light to reach the tubers. The storage boxes provided good control of PTM damage, and tubers had strong, green sprouts at the end of the storage period after the summer months.

The buildup of aphid-transmitted viruses during storage was studied in Peru using the susceptible cv. 69-47-2. Control seed tubers were double-wrapped in paper bags and stored at 4°C. Other samples were exposed in seed trays in open-sided, diffused-light stores in Huancayo (3200 m) and in Cañete on the coast (100 m). The tubers stored in both sites were subdivided into two lots: one lot was sprayed every 15 days with insecticide Tamaron (2 ml of 50% E.C./100 ml H_2O) to the point of runoff; the other lot was left unsprayed.

After six months of storage, tubers from each experimental treatment were

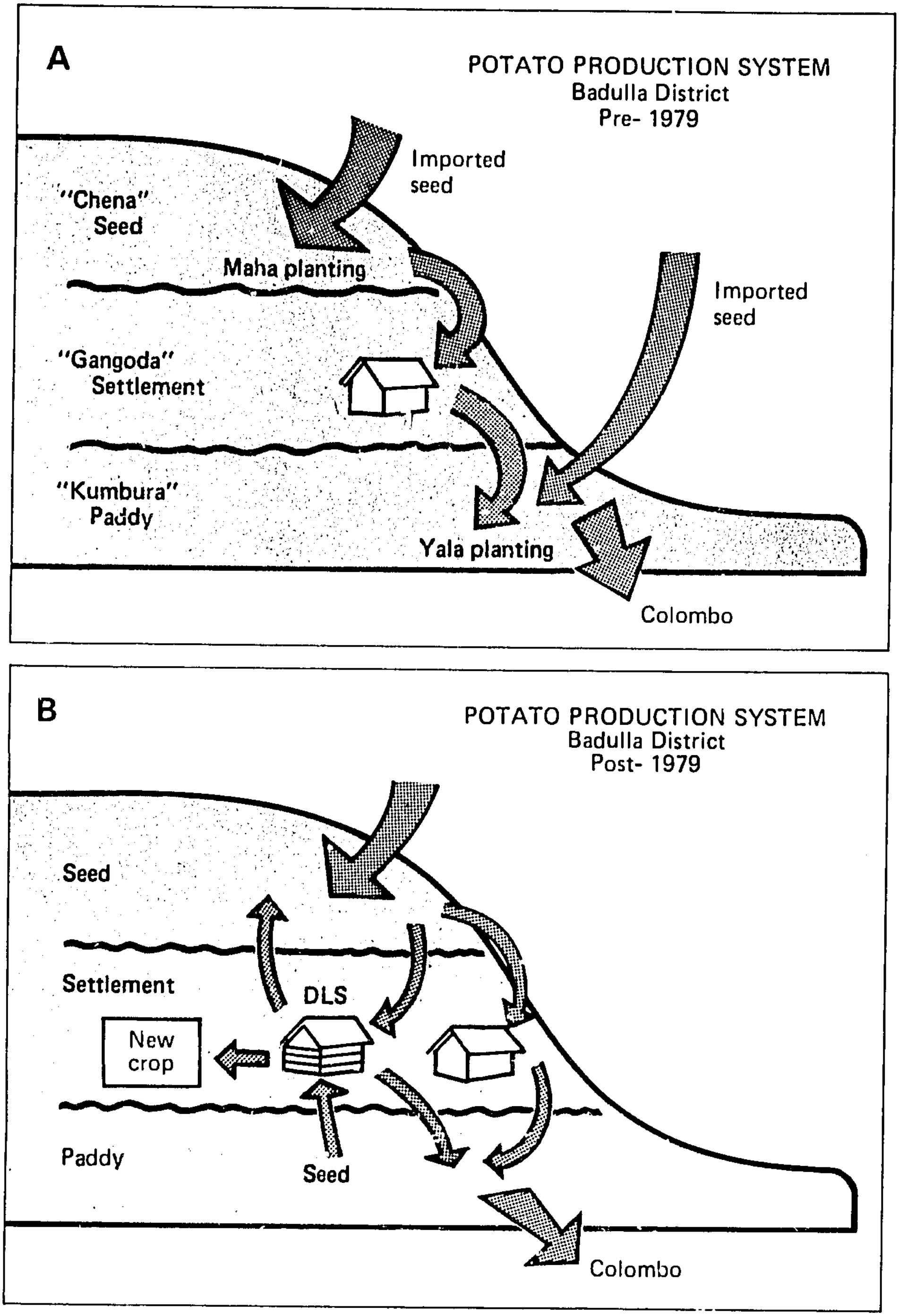


Figure VIII-2. A. Seed tuber flows prior to 1979 when importation of seed was allowed for both major potato production seasons: *maha* and *yala*. B. The introduction of diffused-light storage allows farmers to hold local seed longer and makes possible a new March planting, previously not possible due to a shortage of seed.

planted in a randomized plot design in plots at Lima. Shortly after plant emergence, the plots were visually examined for potato leafroll virus (PLRV) and potato virus Y (PVY). Although differences in virus health could be observed between the treatments, visual recordings of specific viruses were not possible due to the high percentage of mixed infections. Leaf samples from a minimum of 24 plants per replicate were taken at random and tested by the enzyme-linked immunosorbent assay (ELISA) for both viruses.

Results of this testing confirmed an extensive buildup of PLRV and a marked increase in PVY in the unsprayed treatments stored at both Huancayo and Cañete (Table VIII-2). Spraying with Tamaron reduced PLRV buildup under the cool conditions at Huancayo, but did not reduce PLRV in tubers under the higher ambient temperatures at Cañete. Insecticide application had less effect on PVY infection at both locations than did PLRV. Infection pressure and inoculum potential were greater under the warmer Cañete conditions. This finding supports previous observations on the rapid increase of aphid populations on tuber sprouts stored under warm conditions.

Influence of growing conditions and storage on seed tubers. The results from a series of trials showed that the environmental conditions of the growing location had greater influence on subsequent performance of seed tubers than conditions in storage (4° and 12°C). Healthy highland seed (3280 m) yielded an average of 30% more than similarly healthy seed from warmer sites grown at lower altitudes (800 and 240 m).

Studies on sprout growth in diffused-light stores. In contract research at the University of Glasgow, Scotland, the interrelationship of light intensity, temperature, and the rate and pattern of sprout growth are being studied. Preliminary experiments showed that the mean length of the longest sprout on each tuber was a satisfactory measure of sprouting under different light intensities. After dormancy was broken, there was a linear relationship between sprout growth and time. There were indications that only the rate of sprout growth was affected by light, and not the length of the dormant period.

More extensive experiments at Glasgow, using 11 European cultivars, examined the effect that temperature had on sprout growth in the dark. Both narrow

Table VIII-2. Buildup of aphid-transmitted viruses during storage of seed potato tubers, Huancayo and Cañete, Peru.

Storage treatment	Plants infected[a] with PLRV (%)	Plants infected[a] with PVY (%)
4°C cold store, double-wrapped in paper bags	3.0 a**	9.0 c
DLS[b] Huancayo, plus insecticide[c]	6.1 b	20.1 b
DLS Huancayo, no insecticide	72.5 a	55.0 a
DLS Cañete, plus insecticide[c]	85.2 a	23.6 b
DLS Cañete, no insecticide	89.7 a	28.8 b

[a] Determined by ELISA from minimum of 24 samples from each of 4 replicates.
[b] DLS = diffused-light store.
[c] Stored tubers sprayed with Tamaron (2 ml of 50% E.C./100 ml H_2O) every 15 days to the point of runoff.
** Means followed by the same letter are not significantly different at 1% level.

and broad temperature optima (13° to 18°C) were observed. Four of the cultivars were then sprouted at three different temperatures on trays under artificial light that decreased in intensity from about 1.2 W m^{-2} at one end of each tray to 0.02 W m^{-2} at the other end. The light sources consisted of a mixture of fluorescent tubes and tungsten bulbs, chosen as an approximate match for typical daylight spectra in the critical blue and red spectral regions.

The light intensity required for 50% inhibition of sprout growth was almost unaffected by temperature and varied from 0.1 to 0.25 W m^{-2} between cultivars. But since sprout growth without light increased with temperature up to the optimum for each cultivar, less light was needed to produce sprouts of a given length at low temperatures. No effect of light on apical dominance was observed. Tubers from this experiment were planted to observe emergence. Sprouts that developed in light gave early emergence after tubers were planted. Sprouts that developed in the dark were too weak; thus, planting those tubers by removing the sprouts was not practical.

The artificial light intensities mentioned above cannot be compared directly with diffused daylight, as artificial light contained much more energy in the inactive spectral regions. An exact conversion factor is dependent on the action spectrum for sprout inhibition, i.e., its relation to the wavelength of light used. An attempt to measure the action spectrum using quartz-halogen light sources and diffraction filters was unsuccessful, but the problems encountered appeared to be solvable.

STORAGE OF CONSUMER POTATOES

A socioeconomic study of farmer storage practices was initiated in the highland community of Palca (2500 m), Peru. This study was supplemented by observations from other important Peruvian potato-producing regions.

Ninety-two farmers were interviewed in Palca to better understand traditional storage practices and related problems. In this community, damage caused by PTM and rot were the most common storage problems perceived by farmers. In cooler regions, damage by the Andean weevil (*Premnotrypes* spp.) is more important than PTM damage, but farmers frequently do not distinguish between these two pests. A preliminary survey indicated that many highland potato farmers stored part of their crop after harvest, irrespective of credit demands. Frequently, the production credit systems require full repayment at harvest time and make no provisions for crop storage. The quantities of tubers stored are variable; they are used for both home consumption and later for selling, particularly at times when extra cash is needed. This use of stored potatoes is a type of "personal bank deposit," and coupled with the lack of credit for crop storage, it complicates obtaining reliable information.

A series of five on-farm storage trials were started in the Mantaro Valley of Peru to test whether past experiences on storage structures and their management at the Huancayo station could be used to reduce storage losses and improve existing farmer practices. Preliminary results of the trials indicated that losses over a six-month storage period could be reduced from 25.5% to 12.2% by applying the sprout inhibitor CIPC. Losses could be further reduced to 8.6% by using CIPC coupled with the use of simple, naturally ventilated 0.5-ton storage boxes kept inside farmers' buildings.

Much research still needs to be done on adapting the methods used to the specific needs of local farmers. If this can be achieved, it could have considerable impact on potato production at the national level, as the total tonnage stored for sale and home use by individual farmers must be considerable.

In a collaborative project with the national program in Bangladesh, encouraging test results were obtained on storing consumer potatoes in natural ventilation and evaporative-type cool stores. Different varieties were included in the tests. In combination with sprout suppressants such as CIPC, potatoes were stored for up to 150 days in good condition.

In Kenya (Region III), the comparative merits of various low-cost structures for consumer potato storage were evaluated at high and medium-high altitudes. At the higher site (2400 m), average losses after 11 weeks of storage were approximately 5%. At the lower elevation (1820 m), average losses were 10% after 9 weeks of storage. These structures are being evaluated in on-farm trials in collaboration with the Rural Structures Unit of the Kenya Ministry of Agriculture. A similar on-farm evaluation will be initiated in Madagascar in 1984.

Preliminary results of a storage study in Burundi indicated that heat shock treatment can be used as a practical farm method for breaking dormancy. Potatoes are suspended in the roofs of traditional huts where night temperatures, due to cooking fires, reach 50°C. In the daytime, the fires are extinguished and temperatures fall. Ten days of treatment are all that are necessary to break dormancy. Another study started in Burundi will determine how locally available herbs influence insect control in storage. This study is based on test results obtained in Peru on protecting potatoes against tuber moth attack by using deterrent weeds.

POTATO PROCESSING

Development of processing project. CIP has been involved for several years in developing simple technologies for potato processing. A low-cost, village-scale processing system was established at Huancayo in 1980 to produce dehydrated potatoes and starch. This system demonstrated that traditional Andean processes can be enlarged into a village-level operation. This CIP processing plant can be altered, depending on local market requirements, to modify the end product and can also be used to produce other primary food products. Some of these commodities can be sold directly to consumers, or their value and usefulness can be increased by incorporating them into secondary product formulations. Thus, a mechanism is established to use existing or new information on consumer needs. This mechanism has become a priority within the present project, which concentrates on producing products to meet specific requirements already identified.

Research on prototype mixes and consumer testing. During 1983, research concentrated on 1) establishing a market demand and clientele, 2) developing prototype mixes combined with the potato and testing consumer reaction, and 3) encouraging collaboration with national programs.

The prototype mixes, in addition to having a significant cost advantage, can often enhance the nutritional value over the individual components. Several crops indigenous to Peru have been evaluated for their combining acceptability with the potato. Some of the mixes were selected for consumer testing based on flavor and cost. Of those tested, one mixture (M-6) had the widest acceptance at all levels of testing; it contained 30% dried potato mixed with flours of rice, beans, oat, barley, and maize.

Figure VIII-3. The M-6 dried potato mixture is first reconstituted with water before being added to the main meal soup at a communal kitchen in Lima, Peru.

The different mixtures developed at CIP are in a dried powder form, which can be reconstituted by adding one liter of water to 80 gm of mix. The product is boiled for 25 minutes to obtain a consistency comparable to a thick soup. It has a neutral taste and can be used as a base for breakfast foods, main meal soups or sauces, and desserts.

More than 1000 individuals sampled M-6 in Lima and Huancayo during 1983. Families in this group were given 0.5 kg of M-6 for "in-home" tests after a brief preparation demonstration. In all cases, results were encouraging and indicated broad acceptance of M-6. A *comedor popular* (communal kitchen) in Lima was also used as a test-acceptance site. The *comedor* prepares daily meals for about 150 children (ages 3-21) and uses about 3 kg of M-6 per day in different main meal preparations (Fig. VIII-3).

The following national and international organizations have assisted in providing background information on Peruvian food habits and needs, and some have been actively involved with product acceptability testing during 1983: Nutritional Research Institute, National Institute of Agro-Industrial Development, National Agrarian University-La Molina, National Institute of Research and Advancement in Agriculture and Animal Husbandry, Ministry of Health, Lupine and Barley Projects, National Institute of Health, World Food Programme, and various church groups in Lima. Continued involvement and collaboration with these organizations will remain an important part of future developments.

THRUST IX

Seed Technology

Research on true potato seed (TPS) has expanded to countries in South America, Africa, and Asia. Hybrid TPS produced under disease-free conditions in Huancayo, Peru, was distributed to a number of countries for agronomic evaluation. Investigations were made on the influence of environmental conditions during berry and seed development, the effect of various seed treatments, and the relationship among several seed quality components. Studies on TPS sensitivity to salt concentrations indicated that high concentrations severely affected TPS germination. Seed germination and emergence tests were defined more clearly when TPS was subjected previously to stress treatment.

Agronomic research on TPS concentrated on potato production from transplanted seedlings and seedling-tuber production in seedbeds. A large number of progenies were evaluated in Peru under different ecological conditions with yields averaging above 40 t/ha in selected progenies. Different management practices were developed for earlier and uniform production of seedlings in either cool or warm environments. The effect of soil fertility and soil structure on seedling growth was studied in a range of soils. High conductivity and poor soil structure were the main factors associated with poor seedling growth. Several chemicals provided good control of damping-off in potato seedlings. *Rhizoctonia solani* was identified as the most important pathogen causing seedling damping-off before and after transplanting. Seedling establishment after transplanting was greatly improved by proper insecticide and fertilizer applications, as well as by methods to reduce soil temperature in warm climates.

In seedling-tuber production in seedbeds, plant growth was retarded by high salt concentration, resulting from organic material in the substrate mix or fertilizer. Direct sowing in the seedbed gave faster plant development and earlier maturity than transplanting seedlings into seedbeds. Crops grown from small rather than large seedling tubers matured later.

Different TPS technology components and alternative systems for TPS use were evaluated in on-farm trials on the coast of Peru. Adequate potato seedlings and seedling-tuber production were obtained under direct farmer management. In one trial, a yield of 29 t/ha was obtained from a crop of transplanted potato seedlings of a good hybrid progeny. This yield was almost double the farmer's yield using seed tubers of a commercial variety and was significantly higher than using small seedling tubers.

TRUE SEED PHYSIOLOGY

Differences in the germinability of true potato seed (TPS) samples were influenced by conditions during berry and seed development. An experiment in Peru produced TPS from five hybrid progenies under two conditions: field-grown plants or by flowering branches that were cut and placed in bottles of water in a screenhouse. Seed weight and germination at seven days showed significant differences between the two conditions and also for the interaction between hybrids and conditions. TPS produced by three progenies under field conditions had a higher 100-seed weight, while better germination was observed for four progenies at seven days. These differences, however, disappeared at 14 days. The results may reflect variation in growth of parents or in the success of pollinations under the two sets of conditions.

The effect of berry age at time of seed extraction on subsequent germinability was studied. Except for TPS extracted from the youngest berries, germination was similar for a broad range of seed age in two hybrids. While care should be exercised to avoid excessively young berries, there is a range of tolerance for berry age, including both the pre- and postharvest periods. The danger of harvesting over-ripe berries seems small if seed is extracted before berries begin to rot.

Potato berries of four open-pollinated (OP) progenies, ripened at 7° to 40°C, produced marked differences in TPS germination with or without gibberellic acid (GA) treatment to break dormancy. Temperatures above 30°C significantly reduced germination at seven days (Table IX-1). When berries were ripened at 15° or 30°C and seed was extracted at weekly intervals, there was an apparent influence of dormancy (Fig. IX-1). Germination of seed from berries ripened for only five days at 15°C had lower germination than seed ripened at 30°C. In the absence of GA, the dormancy of seed from berries ripened at 15°C for increasing periods of time was significantly increased.

Various seed scarification methods, either chemical or mechanical, have improved germination of dormant and nondormant TPS. In an experiment where the seed was treated with concentrated sulfuric acid, some improvement in seed germination was obtained when the treatment was less than 30 seconds. When acid scarification was compared to mechanical scarification, which consisted of a deep cut at the micropylar end of the seed, the latter method proved superior in its effect on seedling emergence.

Table IX-1. Seed germination of four progenies at seven days when berries were ripened at different temperatures.

Ripening temperature (°C)	Progenies							
	1		2		3		4	
	+GA[a]	−GA	+GA	−GA	+GA	−GA	+GA	−GA
7	81	8	92	7	86	6	99	45
15	56	8	98	64	74	25	98	62
20	55	13	96	84	77	45	98	89
30	32	2	89	76	80	66	89	76
40	0	0	0	0	11	0	14	0

[a] GA=gibberellic acid.

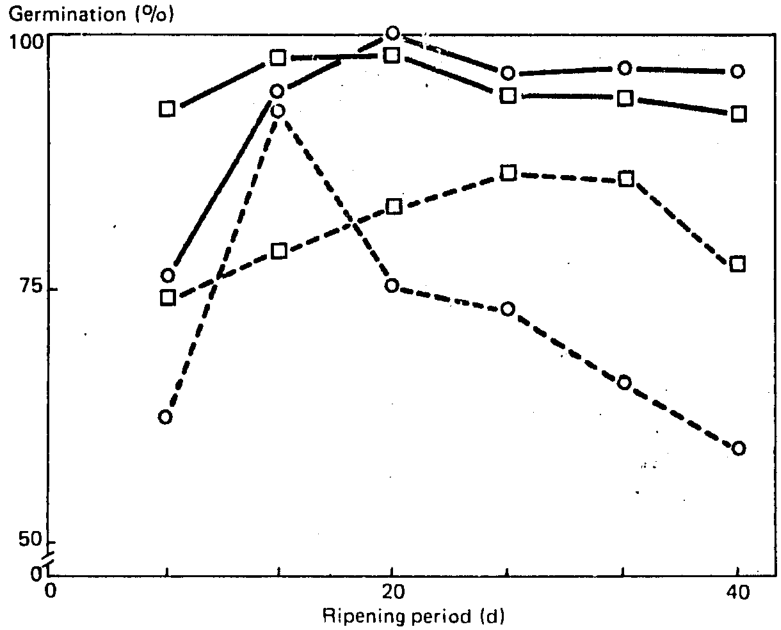


Figure IX-1. Effect of the ripening period at temperatures of 15°C (○) or 30°C (□) on the germination of seed treated (—) or untreated (--) with gibberellic acid.

In an evaluation of TPS from 25 OP progenies, a negative correlation between samples of 100 seeds and berry weight was determined. Although seed number increased in larger berries, large seed size was associated with poor seed set.

The influence of salts on germination was studied. Seed from Atzimba x DTO-33 was germinated in sealed petri plates containing 100, 1000, and 10,000 ppm solutions of the following salts: $CaCl$, KCl, $NaCl$, K_2SO_4, $MgSO_47H_2O$, $(NH_4)H_2PO_4$, NH_4NO_3, and $(NH_2)_2CO$. Solutions with conductivities greater than 4 mS inhibited germination. Slight differences due to the type of salt were observed. Variation in sensitivity to salts among different progenies was minimal when seed of six progenies was germinated in 5000 ppm ammonium nitrate (NH_4NO_3) (6.1 mS) and 8000 ppm magnesium sulfate ($MgSO_47H_2O$) (3.7 mS). Salts stimulated germination slightly in only one progeny; for the other progenies, salt treatments were inhibitory.

Several seed germination and emergence tests, and variants of these tests were evaluated using different TPS lots. By stressing seed prior to germination, differences in seed germination and vigor were more clearly defined. Two seed-stressing methods have shown promising results: 1) accelerated aging by subjecting seed to 35°C and high humidity for one to three days; and 2) soaking seed in 20% aqueous methyl alcohol for two hours.

Research on TPS in India has demonstrated a strong correlation between seedling vigor, seed size, and embryo type. Parental lines selected earlier on general performance for vigor, yield, and uniformity are being tested with respect to their potential for hybrid TPS production.

PRODUCTION FROM TRANSPLANTED SEEDLINGS

Research focused on: 1) several aspects related to quality of seedlings and their ability to recover early from transplanting shock, and 2) general factors to improve productivity of the potato crop from TPS.

A total of 59 selected hybrids and 194 OP progenies were evaluated by transplanting seedlings to the field in Lima, San Ramon, and Huancayo. In general, hybrids showed a higher proportion of large-sized tubers. During the last three years, the yield and average size of tubers has improved due to progeny selection. Open-pollinated progenies generally showed a longer growth period (Fig. IX-2).

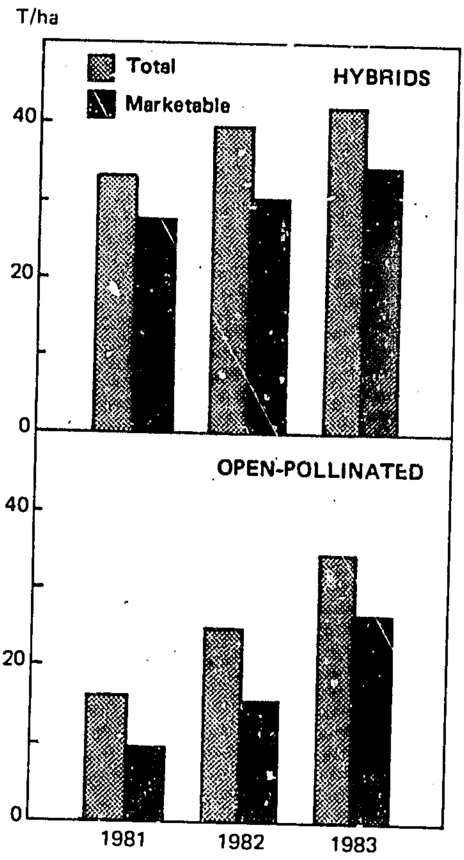


Figure IX-2. Total and marketable yield during three years of ten highest-yielding hybrids and open-pollinated progenies.

In CIP-supported contract research at the University of Wisconsin, more than 100 families of TPS obtained by different breeding programs were evaluated for seedling traits; vegetative vigor, uniformity and maturity; and tuber type and yield at two locations. TPS families were from 4x-2x crosses, 4x-4x crosses, and open pollination. Families from 4x-2x crosses were best in seedling vigor, vegetative vigor, uniformity, and tuber yields, but not in tuber type. They outyielded comparable OP families by 40% to 100% and had yields as large as the mean yield of 36 cultivars. But the best cultivars outyielded the best hybrid transplant families by 20% to 40%. No difference in yield was found between OP_1, OP_2, and OP_3 families.

Seedling survival in cool and warm areas. In cool areas, seedling emergence and growth can be impaired by low night temperatures. The results from experiments using eight selected progenies in either 20° or 30°C day temperatures and different combinations of night temperatures showed that low night temperatures significantly affected seedling emergence. The effect of low night temperatures on seedling growth was also observed when seed of seven progenies was germinated for eight days at 20°C; the seedlings were then maintained at 30°C during the day and various night temperatures. Seedling growth was delayed by night temperatures of 10°C or lower (Table IX-2). For cool night areas, several management practices for potato seedling production were evaluated. Temperature amelioration resulting in earlier production and more uniform seedling growth was obtained by surrounding seedbeds with black-painted stones and covering beds with clear polyethylene during the night.

Table IX-2. Effect of different night temperatures on potato seedling characteristics 35 days after sowing.

Night temp. (°C)	Seedling height (cm)	Internode length (cm)	Top dry wt (mg/plant)	Root dry wt (mg/plant)
5	7.3 a*	1.3 a	37.0 a	2.88 a
10	9.9 a	1.7 ab	48.0 a	4.75 b
15	15.5 b	2.2 b	98.0 b	6.25 b
20	14.0 b	2.1 b	75.0 b	5.25 b

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

In warm tropical areas, high temperatures may also reduce emergence and lack of uniformity in seedlings. The effect of high temperatures on seedling emergence and growth was evaluated at San Ramon during different periods of shading after sowing. During three consecutive seasons, the seedbed was shaded to allow 70% light transmission at full sunshine. Periods of 14 days or more of shading after sowing resulted in better emergence and sturdier seedlings (Table IX-3).

Another experiment in San Ramon during the dry season demonstrated that seedling survival was not influenced after transplanting even though B-nine (daminozide) was applied to the foliage, and leaves were pruned at various periods of seedling growth in the seedbed. Considerable improvement in seedling survival, however, did result during two seasons by protecting transplanted seedlings from cutworms and foliar-feeding insects with proper insecticide applications (Table IX-4).

Table IX-3. Emergence, height, and stem diameter of seedlings shaded for different periods after sowing at San Ramon, Peru. Averages of three growing seasons.

Shade (d)	Emergence (%)	Height (cm)	Stem diameter (cm)
0	47.5 b*	4.3	1.50 c
7	60.9 b	5.0	1.57 c
14	80.1 a	5.2	1.87 ab
21	83.5 a	5.3	1.99 a
28	86.6 a	6.7	1.96 a
35	87.0 a	7.8	1.77 b

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

Efficiency of seed production. TPS progenies are being developed by the national program of ICA in Colombia at the Tibaitata station near Bogota; testing for adaptability and resistance to late blight is being conducted at the La Selva station near Medellin. Part of the work is being done by an M.S. student who is working with CIP regional scientists on the breeding program. Some progenies have shown good levels of resistance. The tubers harvested were sold on the local market, and the price difference obtained for these and local varieties was low.

Another M.S. student in Colombia will investigate physiological aspects of flowering, anthesis, pollen viability, and other factors that could influence the efficiency of seed production and thus the cost of producing TPS. This area of research is also being investigated by a research contract with EMBRAPA in Brazil.

SEEDLING-TUBER PRODUCTION

Methods of optimizing seedling-tuber production in seedbeds were studied. The advantage of the seedbed system is its high efficiency in producing a large number of

Table IX-4. Seedling survival as affected by different insecticides applied after transplanting in two seasons at San Ramon, Peru (progeny DTO-33).

Insecticide	Application method	Plant survival (%)	
		1982	1983[a]
Furadan 75 WP	Sprayed plant base	85 a*	89 a
Lannate	Sprayed plant base	89 a	97 a
Aldrin 2.5%	Powdered on ridge	85 a	94 a
Sevin 20%	Powdered on ridge	83 a	93 a
Ambush	Sprayed plant base	72 b	96 a
Bait (Dipterex 20%)	Band application	69 bc	–
Temik 10 G	Hole of transplant	61 c	–
Sevin 80%	Sprayed plant base	61 c	–
Control	No insecticide	63 bc	62 b

[a]Dash (–) indicates treatment not applied.
*Means followed by same letter are not significantly different at 5% level.

tubers per unit area. Since growing conditions can be easily controlled in a small nursery area, tuber production per unit area can be maximized.

Comparisons were made in Peru on different seedbed substrates prepared with various types of organic materials that were used under high temperature conditions. Peatmoss, compost, and horse manure gave similar total yields; sawdust resulted in lower yield, both in weight and number of tubers per m². When organic material was reduced from 50% to 40%, and 10% loamy topsoil added, tuber number and weight decreased by 30% and 20%, respectively.

Trials in the Philippines on TPS showed that pure compost was a good medium in which to propagate seedling tubers. Close spacing from 6 x 6 cm to 10 x 10 cm provided adequate distance between plants. Under these conditions, 4 kg to 7 kg of seedling tubers/m² were produced from TPS with an average size of 10 to 20 g/tuber.

Several experiments in Peru were designed to investigate the effects of different seedbed substrates and cultural management on production of seedlings and seedling tubers.

In one experiment, fertilizer added before sowing to a substrate mix of 1:1 sand and peatmoss had a negative effect on seedling growth when concentrations of N and K exceeded 200 ppm. Results also suggested that in order to avoid salinity

Table IX-5. Effect of plant population on seedling tuber production in directly sown seedbeds, winter season, Lima.[a]

Plants/m²	Spacing (cm)	Survival (%)	Number of tubers/m²				
			< 1 g	1-10 g	10-20 g	20-40 g	> 40 g
50	14 x 14	72	202	496	170	69	23
100	10 x 10	48	318	700	196	81	30
150	8 x 8	41	478	782	201	89	31
LSD (5%)			57	93	21	12	ns[b]

[a]Mean of three TPS progenies: DTO-33 OP; Atzimba x DTO-33; Atzimba x 7XY.1.
[b]ns = not significant.

problems associated with the use of some N and K fertilizers, additional applications should be applied in partial doses starting one to two weeks after emergence.

The effect of plant population on seedling tuber production was studied during the winter period in Lima using two hybrids and one OP progeny (Table IX-5). The highest number of seed tubers, i.e., larger than 1 g, was obtained at a density of 100 to 150 plants/m². Although the average tuber size decreased with increasing plant population, the number of tubers larger than 20 g tended to increase. This finding is in agreement with previous results, indicating that a final plant population of 100/m² after thinning is adequate for producing larger, usable seedling tubers.

Direct sowing versus transplanting. A comparison of direct sowing in seedbeds with transplanting of seedlings indicated that direct-sown beds gave faster tuber development and plants matured 15 days earlier than those transplanted at the same time. At maturity, however, there was no difference in yield between planting systems. This indicated that, providing soil temperatures do not affect germination, direct sowing can be a labor-saving system for producing seedling tubers in seedbeds.

In another experiment, the effect of hilling on stolon formation and number of tubers was investigated in direct-sown seedbeds. Plants grown in beds that received an added 3-cm layer of substrate covering 2-3 nodes produced a significantly higher number of stolons as compared to no hilling. Hilling of 6-7 cm did not produce any further increase in number of stolons. Observations on the pattern of stolon formation showed that more than 70% of the stolons originated from the two lower nodes. The effect of hilling on the number of tubers at harvest was similar to its effect on the number of stolons, suggesting that 2-3 cm hilling is sufficient for good seedling tuber production (Fig. IX-3).

Evaluations on sprout growth and subsequent growth of plants from small seedling tubers showed that increasing tuber size had a positive effect on sprout length before planting and on early plant development (Fig. IX-4). This frequently resulted in later maturity of the crop from small seedling tubers compared to a crop from larger tubers. Sprout management in small tubers appears rather critical for early plant growth in the field.

In areas of the world where small tubers are accepted as food, the high yield

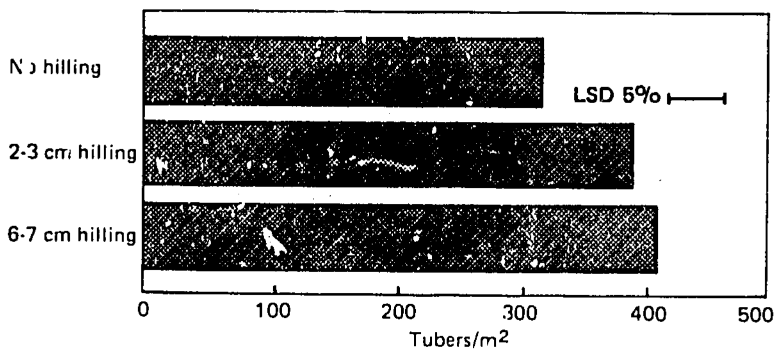


Figure IX-3. Effect of hilling level on number of seedling tubers in directly sown seedbeds.

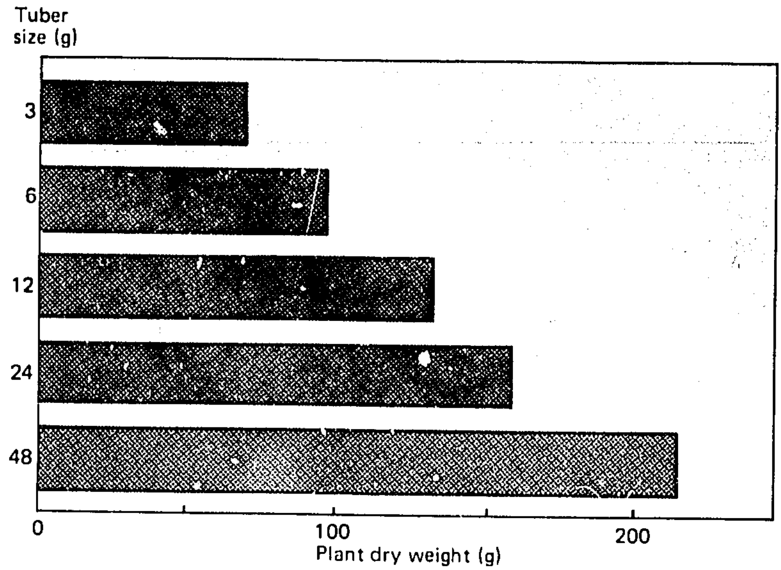


Figure IX-4. Dry weight of plants from single-sprout tubers, 24 days after planting in pots.

of seedling tubers produced in seedbeds could be used effectively. In selected progenies, a large number of tubers were produced per unit seedbed area and also a high total tuber weight was achieved (Fig. IX-5).

Intensive TPS research in Rwanda. An intensive program of TPS research covering agronomy, breeding, and on-farm trials was continued in Rwanda with the national potato program (PNAP). The optimum fertilizer dosage for field production from transplants was 500 kg/ha of diammonium phosphate (DAP). In nursery trials to produce seedling tubers, the fertilizer treatment giving the greatest number of tubers (570/m^2) was 1500 kg/ha of DAP and fungicide sprayed once a week. Positive selection of vigorous plants in nursery beds produced seedling tubers

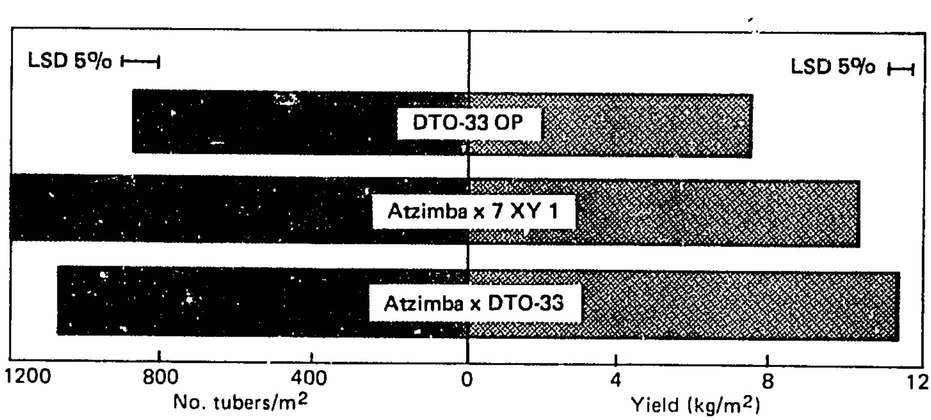


Figure IX-5. Yield from different progenies in directly sown seedbeds (mean of 15 m^2).

that considerably outyielded unselected seedling tubers in the next generation. Hybrid populations produced locally in Rwanda and grown as transplanted progenies varied widely in yield. Several hybrids gave yields approaching those obtained from a regular crop planted with tuber seed. The size of tubers from seedlings produced from a hybrid progeny was smaller than the size of tubers produced by the var. Sangema grown from seed tubers.

TRUE SEED PRODUCTION

Two hundred clones were analyzed for flowering, male fertility, fruit set, and seeds per fruit to identify clones with high male sterility that produced fruit from bumblebee activity. Ten clones were found with low pollen stainability that produced from 2000 to 4000 seeds per plant, as compared to 10,000 to 40,000 in male clones that were highly fertile. Tuber yields of progeny from OP seed of male sterile clones were significantly higher than those from progeny of male fertile clones.

In a research contract with the National Agrarian University (UNA) of Peru, preliminary experiments evaluated the effect of NPK levels on development of flower buds, flowers, and berries. Significant improvement in fruit set was achieved by increasing P_2O_5 and K_2O levels from 80 to 160 ppm.

Production costs. Preliminary data on actual cost of producing TPS varies according to local conditions. In India, hand-pollinated TPS was produced at a cost ranging from US$5 and $20/ha. The cost of producing hybrid seed in the Philippines ranged from $4 for non-emasculated crosses to $31/ha for an emasculated cross. Open-pollinated seed was estimated to cost less than $1/ha.

PATHOLOGICAL STUDIES ON TRUE SEED

Rhizoctonia solani is one of the most important pathogens causing damping-off in potato seedlings. At CIP and the Research Institute for Plant Protection (IPO), Netherlands, several experiments were conducted for controlling damping-off both in the nursery and after transplanting. At the nursery stage, several fungicides were applied individually in 250 L of water/m^2 after sowing TPS in artificially inoculated soil. The soil was inoculated by incorporating 7 g of infected wheat kernels per kilogram of soil. The fungicides Rizolex, Benlate, Monceren, Campcgran, Solacol and Iprodione 1861 provided good control. In trials to control damping-off after transplanting, 35- to 40-day-old seedlings were transplanted into soil that had been previously mixed with a fungicide four days after inoculation. All of the fungicides tested controlled *Rhizoctonia* damping-off (Table IX-6).

Pythium spp. are also associated with damping-off in transplanted potato seedlings. In an experimental field at San Ramon, *Pythium* was found in 21.6% of the seedlings showing symptoms of damping-off; three different species of *Pythium* were identified. Whole tuber inoculation of nine potato cultivars showed that all isolates were pathogenic when tubers were surface-damaged. After four days at 17° to 20°C all tubers rotted.

During the process of berry ripening or extraction and processing, TPS may become highly contaminated with fungal or bacterial saprophytes and pathogens. Various chemicals have been tested to eliminate some of these pathogens from the seed surface. A ten-minute dip in a 0.5% solution of sodium hypochlorite was the most effective control treatment (Fig. IX-6).

Table IX-6. Fungicide control of *Rhizoctonia* damping-off in TPS seedlings in the nursery and after transplanting.

	Nursery		After transplanting		
Fungicides	Dose/m²	Seedling survival[a]	Doses/kg soil	Seedling survival[b] (%)	Avg seedling[b] wt (g)
Benlate	8.4 g	98.3	2.00 g	90	1.98
Rizolex	7.5 g	87.0	1.50 g	100	5.01
Campogran	5.5 g	97.0	1.50 g	100	2.45
Iprodione-1981	8.5 ml	96.0	2.70 g	100	2.54
Monceren	8.0 g	95.0	1.50 g	95	2.86
Sterile soil	–[c]	–	–	100	3.22
Soil + *Rhizoctonia*	–	13.6	–	15	0.58

[a] Data at 30 days after sowing, adjusted to 100% of nontreated sterilized soil.
[b] Data at 15 days after transplanting.
[c] Dash (–) indicates no application done.

In Brazil, various factors that influence transplanted seedling establishment were investigated. Soil pathogens such as *Rhizoctonia solani*, *Fusarium* spp., and *Erwinia* spp., and insect pests including *Diabrotica spiciosa*, and *Liriomyza huidobrensis*, were among several factors causing difficulty in seedling establishment.

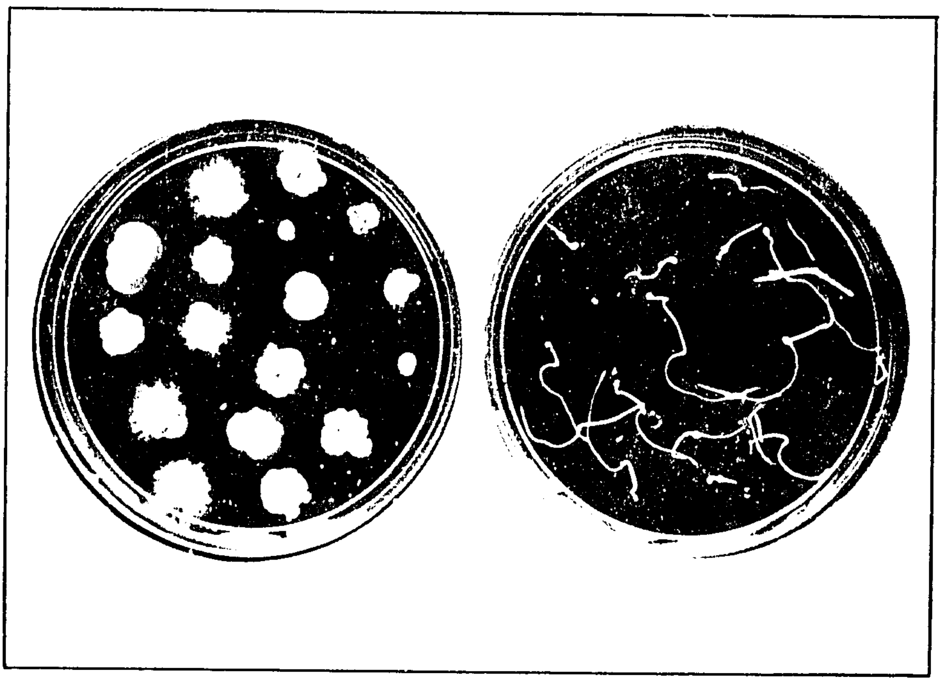


Figure IX-6. TPS disinfection. *Left*: contaminated true potato seed. *Right*: germinating seed after treatment with sodium hypochlorite 0.5% for ten minutes.

ON-FARM EXPERIMENTS AND SOCIOECONOMIC RESEARCH ON TRUE SEED

Several on-farm trials in the coastal area of Peru continued to evaluate TPS technology. The objectives were 1) to test different technology components under farmer management conditions and 2) to evaluate different alternative systems of TPS use under the different agroeconomic conditions present in several farming areas.

At Callao, a coastal city near Lima, there are two potato production seasons; the early season is characterized by low yields, but a high market price is paid for these potatoes even though seed tubers with high virus content are used. During this season, the productivity of different-sized tubers, produced the previous season from TPS, was compared with transplanted seedlings of a hybrid progeny and with farmers' seed tubers. The farmers' tubers were of a local variety produced on the farm but stored either in the cold or in diffused light. Yields obtained by transplanted seedlings almost doubled the yields of farmers' seed tubers and were significantly higher than yields of small tubers produced from TPS. Crops from transplanted seedlings, however, had a longer growth period (Table IX-7; Fig. IX-7).

A distinct economic advantage of TPS technology over conventional seed tuber technology is the potential saving in seed cost. Experiments in Peru during 1982 indicated that significant increases in labor may occur in seedling production and transplanting, partially cancelling the potential cost saved by using TPS. In 1983 experiments, however, the labor needed for seedling production and transplanting was reduced by 17%. Further reduction in labor can be expected as farmers become accustomed to the technology, and as new and simplified practices are developed, which are better adapted to farm-level commercial scale of production.

In the development and diffusion of TPS technology, it is important to identify the agroecological zones and farming systems where farmer adoption would most likely occur. On-farm trials in Peru showed that TPS technology is more profitable than seed tuber technology only during the early planting season on the coast, when inexpensive but highly infected seed tubers are used. In the main season, crops from TPS were not as profitable as the seed tuber crop because the saving in seed cost was smaller than the decrease in return produced by lower yield and selling price (Table IX-8).

Table IX-7. Yields obtained from different systems of TPS use and from seed tubers in a farmer's field, Callao, Peru.

System	Total yield (t/ha)	Proportion marketable (%)	Growth period (d)
Transplants (0.80 m x 0.20 m)	29.1 a*	77.4	125
Transplants (0.80 m x 0.30 m)	27.1 ab	75.9	125
Seedling tubers (35 g)	23.5 bc	88.4	105
Seedling tubers (8 g), 2/hill	20.1 cd	72.0	105
Seedling tubers (8 g), 1/hill	17.4 d	79.9	105
Farmer's seed tubers stored 4°C	16.5 d	79.8	110
Farmer's seed tubers stored in diffused light	16.3 d	80.5	110

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

Figure IX-7. On-farm experiments on alternate systems of using true potato seed. *Top*: 40 days after planting transplants. *Bottom*: harvest from plots of transplanted seedlings.

Table IX-8. Profitability of TPS and seed tuber technology, central coast of Peru, 1983.

Variables	Main season		Early season	
	Seed tuber	TPS	Seed tuber	TPS
Yield (t/ha)	20.00	18.70	13.20	22.50
Cost/ha (US$)	1404.00	1385.00	3016.00	3145.00
Cost/kg (US$)	0.07	0.07	0.23	0.14
Selling price (US$/kg)	0.27	0.23	0.35	0.30
Net return (US$/ha)	3996.00	2916.00	1604.00	3605.00

Comparative on-farm trials at three locations in Rwanda demonstrated that the combination of clean seed and an improved variety produced by the national program (PNAP) yielded three times more than farmers' seed. In these trials, seedling tubers of the new variety Nseko, produced by farmers in their own nurseries from TPS, also outyielded farmers' seed by a considerable margin (Table IX-9).

In Sri Lanka, the Department of Agriculture has started to produce TPS seedlings of Desirée (OP) in flat trays for sale to farmers. Reported yields are good; one farmer produced on 0.2 ha the equivalent of 25 t/ha. Farmers in Sri Lanka have been producing seedlings of other horticultural crops and are interested in producing their seedlings if seed is available. Several TPS progenies have been evaluated by the Department, three of which had good overall performance in 1983 and may be made available to farmers in the near future.

TPS project development. To help initiate projects in developing countries and strengthen existing projects, the second international course on potato production from TPS was held at CIP headquarters in Lima. Of the eight scientists attending, four were from Asia where there is a potential for TPS technology. Individual training on TPS production was also given at Lima. In Mexico, the annual production course presented by the national potato program added, in 1983, a one-week training section for the PRECODEPA countries. In India and Colombia, TPS research is being supported through scholarships to three students studying for their M.S. degrees.

SEED TUBER PRODUCTION

A number of diverse observations related to seed technology have been reported from several CIP regional programs. In the Philippines, the use of rooted cuttings

Table IX-9. Comparative on-farm trials in Rwanda with tuber seed and with seedlings and seedling tubers produced from TPS.

Treatment	Marketable yield (t/ha)		
	PNAP[a] station (volcanic soil)	Farm 1 (volcanic soil)	Farm 2 (lateritic soil)
Farmers' seed tubers	21.7	9.7	15.7
PNAP seed of improved variety	61.7	43.2	44.0
Nseko-OP seedling tubers	39.0	35.9	33.0

[a] PNAP = Programme National de l'Amelioration de la Pomme de Terre.

has shown promise. A system of training farmers' children to make cuttings from mother plants of the vars. Cosima, Conchita, Greta, and Granola has been established. At a density of ten cuttings in farmers' fields, approximately 120 tubers were obtained per m^2 of which more than 90% were suitable as seed.

In Tunisia, the national seed potato program (GIL) is producing quality tuber seed for the early and late seasons. The potential size of the seed market was estimated at 2800 t for the early season and 4600 t for the late season. In 1983, the seed program had already satisfied 20% of the potential seed requirement for the late season. The seed program's objective is to satisfy the total seed demand for both seasons, which would have a significant economic impact. First, potato production would increase to about 20,000 t due to the use of good quality seed. Second, the country will save at least US$200,000 compared with the current level of seed imports. Finally, the national income is estimated to increase by $3.5 million, due mainly to the increased value of potato production.

Research by the national program (INIAP) of Ecuador used a rapid multiplication technique developed at CIP to produce about 18,000 stem cuttings of three varieties and obtained 3.2 t of first generation tubers. Twenty-two tons of second generation tubers of one variety were harvested before the end of 1983. All "mother plants" were free of virus, and random samples of first and second generation plants had less than 2% field infection.

In Rwanda, an economic evaluation of the national potato program (PNAP) indicated that this program is generating high net social returns. Considered in the evaluation were all program costs and only those benefits associated with the diffusion of seed of improved varieties. If all social costs are deducted from gross social returns over a period of 12 years, the country will obtain a net benefit of at least $1.2 million.

Seed-tuber production technology was the subject of three regional courses in Peru, Chile, and Zambia, attended in total by 48 scientists. In Africa and Asia, different aspects of seed tuber production, applicable to local conditions, were also presented in several in-country production courses. To meet the demands of national programs for information on identifying and controlling diseases – a priority in seed tuber production – a series of courses on pathological problems in seed production have been initiated by CIP. The first was held in Colombia in October 1983, attended by 24 scientists representing ten countries of Central and South America.

THRUST X

Potatoes in Developing Country Food Systems

National, regional, and world trends in potato production and use, based on data from the World Bank and Food and Agriculture Organization (FAO), were documented and analyzed for inclusion in the 1984 second edition of CIP's comprehensive *Potato Atlas* and the pocket-size *World Potato Facts*. Information on potato farming systems in 74 developing countries, extracted from various sources, was compiled in a Country Reference File and rendered on maps of potato-growing zones.

Diffused-light seed storage technology has been adopted extensively by farmers in Sri Lanka and has stimulated local seed production, resulting in far-reaching changes in farming systems. A study on potato marketing in Bhutan revealed that demands for both seed and consumer potatoes were much greater than previously thought. The study recommended that Bhutan, to help achieve its official goal of greater food self-sufficiency, curtail subsidized sale of imported rice during the peak potato harvesting season. Nutritional aspects of the potato—a little understood topic—were reviewed in more that 600 related publications to prepare a seven-chapter book entitled *Potato in the Human Diet*.

RESEARCH OBJECTIVES AND PRIORITIES

This new tenth Thrust will focus on obtaining information on priority problems and client needs in production, marketing, and utilization of potatoes in developing country food systems. Accordingly, research priorities are to 1) document the present status and trends of potato production and use; 2) characterize major farming systems in which potatoes are, or may be, produced; 3) identify key marketing problems and potential solutions; 4) analyze potato consumption and demand; and 5) determine the potential role of the potato in improving diets and nutritional well-being.

WORLD TRENDS IN POTATO PRODUCTION AND USE

Documenting and analyzing trends. T... objective is to document trends in potato production and use at national, regional, and world levels and to evaluate the present and potential role of the potato as a food crop in developing countries. A data bank with national, regional, and world statistics has been established and will be updated annually. In 1983, data on all major root crops were collated and analyzed for the second edition of CIP's comprehensive *Potato Atlas* and the pocket-size *World Potato Facts*.

The new edition of the *Potato Atlas* is the most comprehensive and up-to-date statistical compilation in the field. All work, including preparation of text, tables, and graphs, was done on a microcomputer to ensure a high degree of accuracy and timely publication. Since all data is computerized, updating is easy and interested parties can receive available information quickly and at a low cost.

Today, Asian countries are among the world's largest potato producers (Fig. X-1). China is the world's second largest producer and India is sixth. Among all crops grown in developing countries, potatoes are superior in terms of dry matter,

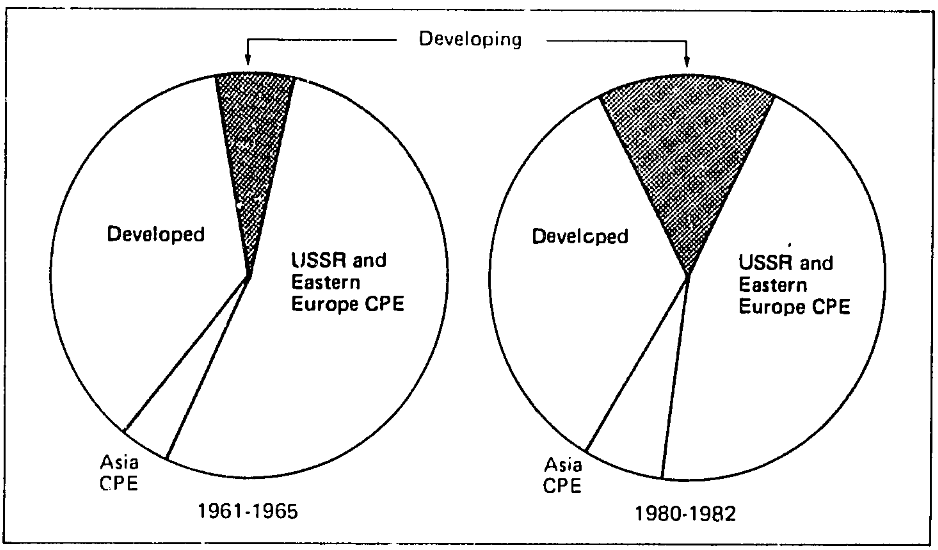


Figure X-1. World potato production in developing market economies, 1961-1965 and 1980-1982. CPE = centrally planned economies.

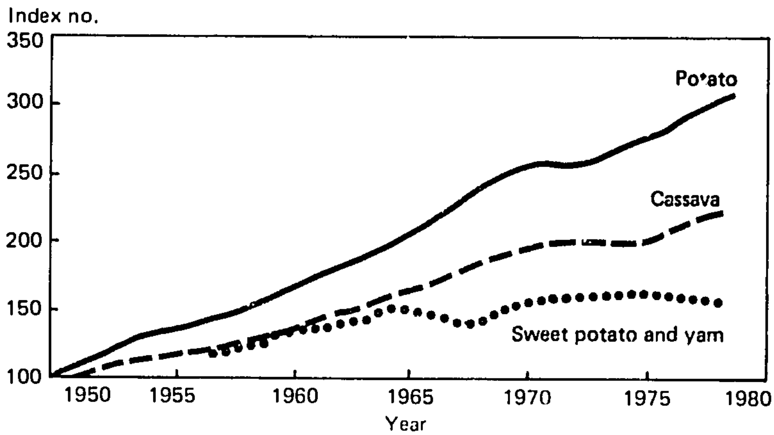


Figure X-2. Root crop production in developing market economies, 1948-1950 and 1978-1980 (three-year moving averages 1948-1950 = 100).

protein, and energy production per hectare per day. They are also near the top in terms of increase in production and yield over the last two decades.

Patterns and trends of potato and other root crops. Many people assume that patterns and trends of potato production and use are similar to those of other root crops. To test this hypothesis, recent developing country patterns and trends in potato production and use were documented and related to the corresponding patterns and trends for cassava, sweet potato, yam, and cocoyam. Production costs and prices were related to root crop marketing and use. The position of root crops in different production zones and farming systems was analyzed.

The findings indicated that among root crops such as cassava, yam, sweet potato, and cocoyam, the potato ranks second in terms of developing country production (30 million tons; 1980 estimate for all developing market economies, from FAO 1982) and first in terms of rate of production increase (Fig X-2). Relative to other root crops such as cassava and sweet potato, potatoes have higher production costs and are generally grown under more favorable conditions. As food needs expand and agriculture intensifies in developing countries, the advantages of the potato over other root crops become evident: short growth cycle, relatively high protein/energy balance, high quality protein, broad consumer acceptance, storage is relatively easy, and no processing is required.

POTATO FARMING SYSTEMS

Little is known about the farming systems in developing countries where the potato plays or can potentially play an important role. Moreover, no up-to-date map of potato-producing zones is available. To remedy this lack of information, a set of International Potato Reference Files was established with data on ecology, climate, population patterns, cropping systems, and major technological and socioeconomic constraints to potato production.

During 1983, data on potato production in 74 developing countries were extracted from many sources, including country reports, personal interviews, and information compiled by CIP regional representatives and national program staff. Information is still lacking on 53 tropical countries. Most of the principal countries in CIP's regions are well represented in the International Country Files, except for West Africa and the Middle East. Information on these regions is being accumulated and compiled. For several countries, potato production zones have been mapped for the first time.

Over 300 country documents are catalogued at CIP headquarters in the International Potato Reference Files. These files show the geographical distribution of documents by continents: Africa (98), Americas (53), Asia (139), and Oceania (12). This information is useful for determining such things as national programs' perceptions of production constraints (Table X-1) and distribution of diseases and pests (Table X-2).

Table X-1. Major limiting factors of potato production as cited in documents from 62 developing countries.

Factors	No. countries
Postharvest (storage and marketing)	51
Bacterial and fungal diseases	50
Seed	41
Pests and nematodes	40
Virus	36
Agroeconomic	32

Table X-2. Distribution of bacterial and fungal diseases, cited in documents from 62 countries.

Disease	No. countries
Fungal diseases	
Late blight	39
Early blight	22
Rhizoctonia	12
Fusarium wilt	4
Verticillium wilt	2
Wart	2
Bacterial diseases	
Bacterial wilt	23
Black leg	7
Common scab	4

FARMER ADOPTION OF POTATO TECHNOLOGIES

Research is concentrating on two technological areas: new varieties and storage technology. In conjunction with interdisciplinary efforts in Thrust VIII, the transfer and diffusion of rustic seed stores has been partially documented in Peru, the Philippines, and Sri Lanka. The diffusion of varieties has been studied in Eastern Nepal in coordination with Nepal's National Potato Development Programme (Fig. X-3).

Research in Nepal conducted with the national program revealed a complex traditional potato agriculture, especially in relation to farmer selection of varieties. While the total Himalayan potato germplasm is not as diverse as that of the Andes, a surprisingly large number of local varieties are grown in Nepal. In several Himalayan villages studied, farmers identified 30 to 35 varieties, although normally only 4 or 5 varieties are planted in a given season. As in the Andes, Nepalese potato farmers maintain their own "potato germplasm banks."

An exploratory study was conducted in Peru's Department of Cajamarca on farmer adoption of Molinera, a bacterial wilt- and late blight-resistant variety. Molinera was found to be the second most important variety in the department (total 2491 ha). The findings indicated that farmers were motivated to adopt Molinera partly for its earliness and partly for its floury texture which permits farmers to sell at a higher price. A more detailed follow-up is planned for 1984.

During the last two years more than 150 on-farm trials were coordinated by national program (PNAP) staff in Rwanda. Several innovations were tested such as control of late blight (fungicides), use of compost, new varieties, new varieties combined with compost, and improved

Figure X-3. The Social Science Department at CIP initiated research on farmer adoption of new potato varieties. One study, conducted in Nepal with the National Potato Development Programme, revealed that farmers in one village were able to identify 23 Himalayan varieties and their characteristics.

seed stores. Although all treatments gave increased yield in more than half of the trials, adoption by farmers was not uniform for all treatments.

New varieties were the most successful innovation introduced in Rwanda. All of the participating farmers and 90% of their neighbors adopted a new variety. By contrast, 84% of participating farmers adopted the use of fungicides to control late blight, while only 30% of their neighbors did. This lower adoption rate prevailed in spite of the neighbors' keen interest in the trials and full knowledge of the results. The conclusion was that an innovation such as a new variety is easy to disseminate without additional inputs, it has late blight resistance and gives improved yields. In 1983, 25 on-farm trials showed a positive effect on farm income when a combination of clean seed and a new variety was used: the new variety doubled the net income over the farmer variety.

MARKETING AND DEMAND FOR POTATOES

Based on a typology of potato-producing countries, case studies are being conducted to analyze marketing problems and demand for potatoes in representative developing countries. In 1983 a case study of Bhutanese potato marketing was completed, and final reports were issued on an earlier Peruvian study (Fig. X-4) and the Bhutanese study. The Peruvian report, entitled *Markets, Myths, and Middlemen*, will be published in English and Spanish in late 1984. Fieldwork on potato marketing in Central Africa was conducted in late 1983 in Burundi, Rwanda, and Zaire.

Bhutan. The Bhutanese study, done in conjunction with the Bhutanese national potato program, addressed the question of where will additional potatoes be marketed if Bhutan produces more potatoes. Fieldwork showed that potential outlets for different quality potatoes existed both at home and abroad. The study concluded that if Bhutan is to maintain its present potato markets and capture new ones, varietal trials, seed multiplication, and marketing policy should take into account the special features of local and foreign markets. Several specific recommendations were as follows:

- to help achieve Bhutan's official goal of greater food self-sufficiency, subsidization of imported rice during peak potato harvests should be curtailed;
- improve dissemination of information about the potato's nutritional value and dietary uses;
- retain high-quality Bhutanese seed for local sale rather than for export;

Figure X-4. Potatoes are weighed before being sold in Lima's wholesale market, *Mercado Mayorista Número 1*

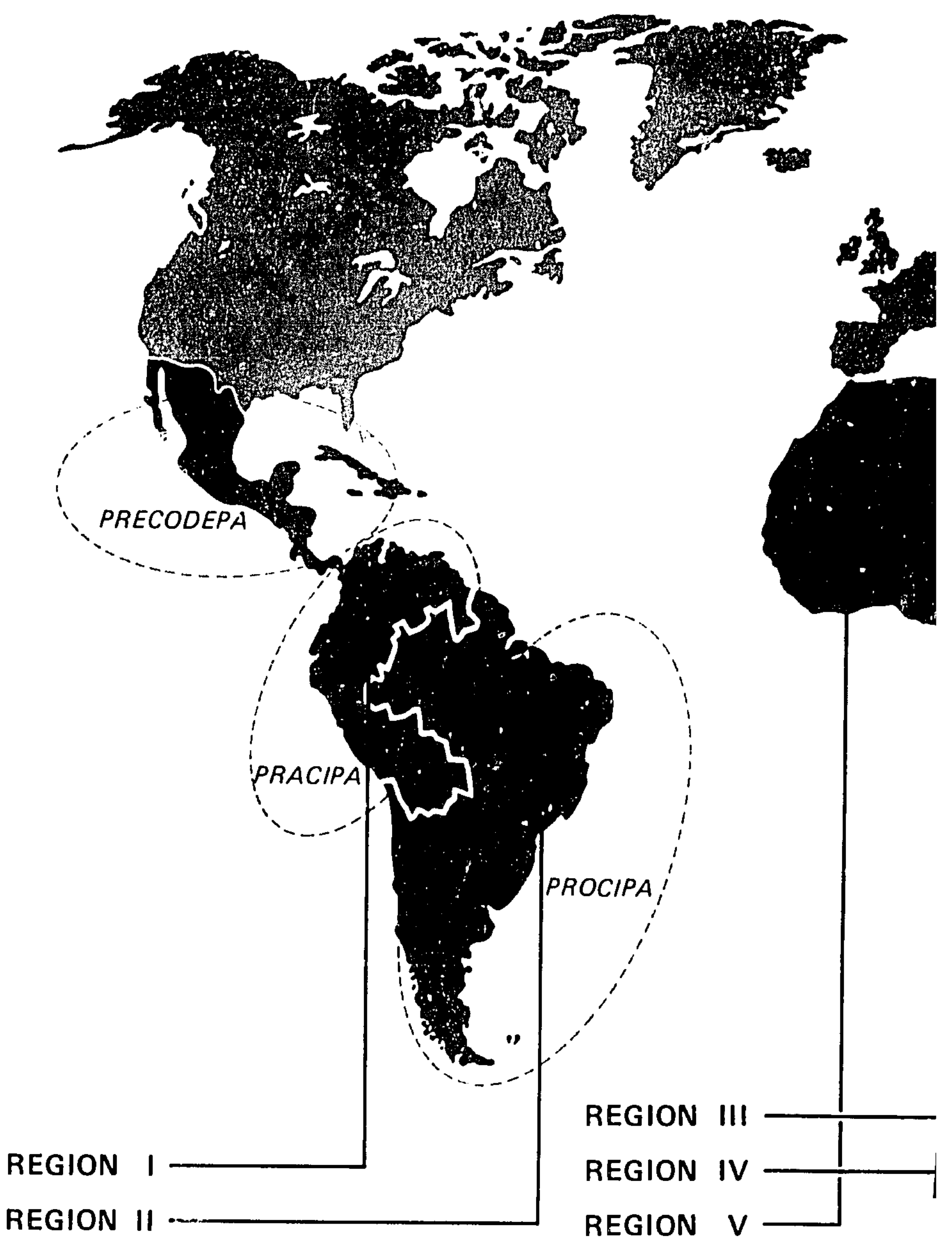
- explore the feasibility of selling improved seed at a slight profit to help generate internal financial support for the national potato program.

NUTRITIONAL VALUE OF THE POTATO

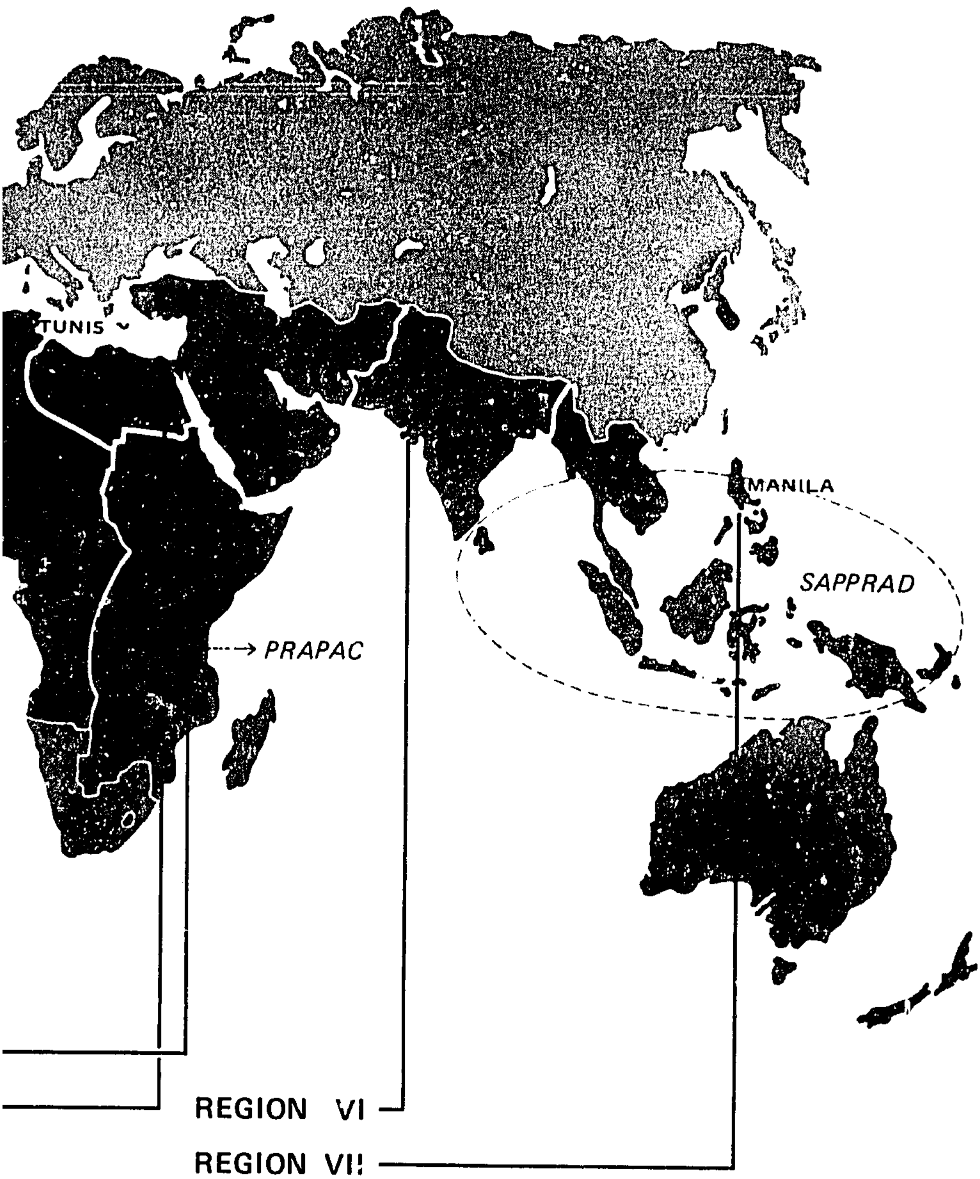
The potato's nutritional value and present and potential role in the diet are little understood and are highly controversial topics. Based on a review of over 600 publications on various aspects of potato nutritional value and on studies of potato consumption in seven countries, a book entitled *Potato in the Human Diet* was prepared and will be published in 1984.

The book's major objective is to provide a concise and reliable reference on the nutritional value of the potato for use by agricultural and nutritional planners and policy makers, researchers, nutritionists, potato program workers, and students of food and agricultural sciences. Emphasis is placed on the importance of maintaining nutritional quality while searching for means of increasing yields and enhancing disease resistance.

It is generally believed that the potato is a high energy food that provides little else in the way of nutrients. In fact, the potato is not an especially rich energy source, but does contain high quality protein and substantial quantities of essential vitamins, minerals, and trace elements (e.g., vitamin C, niacin, and potassium).


PRECODEPA
PRACIPA
PROCIPA
REGION I
REGION II
REGION III
REGION IV
REGION V

Regional Research and Country Networks



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REGIONAL RESEARCH AND COUNTRY NETWORKS

Introduction

To present a more concise picture of CIP's integrated research network, which includes research at headquarters and throughout CIP's seven regions, all regional research has been reported within the ten Thrusts. The Regional Research and Training section has been divided into two separate reports: "Regional Research and Country Networks" and "Manpower Development Through Training."

This report focuses on national program and institutional development within the regions and gives the general background on five country network systems.

CIP Regional Program Development

The map of the world introducing this report illustrates the current status of CIP's seven regions (I-VII) and the location of the five country networks: PRECODEPA, PRACIPA, PROCIPA, PRAPAC, and SAPPRAD. The only change in the regions has been in Region IV, Near and Middle East, where the headquarters was moved from Turkey to Egypt during 1983.

Two staff additions were made during the year and two more were confirmed for early 1984. These positions are supported by donors of the Consultative Group for International Research (CGIAR) and the Associate Expert Scheme of the Food and Agriculture Organization (FAO). Associate scientists were assigned to regional headquarters in Tunisia and the Philippines, where they will assist in the research programs. Two additional postdoctoral research assignments were confirmed with the German Agency for Technical Cooperation (GTZ) and the Swiss Development Cooperation (SDC) and will begin in 1984. One is for the regional program in Tunisia to investigate integrated control of potato tuber moth (PTM), and the other is for CIP research in Egypt on true potato seed (TPS).

The development of seed improvement programs continues to be a priority for many national potato programs. Seed programs designated to meet national requirements are essential to introduce improved germplasm in sufficient enough quantities to have an impact on potato production. CIP receives frequent requests to assist in developing these seed programs. In Table 1, the magnitude of this task is illustrated by the number of countries embarked on some type of seed program as of 1983.

The large quantity of germplasm flowing into national seed improvement programs comes from CIP and associated institutions, national breeding programs, and commercial breeders in developed countries. In the last two years, approximately 20 new varieties have been released by developing countries, some of which are derived from germplasm distributed by CIP. Of the 118 countries producing potatoes worldwide, 88 are evaluating CIP's germplasm (Table 2).

Table 1. National seed improvement programs collaborating with CIP, 1976-1983.

Technique	Number of countries: Using	Receiving training/technical assistance	Receiving clean seed stock[a]
Multiplication of imported seed	33	33	...
Negative selection (roguing)	34	...	...
Positive selection	4	54	...
Clonal selection	15	...	25
Rapid multiplication	25	33	...
In vitro	4	14	...

[a]Clean seed stock from country varieties.

Table 2. CIP germplasm distribution and evaluation, 1983.

CIP region	Number of countries: Producing potato	Evaluating germplasm	Releasing or naming vars.
I	5	5	4
II	15	10	2
III	21	21	9
IV	15	7	1
V	14	7	2
VI	6	6	2
VII	14	14	2
Subtotal	83	70	22
Developed market economies	32	13	
Centrally planned economies	10	5	
Total	125	88	22

Other technologies are being transferred to national programs through CIP's regional program. One example is the use of diffused-light storage (DLS) technology, which was first introduced successfully to the Philippines in 1979 and has now been adopted in 22 countries. The rate of adoption has quadrupled annually in the last three years (*see* Thrust VIII, Fig. 1). When a technology is as readily adopted as DLS, the transfer process requires only a small input by the regional scientists to successfully introduce it elsewhere.

Associated with seed production is the importance of effectively controlling various species of PTM in the field and stores. CIP scientists in the regions and at headquarters are examining several possible control measures; in some cases, the projects are still in the initial phase of development. Because of collaborative research with national programs, several developing countries have already initiated parallel PTM investigations in collaboration with CIP entomologists (Table 3). These collaborative investigations should produce appropriate control measures more rapidly.

Table 3. Ongoing research in national programs, as of 1983, on control of potato tuber moth.

CIP region/ countries		Type of control: Chemical	Sex pheromone[a]	Plant repellant	Crop management	Biological
I	Peru	x	x (SYN)[b]	x	x	x
	Colombia	x	x	x		
II	Chile	x	x			
	Mexico	x	x (SYN)	x		
	Costa Rica	x	x (SYN)	x		
	Guatemala	x	x	x		x
III	Kenya	x	x	x		
	Rwanda	x	x		x	
IV	Egypt	x	x			
V	Tunisia	x	x	x		x
VI	India	x	x			
	Nepal	x	x	x		
	Sri Lanka	x	x	x		x
VII	Thailand	x	x	x		x

[a] CIP has distributed 5000 pheromone samples.
[b] SYN indicates countries collaborating in synthetic pheromone production.

Perhaps the most innovative approach to technology transfer has been the establishment of cooperative research networks between several countries in a geographical region. CIP's role in this development has been to provide assistance to a group of countries in identifying common problems that are then developed into specific research projects. The group assigns responsibility for these projects to research institutions within the member countries. This type of cooperative action eliminates the necessity of each country having to set up an extensive potato research program, especially when financial resources are limited.

The existence of these country networks permits CIP regional scientists to concentrate their technical support on those institutions that have been assigned leadership by network members. Subsequently, the diffusion of technology through training and consultancies is carried out by the countries themselves. Before this strategy can be successful, however, two other essential factors must be considered:

- strong administrative coordination is necessary, particularly during the formative years of the network;
- external funding is necessary to start individual research projects and to finance additional activities such as training and consultancies between countries, which are difficult to justify from national research budgets.

Five country networks have been established between 1978 and 1983, with CIP providing the administrative and technical support necessary for their development. Three networks are in Latin America (PRECODEPA, PRACIPA, and PROCIPA) and one each in Africa (PRAPAC) and Asia (SAPPRAD). The development of these networks will be discussed in detail in other sections of this report.

REGION I
Andean South America

The Andean Region is characterized mainly by high-altitude potato cultivation (up to 3800 m) between latitudes 10°N and 20°S in the five countries of Bolivia, Colombia, Ecuador, Peru, and Venezuela. In most of these countries, particularly at the higher altitudes, farm sizes are small and unmechanized and traditional native varieties are mainly used. Venezuela is an exception and has traditionally imported seed from North America and Europe.

CIP, since its inception in 1972, has maintained close cooperation with the national programs in this region. Region I headquarters was located originally in Lima, Peru, but in 1979 it was moved to Colombia with the Colombian national potato program of ICA in Bogota. With CIP's headquarters well established in Lima, the relocation of the regional headquarters to Colombia would better serve the needs of the northern Andean countries.

In this zone, resistance to late blight and nematodes is important, as well as frost resistance at the higher altitudes. These characters have been incorporated into the germplasm introduced by CIP and national institutions, and several varieties have already been selected, which have been adopted by countries in this region. The next step is a well-developed seed program in each country, where the improved varieties can be rapidly multiplied for distribution to farmers in the shortest possible time.

In Peru, a basic seed multiplication project, financed by the Swiss Government and administered by CIP, has been initiated. The new project is making maximum use of rapid seed multiplication methods developed at CIP. In eight months of operation, the project has established six subcenters throughout the country, and large numbers of virus-free, rooted plantlets have been produced for field multiplication. Apart from improved varieties, a number of native varieties with specific characteristics for the high altitudes, maintained pathogen free at CIP, have been included in the project.

Another way that CIP is able to assist national programs worldwide is through a consultantship, which can, when the need arises, provide immediate assistance. A recent example is a situation that occurred in Colombia in 1983 where a devastating outbreak of PTM was causing heavy damage to potato crops in parts of the country. The national program of Colombia contacted

CIP for assistance, and a CIP entomologist flew to the infected zones to help national scientists identify the causal pest, propose certain control measures, and verify that certain zones, proposed by the authorities, were free of the pest to avoid further destruction of the crop.

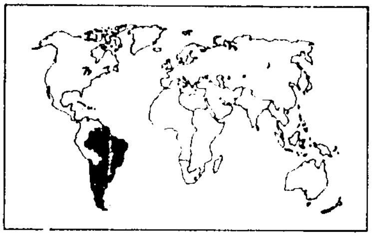
In this region, a close relationship has existed between national scientists through their participation in CIP research and training activities. At an initial meeting at CIP-Lima in 1982, national research directors decided to form a collaborative research network between the countries of Region I.

PRACIPA

The cooperative country network PRACIPA (Programa Andino Cooperativo de Investigación en Papa) was proposed in 1982-1983 among the five countries of Region I: Bolivia, Colombia, Ecuador, Peru, and Venezuela. Financing by Canada's International Development Research Centre (IDRC) is committed for five research projects, one in each country; however, an equal number of research projects still require financing as donors are identified. The projects, which will be initiated in 1984, include the following: 1) Bolivia, low cost seed improvement methods; 2) Colombia, control of white grubs; 3) Ecuador, rapid seed multiplication methods; 4) Peru, control of leaf miner fly; 5) Venezuela, low cost storage for seed and consumer potatoes.

Seed program development with PRACIPA members in Region I.

REGION II
Non-Andean South America



The four main potato-producing countries of this area are Argentina, Brazil, Chile, and Uruguay. The main production areas lie in the temperate latitudes. All of these countries, with the exception of some northern Andean areas of Argentina and Chile, cultivate *Solanum tuberosum*, which is particularly suited to temperate conditions. These countries, which traditionally have used European varieties and imported seed annually, are highly motivated to reduce their dependence on expensive imported seed and to improve local seed production.

There is an excellent level of technical skills available in the national potato programs of this region. The CIP regional scientist has been able to identify several institutions with which collaborative projects or research contracts have been established, which complement several aspects of CIP research at Lima. In Chile, one project with the national program of INIA will identify long-day adapted parents for CIP's breeding program; another will assist CIP in resolving the problem of inadequate seed production of TPS for research and distribution. In Argentina, a collaborative project with the national program of INTA has produced several clones that have been valuable for national programs in Asia and East Africa. Similar projects or research contracts also exist in Brazil.

The national potato programs in this region also decided to organize collaborative research networks—one as early as 1978, the other in 1982—to pool their scientific resources for the mutual benefit of all member countries.

PRECODEPA

The effectiveness of the cooperative networks can be illustrated by the first country network, PRECODEPA (Programa Regional Cooperativo de Papa), which was initiated in 1978 with ten research projects. The original members included CIP, Costa Rica, Dominican Republic, Guatemala, Honduras, Mexico, and Panama. During the past five years, two new members have joined, Cuba and El Salvador; seven of the original projects remain; and two new projects have been added. The status of the present membership and the research projects is shown in Table 4.

For the first two years CIP provided an administrative coordinator, but the position is now filled by the annual appointment of a coordinator selected from among the scientific staff of the member countries.

Research in the major projects has progressed rapidly to the point that results and technology have been transferred to most countries within the original group (Table 5). Three areas—late blight-resistant germplasm, seed improvement programs, and rustic storage technology—have not only been

Table 4. Current projects and countries of the country network PRECODEPA.

Project[a]	Leader	Subleader
1. Late Blight	Mexico	
2. Seed Production	Mexico	Guatemala, Costa Rica
3. Tuber Moth	Costa Rica	Guatemala
4. Golden Nematode	Panama	Mexico
5. Bacterial Wilt	Costa Rica	Dominican Republic
6. Rustic Storage	Guatemala	
7. Socioeconomics	Regional	
8. Processing	Guatemala	Mexico
9. Regional Trials	Cuba[b] El Salvador[b] Honduras Dominican Republic and other members	

[a]Numbers 1-7 were the original research projects, 1978.
[b]New member as of 1983.

transferred to various programs, but are already having considerable impact at the farm level.

The most striking example of this impact has been reported in detail by the Dominican Republic. In 1983, a government-inspired production campaign led to a spectacular increase in the potato crop, which was way beyond the storage capacity of the government price stabilization agency (INESPRE). Through technical expertise available in the PRECODEPA network – Panama and Guatemala – the Dominican Republic was able to build and load four large rustic stores within four weeks and save their surplus consumer crop.

During the year, the members of PRECODEPA requested an independent evaluation of the network to review its accomplishments over the last five years. The findings of the evaluation will be reported in 1984.

Table 5. PRECODEPA country network, research transfer between member countries.

Member country	Seed production	Late blight	Rustic storage	Tuber moth	Golden nematode
Mexico	x[a]	L[b]	x		x
Costa Rica	L	x	x	L	
Guatemala	x	x	L	x	x
Honduras	x	x	x		
Panama	x	x			L
Dominican Republic	x		x		
El Salvador		x			

[a]The symbol x signifies countries to where technology was transferred by the leader country and is being tested and adapted.
[b]The symbol L signifies the leader country of the project.

PRECODEPA ASSISTS THE DOMINICAN REPUBLIC WITH SURPLUS STORAGE OF CONSUMER POTATOES

A deficit in rice production in 1983, prompted the Dominican Republic Government to promote potato production through radio and television by offering credits and guaranteed purchase of the crop by the government price stabilization agency (INESPRE). As a consequence, a surplus was produced, which was purchased by INESPRE, with a storage capacity of only 1500 tons. Additional storage facilities had to be found immediately.

Potato scientists in the Ministry of Agriculture were consulted, and technical documents on storage were produced from Guatemala and CIP. Scientists were immediately sent to Guatemala for training in rustic storage construction. On their return, they recommended appropriate storage designs and selected the construction site. Four stores were built for the surplus potato crop, using local materials such as cane and burned pine logs. To ensure good storage, it was decided to use growth inhibitors, and information on the availability and application of these compounds was obtained from potato scientists in Panama.

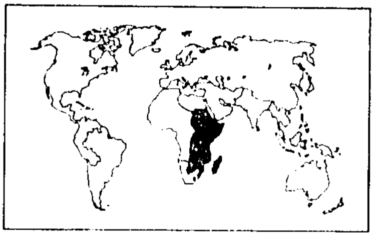
The 1200-ton surplus of consumer potatoes was stored in the rustic stores just four weeks after INESPRE and the Ministry decided to take action. Results were highly successful—the potatoes were stored for six months with losses of less than 2%.

This brief account illustrates how the resources within a country network such as PRECODEPA rapidly assisted a member country in solving an emergency situation.

PROCIPA

The country network PROCIPA (Programa Cooperativo de Investigaciones en Papa) was established in 1982 between Argentina, Brazil, Chile, and Uruguay, with CIP providing a small amount of financial assistance to start the projects, which included research on seed tuber production (Chile), breeding for virus resistance and earliness (Argentina), and efficient plant use of phosphorus and resistance to aluminum toxicity (Brazil). Although the more important projects have been identified and leader countries assigned, the network is still actively seeking external funding to initiate additional research projects.

REGION III
Tropical Africa



This region, headquartered in Kenya, includes the countries of East and Central Africa. In this zone of the world, the potato is an important cash crop in countries such as Kenya, Rwanda, Burundi and Tanzania; and at least in one–Rwanda–it is the staple diet in the north. Many areas in Region III are in relatively high altitudes (up to 2700 m), thus the potato is well adapted to the climatic conditions.

The CIP regional base in Nairobi relies on the excellent facilities provided by the Muguga station of the Kenya Agricultural Research Institute (KARI), where Kenya's plant quarantine station is located. CIP has established a center at Muguga to multiply and distribute improved germplasm. Because of available expertise in handling plants in quarantine, the station has a great advantage in being able to distribute plant material that meets proper phytosanitary requirements. CIP has provided training to the station staff in such techniques as meristem culture and rapid multiplication–techniques which they also use for crops other than the potato.

The most important diseases in East Africa are late blight and bacterial wilt. The latter is especially important whenever a seed improvement program is initiated in any of the East African countries. A contract with the National Agricultural Laboratories in Kenya is identifying genetic resistance in CIP germplasm to local pathotypes. This identification enables the Region III scientists to better define clones adapted for specific agroclimatic conditions. As a result, five new varieties, multiplied by the national potato program of Rwanda (PNAP) in 1983, are also being tested by national programs in Burundi and Zaire. The germplasm distributed from Kenya is also being adopted in Tanzania, Mozambique, and Madagascar.

In both Rwanda and Burundi, CIP has special programs, financed by the government of Belgium, that are coordinated by CIP staff based in each of these countries. The national program of Rwanda (PNAP) has been acknowledged by the Ministry of Agriculture as an ideal model for the development of other national research programs such as maize improvement. PNAP has collaborated closely with the potato programs of Burundi and Zaire by supplying seed of improved varieties and by providing training in other technologies. The logical outcome of this inter-country collaboration was the organization of a country research network.

PRAPAC

The country network PRAPAC (Programme Regional d'Amelioration de la Culture de Pomme de Terre en Afrique Centrale), which includes Burundi, Rwanda, and Zaire, was established in late 1982. Throughout 1983, only

Representatives of PRAPAC are meeting to evaluate on-farm research conducted in member countries.

training activities and research collaboration took place, based on available funding. The research projects assigned to individual national programs will be initiated when funding becomes available. The major projects include 1) bacterial wilt and late blight resistance and control (Burundi and Rwanda); 2) potato seed production including TPS (Rwanda); and 3) potato production in different ecological zones (Zaire).

REGION IV
Near and Middle East

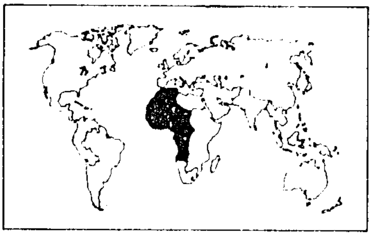
In this region, the potato is a major food crop in Turkey and Egypt, which produce 3 million and 1 million tons per annum, respectively. In Cyprus, Lebanon, and Egypt the potato is an important export crop.

Region IV headquarters was first established in Lebanon in 1974, but in 1976 a new base was opened in Turkey, where it remained until 1983. In the late 1970s, an intensive program on germplasm evaluation was started in Turkey, emphasizing the selection of clones resistant to the major virus diseases of the region. During the past seven years, the scientific staff of the Turkish potato program have grown in both numbers and experience. There is now a complete staff in the program with sufficient expertise to cover all major research priorities.

Most other countries of the region, except for Turkey, use imported seed of European potato varieties. During 1983, in agreement with the Egyptian Ministry of Agriculture, the regional headquarters was moved to Cairo, where a major research project will test the alternative technology of producing both consumer and seed potatoes from true potato seed (TPS). This technique could have considerable advantages to the small potato producers in Egypt by reducing the cost of planting materials. The move to Egypt from Turkey will enable Egyptian scientists to participate as instructors in several workshops and other training activities planned during the next two years, as most of the training in Region IV in Arabic.

Turkey has continued its collaboration with CIP through a contract to breed and select virus-resistant material, using parents and segregating progenies provided by CIP. Any varieties or important clones derived from this contract will be freely available to other countries in the region.

REGION V
North and West Africa



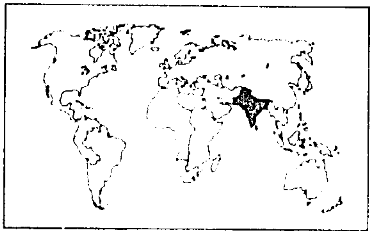
The principal potato-producing countries of North Africa – Tunisia, Algeria, and Morocco – were assisted for many years by the CIP regional program when it was based in Turkey. During 1976-1981, a special project financed by the Canadian International Development Agency (CIDA) to improve seed production in Tunisia was coordinated by a Tunisia-based CIP scientist. During this period, a potato training program in French was developed with the Centre de Perfectionnement et de Recyclage Agricole (CPRA Saïda), a Tunisian training center. In 1982, CIP decided to create a new region to better meet the needs of the francophone countries of Africa, particularly those in West Africa. Since training was expected to be one of the important initial requirements for this region, Tunisia, because of its background in research and training, was chosen for the new headquarters.

In Tunisia, a good research infrastructure exists, and several collaborative projects have been initiated with different institutions such as the National Institute of Agricultural Research (INRAT). The control of PTM is being studied, and the plan for 1984 is to add another scientist to the regional team to support this important project. This pest is considered in many African countries to be a major source of yield loss, both in the field and stores.

In West Africa, the potato is traditionally cultivated in the highland areas of Nigeria and Cameroon. In other West African countries such as Togo and Mali it is a relatively minor crop; however, requests for technical assistance to increase potato production from these and other countries is increasing. In most West African countries, the potato will be grown at lower altitudes in relatively warm climates; thus, technologies developed by CIP to improve production in these climates is of immense importance. For example, the work being done in Thrust VI has a direct application.

Senegal has been moving in this direction and has already named one CIP clone adapted to warm climates and is investigating appropriate agronomic technology to improve yields. Senegal also has the potential to serve as a suitable base where training can be made available to other countries of West Africa with similar climatic conditions.

REGION VI
South Asia



This region includes those countries of the Indian subcontinent, where more than 11 million tons of the potato are produced annually. The regional headquarters is based in India, where average annual production exceeds 9 million tons.

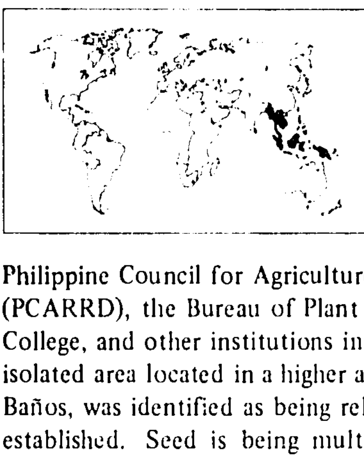
Potatoes in Region VI are grown in a range of climates from the high areas of the Himalayas to the northern plains of India, the coastal areas of Sri Lanka, and the flat riverine areas of Bangladesh. In India, the scientific team of the Central Potato Research Institute (CPRI) in Simla works entirely on potatoes and has bred many improved varieties and has developed a well-organized seed multiplication system, which supplies seed of excellent quality. The knowledge on potato produc n that exists in India can be of benefit to surrounding countries; for exampl, Pakistan and Bangladesh are starting to use techniques similar to those used in India for producing quality seed.

Both Pakistan and Bangladesh have collaborated closely with CIP for several years. Pakistan was a CIP regional headquarters until it was transferred to Tunisia in 1981. A bilateral project in Pakistan on improving potato production, funded and implemented by the government of Switzerland, has been confirmed for 1984 with a resident three-man team that includes a CIP scientist. Additional technical assistance for the project will be available from Region VI and CIP-Lima when requested. In Bangladesh, CIP assigned its scientist to be a member of the International Agricultural Development Service (IADS) team. This team is giving technical support to the overall development of the agricultural research program under the auspices of the Bangladesh Agriculture Research Council (BARI). The CIP scientist will be helping to identify suitable, locally produced varieties and to develop a basic seed production program. His research project is being supported by the Australian Government.

In Nepal, Bhutan, and Sri Lanka three different situations exist. In Nepal, a bilateral Swiss team has been assisting the national program since 1979, when CIP completed its special project in that country. In Bhutan, CIP has helped the Ministry of Agriculture start a potato program by using special project funding provided by Helvetas of Switzerland. The main objective of the Ministry is to stabilize potato production, since the potato is an important export crop to India both for consumption and seed. The CIP scientist stationed in Bhutan is helping to build a self-reliant potato program, even though a shortage of scientific staff exists. CIP's direct input will eventually be phased out as a new Swiss bilateral project assumes full responsibility in 1985.

Potato research in Sri Lanka is conducted by national scientists of the Ministry of Agriculture, several of whom were trained by CIP. Sri Lanka is actively using many technologies originally tested by CIP, but adapted by national scientists to local conditions. These technologies include low cost storage, rapid seed multiplication methods, and selection of clones with heat tolerance and late blight resistance. The advances made by Sri Lanka in investigating the use of TPS have given this country the lead role in the Southeast Asian country network SAPPRAD (for details *see under* SAPPRAD). This new system of potato production is already being tested by farmers. The government's policy to eliminate reliance on seed importation has resulted in no further seed being imported since 1982. Sri Lanka also has two research contracts with CIP, covering selection of heat tolerant clones and resistance to local strains of bacterial wilt.

REGION VII
Southeast Asia



In this area of the world potatoes are of major importance in the Republic of Korea, Vietnam, Indonesia, Burma, and China. China leads the developing world in potato production by producing 50 million tons each year.

Region VII headquarters, based in the Philippines, collaborates closely with the Philippine Council for Agriculture and Resources Research and Development (PCARRD), the Bureau of Plant Industries, the Mountain State Agricultural College, and other institutions in Luzon and Mindanao. Santa Lucia, a small, isolated area located in a higher altitude valley near CIP's headquarters at Los Baños, was identified as being relatively pathogen-free and a testing site was established. Seed is being multiplied at this site for distribution to other countries in Region VII. Sta. Lucia is also a valuable training site, where modifications of the rapid multiplication system developed in Vietnam are being taught to scientists from other national programs in the region.

Many potential potato-producing areas in this region are at medium altitudes (500 to 1000 m). Research is needed to solve the specific growing problems in these altitudes such as seed supply, warm temperatures, and bacterial wilt. Although traditional seed technology may suffice for some countries in the region, several others are beginning to test nontraditional methods. An outstanding example of this type of testing is Vietnam, where the national program in Dalat is using tissue culture techniques to multiply plantlets in vitro and to provide farmers with rooted plantlets. The lessons learned from Vietnam's successful potato project are now being tested in the Philippines.

Tropical agronomy research on potato production in warm climates is important for countries in Region VII. To help augment this type of research, CIP sent one of its agronomists to Indonesia to work for six months with Indonesian scientists in designing a series of tropical agronomy experiments. This type of short-term assignment is becoming an important part of CIP's research program, as it is an effective way for CIP scientists developing a technology to collaborate in its testing and transfer to national programs.

Some of the national programs in this region, before making a major investment in potato research, have requested CIP to study the existing situation and recommend a proper framework for research. Studies have been completed for South Korea, Burma, and Indonesia.

In 1981, several countries in the region proposed a plan to organize a cooperative research network, similar to PRECODEPA. The government of Australia committed funding and the network SAPPRAD was organized in 1982.

SAPPRAD

The country network of SAPPRAD (Southeast Asian Program for Potato Research and Development), initiated in Region VII in 1982, includes five countries, each having one major project to contribute. Several major areas of research are potato production from TPS, tropical agronomy for potatoes, and breeding for potato adaptability to the tropics. In addition to Sri Lanka, mentioned previously, the SAPPRAD countries are Indonesia, Papua New Guinea, Philippines, and Thailand. Distances between these countries are greater than in other networks, therefore, project coordination requires greater attention. The first administrative coordinator, a CIP staff member, will be superseded in 1984 by the appointment of a full-time scientist from one of the member countries.

Manpower Development Through Training

Since CIP's early days, it was recognized that improving potato production in Third World countries depended not only on CIP's ability to generate new technology, but, more importantly, on the abilities of researchers, extensionists, and educators in national potato programs to make use of the newly generated technologies.

CIP recognized that:

- national programs have the ultimate responsibility to reach farmers
- information and expertise on potato production are not available in many developing countries
- national programs must be capable of using new or improved technologies–germplasm and production techniques
- the flow of technology transfer should operate in both directions, with the potential user participating in the selection of appropriate technologies

These ideas formed the basis for CIP's program, *national manpower development through training.*

Philosophy and Objectives

CIP's training program is based on the philosophy that research and extension efforts conceived and executed in collaboration with national programs will be more appropriate for the conditions of the country and have a longer-lasting beneficial effect than those conceived and executed independently by CIP. This philosophy is further based on the conviction that national programs are in the best position to examine the growing conditions of their crops, analyze government agricultural policies, assess research and training needs, and undertake the transfer of technology to farmers. CIP, in its relationship with national programs, plays a catalytic role by addressing individual country priorities for research and training. CIP's training activities, therefore, are directed toward improving the abilities of national programs to:

- identify research priorities and needs
- conduct research on priority problems
- use existent technology that has been identified as relevant to the country's needs
- evaluate research results from other sources under home-country production conditions
- participate in transferring appropriate technologies within their countries and surrounding countries
- train others to identify existent technology and research needs, to conduct research and evaluate results, and to participate in the transfer process

Regional scientists and national program leaders in Chile plan research and training activities.

Training and National Program Development

Training offered by CIP is directed at the national potato programs of developing countries. CIP's regional research and training staff, assigned to seven regions worldwide, establish and maintain dialogue with national program leaders to analyze production potential and constraints, identify research needs, and assess training requirements.

The process of planning collaborative research and training allows for a continual analysis of the state of national program development. In Figure 1, advanced programs where there is a demonstrated potential for increasing potato production and a national policy to increase production are at the top of the scale. Research and extension programs with stated objectives and credibility within the country complement the national policy. The bottom of the scale represents national programs in countries that possess potential for increasing potato production, but where there is lack of national interest to improve production. There may be some isolated areas where farmers produce potatoes and where a few researchers and extensionists have shown interest, but government support may be nonexistent. In these countries, CIP attempts to establish contact with the interested parties, even though organized programs do not exist.

Through communication between CIP regional staff and national program leaders, collaborative plans for research and training emerge. These plans address national production problems and, more importantly, reflect the contributions that can be made by existent expertise in transferring improved technology and in developing manpower through training. Based on experience over the past twelve years with some 60 national potato programs, CIP offers two types of training: production-oriented and specialized.

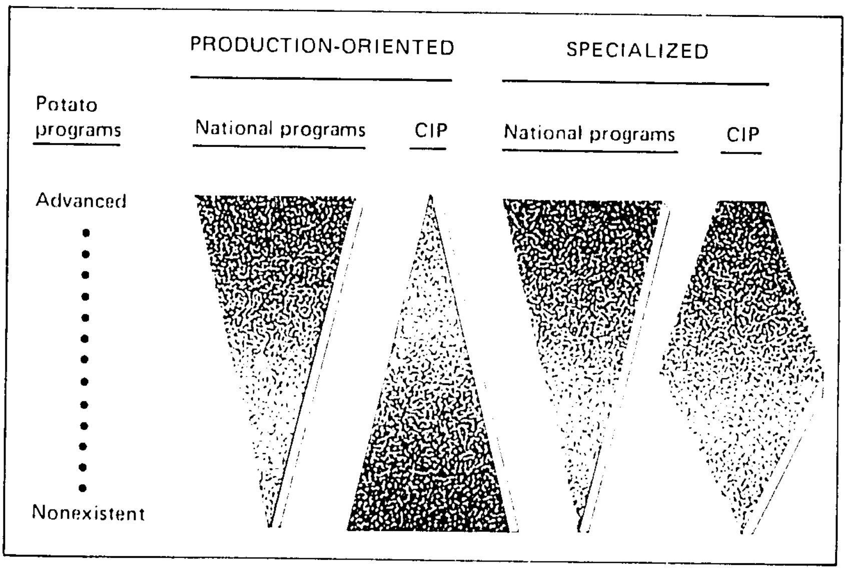


Figure 1. Training interaction between CIP and national potato programs.

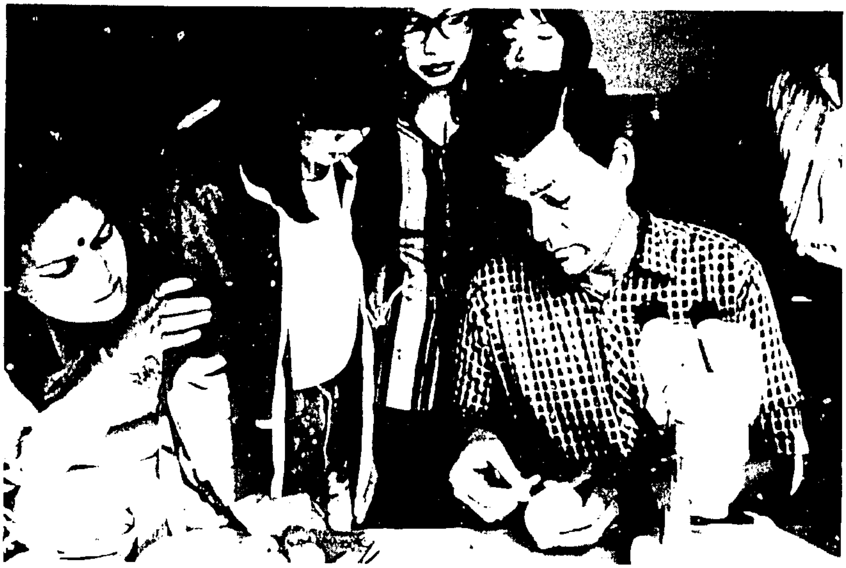
Production training (left) answers farmer questions, while specialized training (right) helps to conduct research.

Production-oriented training focuses on general principles of potato production and is designed to enable national researchers and extensionists to respond to farm-level production situations. This type of training is conducted only in the regions as international or in-country short courses. Advanced national programs provide direct input by assisting in organizing activities and by instructing. Conversely, in those countries where expertise is lacking, it is necessary for CIP to provide greater input.

Advanced degree thesis research, India.

Specialized training concentrates on areas of research for which CIP is the principal source of information and experience. The objective is to provide researchers with additional skills to conduct research. Various components of this training include: headquarters and regional specialized courses; midcareer and individual training; training of training assistants; postdoctoral training; and scholarships. Specialized training is similar to production-oriented in that the more advanced national programs provide greater training inputs than the less advanced ones.

For both types of training, where country programs do not exist, no CIP input is made until the countries have determined their research and training priorities. As national capabilities emerge, the need for direct input from CIP often dimin-



CIP regional specialized training, Vietnam.

ishes. For example, advanced programs may need CIP only for certain specialized activities where expertise is lacking and may not need CIP at all for production training. This strategy is reflected in all planning for training.

Individual training at CIP Peru focuses on special needs of national programs.

Planning Ahead with National Programs

Recognizing the importance of capable manpower, CIP's regional staff, as well as other staff traveling to the regions, discuss training needs with national program leaders. During CIP's annual meeting in Lima, regional and headquarters staff plan training activities around these needs. National program leaders often participate in the discussions. From these interactions, CIP projects a five-year plan of group training activities that is revised annually. Plans for other types of training – midcareer or individual – are also reviewed.

This planning process ensures that:

- research topics of priority to CIP's mandate and individual country needs are included, particularly where emerging technologies are ready to be transferred and evaluated under local farming conditions
- training is properly phased so that the topics are taught over a period of years at strategic sites around the world
- CIP's scientific staff know their future involvement and can plan accordingly
- national programs can plan ahead
- CIP's training and communications staff and scientists can prepare courses and training materials

This process, more specifically, allows national programs time to plan manpower development, identify candidates for training, prepare for involvement in the training, and budget for sharing the costs. The plan reflects a manpower development component to CIP's seven priority research areas: 1) germplasm management, 2) production of potatoes from true seed, 3) potato production in warm climates, 4) postharvest technology, 5) on-farm research, 6) seed production, and 7) general production techniques.

CIP regional course on rapid multiplication techniques, Colombia.

National program scientist in Colombia instructs in a specialized course.

The strategy is to hold specialized courses at CIP headquarters at least twice before they are conducted in the regions. This allows sufficient time to develop appropriate teaching methods and training materials, gives participants in the initial courses time to adapt what they have learned to home-country production conditions, and enables them to share their experience in future training activities.

From 1984 through 1989, CIP has planned 179 courses: 59 specialized, and 29 regional and 91 in-country production. National program staff will provide a large part of the manpower needed to do the training. In 1983, as could be expected, in specialized courses 50% of the instructors were CIP international staff; however, in production training, only 20% were from CIP.

Training funded by the United Nations Development Programme (UNDP) and the German Foundation for International Development (DSE) has been used primarily to help national programs assume responsibility for organizing and conducting training. For example, since mid-1981, a portion of the UNDP project has permitted national programs to conduct 18 regional courses on seed production, storage, and on-farm research. Through these courses, 152 national instructors trained 471 participants from 45 different countries. A similar experience occurred in 1983 with two DSE courses: 30 national instructors trained 35 participants representing 13 different countries. Table 1 presents a complete list of all CIP group and individual training activities for 1983.

Communications Support

CIP's long-term plan to the year 2000 calls for "the development of a global communications network for the transfer of technology," involving national scientists, extensionists, and educators in research and training. Communications support is an essential element to plan, synthesize, produce, and evaluate publications and visuals aids, and also to assimilate and interpret feedback.

Table 1. CIP training activities, 1983.

Region	Activity	No. of participants	No. of countries	Type[a] of training
Region I				
Peru	Production with special emphasis on seed production[b]	16	5	P
Colombia	Germplasm management	12	8	S
Colombia	Storage[b]	24	7	P
Colombia	CIP/CIAT/IITA global workshop on root and tuber crop propagation[b]	16	12	S
Colombia	Pathological problems in seed production[c]	24	10	S
Region II				
Chile	Storage workshop	11	5	P
Brazil	Production[c]	18	3	P
Chile	Production and storage of certified seed[b]	18	7	P
Mexico	Potato production from true seed	12	4	S
Region III				
Zaire	Production	25	1	P
Malawi	Production	40	1	P
Rwanda	Production	30	1	P
Rwanda	Production	21	1	P
Rwanda	On-farm research workshop[b]	12	4	S
Zaire	Production	15	1	P
Zambia	Seed production	14	8	P
Rwanda	Production	17	1	P
Region V				
Tunisia	Production	20	12	P
Tunisia	On-farm research methodologies and storage[b]	16	11	S
Region VI				
India	Production	21	4	P
Bhutan	Production	17	1	P
Sri Lanka	Storage[b]	27	2	P
Bangladesh	Storage[b]	21	1	P
Region VII				
Philippines	Production and germplasm management	20	7	S
Headquarters-Peru				
Agronomy for potato in hot tropics		8	7	S
Potato production from true seed[c]		8	8	S
Individualized training		48	28	S
Training of assistant trainers		1	1	S
Scholarships		12	7	S
Student assistantships		22	2	S
Student practical work		28	1	S

[a] P = production; S = specialized.
[b] United Nations Development Programme (UNDP).
[c] German Foundation for International Development (DSE).

Communications support plays an important role in the support of training activities, bringing together national program staff, CIP scientists, and training, communications and information specialists. When this interaction takes place—at CIP headquarters or in the regions - a better, in-depth understanding is gained about the world of the intended recipient of CIP's technology. This information is used by CIP communications specialists to develop more appropriate training materials. The importance given to training materials is illustrated in Table 2, i.e., more than 25% of CIP's communications effort is dedicated to the training program.

Production training materials. The basis for production training is a course organization manual that is intended to be used as a guide. It suggests topics to be covered and training materials to be used such as *Technical Information Bulletins* (TIBs) and visual aids. TIBs and visual aids are prepared for intermediate level professionals and can be used for individual study, potato production, experiments, training, or adapted for use by farmers. Valuable feedback is received through evaluation forms inserted in the manuals and other training materials.

Specialized training materials. For specialized training, instructors prepare their materials in the form of class notes or handouts. The format is similar to the TIBs, but subject matter is more technical, which enables the user to conduct research. After a specialized activity, training materials are published in the form of *Specialized Technology Manuals* (STMs); for example, STMs on germplasm management have been produced in Spanish, and on potato production in warm climates and potato production from true seed in English and Spanish. Although STMs have been produced in only two languages, CIP recognizes that information in other languages is also necessary.

One method of processing information in other languages is through copublication, i.e., contractual agreements with publishers to translate and publish key documents. Copublication has already had some success among the International Agricultural Research Centers. CIP is making contact with publishers, primarily through participation in international book fairs, who are interested in cooperating with national programs on publishing relevant information at affordable prices.

Table 2. Communications jobs processed at CIP headquarters, 1983.

	Publications[a]				Others[b]				
Year	Adminis-tration	Re-search	Train-ing	Sub-total	Adminis-tration	Re-search	Train-ing	Sub-total	Total
1982	31	63	54	148	309	321	293	923	1071
%	3	6	5	14	29	30	27	86	100
1983	8	38	53	99	475	512	305	1292	1391
%	6	3	4	8	34	36	22	92	100

[a] Includes annual report, technical bulletins, circulars.
[b] Includes visual aids, translations, graphs.

Library and Documentation Services

A constant flow of the latest research information to national program researchers is essential for the development of a global communications network. CIP's library is primarily designed to provide specialized services for CIP scientists. This role, however, is rapidly changing as demand for providing services to 1300 national researchers who have received specialized training since 1978 is increasing.

Presently, CIP's library is assisting national students and researchers at headquarters and in the regions with bibliographic requests. Table 3 highlights the more important library activities for 1983. Growth in the library collection reflects areas of priority interest at CIP: viruses, seed quality, embryological studies, growth inhibition, efficiency of nutrient uses, nutritive value of the potato, stress and survival of vegetable crops, and demand price and consumption of potatoes. Three bibliographies were prepared during the year on plant growth regulators, tissue culture, and true potato seed, flowering, and pollination. In addition, computer searches were carried out for CIP scientists mainly through the following data bases: CAB, FAO, and NAL.

Table 3. CIP library collection, additions, and services, 1983.

Library:	Total 1982	Additions 1983	Total 1983
Collection			
Book collection	4569	519	5088
Journal titles	398	19	417
Journals by subscription	83	3	86
Annual report	136 (613)[a]	7 (99)[a]	143 (712)[a]
Bulletins	360	7	367
Reprints	3426	405	3831
Services			
Loans to CIP staff and training program	5168		6499
Interlibrary loans	427		582
External users	350		195
International exchange	321 (68)[b]	46 (5)[b]	367 (73)[b]
Photocopies			
Requests to CIP library			8452
Requests by CIP library			1217

[a] Titles registered (total annual reports).
[b] Libraries (countries).

Follow-up on Technology Transfer

In the process of technology transfer, the phase following actual instruction is as important as the training itself. Often, the training activity is the point of departure for technology transfer. The impact of training and the applicability of a technology, however, can only be seen when action is taken by the

Preliminary on-site visit with former CIP trainees to develop a follow-up questionnaire.

Follow-up visit to tropical agronomy field experiments in Vietnam.

participants in their work. CIP's follow-up is composed of two complementary aspects: follow-up support and follow-up evaluation.

Follow-up support is continuous communication and assistance provided to former trainees that enable them to conduct research and extend potato technologies in their home countries. Through CIP's network of regional staff and linkages with national programs, contact with former trainees can be maintained by frequent visits by regional scientists and by CIP training and communications specialists. During these visits, CIP staff participate with trainees in evaluating germplasm, planning and reviewing research and training, assessing laboratory needs, examining experimental station and on-farm trials, and fostering government research efforts for improving potato production.

Former trainees are kept informed of CIP's worldwide activities through the *CIP Circular*, which includes information on CIP's latest research worldwide, national program research, training events, and recent publications. The intent is to provide information in such a form that it will generate ideas and motivate action among the intended audience of the *Circular*.

Another means of follow-up support is to incorporate course materials into manuals and distribute them to participants, corresponding national program leaders, and instructors. These follow-up manuals inform co-workers of what was covered in courses and provide additional support for participants' work in their home countries.

Follow-up evaluation is a continuous assessment system of former trainees' achievements and needs. This type of evaluation is imperative in a dynamic system of manpower development.

The overall strategy of the follow-up evaluation is to involve national program, as well as CIP regional and headquarters staff, in the evaluation process. A questionnaire serves as a guide for on-site evaluation and continuous feedback. The objectives of the evaluation are 1) to continually assess effect

Trainees are pretested during a seed production course, Peru.

of training, 2) to provide feedback for improvement of CIP's research and training, and 3) to direct follow-up support to former participants.

The questionnaire and interviews obtain information on five major indicators:

1. Use of training: changes in percent of time dedicated to potatoes following the training, consultation, adaptation, or duplication of training materials.
2. Training of others: how many and what types of persons have national program personnel trained in topics covered during the training; what situations limit training?
3. Involvement in research: since the completion of training, have they become involved in research related to what they learned; what situations have limited their research involvement?
4. Communication with farmers: have they talked with farmers, what practices where changed, what limits farmer adoption?
5. Contact with CIP: what kind of contact have they had with CIP, how useful have these contacts been, what type of contact is needed?

The questionnaire was mailed to more than 1000 former CIP trainees. The first 333 responses gave the following indications:

- Although 32% indicated their profession to be agronomist, 47% indicated their main responsibility to be research.
- After the training, former trainees appear to spend more time working on potatoes. Ninety indicated spending 0-24% of work time on potatoes prior to the training; this was reduced to 63 who were spending the same percentage after the training. Those spending 75-100% of their time on potatoes increased from 121 to 142 after training.
- A total of 186 indicated they had begun, completed, or published 408 research projects related to their training.
- A total of 264 have used what they learned to train over 31,000 others: 15,100 farmers; 7500 researchers, extensionists, and educators; 6100 university students; and 1700 potato workers from other countries.

Future Indications

The effect of training for manpower development will ultimately be seen in what national researchers, extensionists, educators, and agribusinessmen accomplish in their working environments. CIP's role in training is to assist in those areas of expertise where CIP is the major source of information and to help national programs conduct training for which they have a comparative advantage. The preliminary indications of an evaluation underway indicate that this is happening.

It is indeed imperative that research be initiated and training conducted as a result of CIP's initial training. As we look to the future, it is evident that 1) specialized training will need to be continued, 2) follow-up support in making latest research available to national programs will need to be strengthened, and 3) efforts that make possible the involvement and participation of communications support units within national agricultural research systems be initiated.

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Financial Report

COLERIDGE Y ASOCIADOS
REPRESENTANTES DE
ARTHUR ANDERSEN & CO.
LIMA — PERU

To the Board of Trustees of
International Potato Center - CIP:

We have examined the balance sheet of INTERNATIONAL POTATO CENTER - CIP, (a non-profit organization incorporated in Peru) as of December 31, 1983, and the related statements of sources and application of funds and changes in financial position for the year then ended. Our examination was 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 as of December 31, 1983, and the sources and application of funds and the changes in its financial position for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

The financial statements as of December 31, 1982 presented for comparative purposes, were examined by other independent public accountants whose report dated April 8, 1983 was unqualified.

Coleridge y Asociados

Lima, Peru,
February 29, 1984

INTERNATIONAL POTATO CENTER – CIP

BALANCE SHEET
AS OF DECEMBER 31, 1983 AND 1982
(Expressed in U.S. dollars)

	1983	1982
ASSETS		
CURRENT ASSETS:		
Cash on hand and in banks	1,484,240	1,240,636
Accounts receivable –		
Donors	1,459,359	609,961
Executives and employees	56,700	49,365
Current portion of loans to executives and employees	150,911	144,425
Other	168,419	239,894
	1,835,389	1,043,645
Inventories of laboratory and other supplies	567,007	457,619
Prepaid expenses	46,385	41,399
Total current assets	3,933,021	2,783,299
LONG-TERM LOANS TO EXECUTIVES AND EMPLOYEES (Note 3)	712,147	754,527
FIXED ASSETS (Note 4)	7,336,468	6,707,572
	11,981,636	10,245,398

The accompanying notes to the financial statements are an integral part of these balance sheets.

	1983	1982
LIABILITIES AND CAPITAL AND UNEXPENDED FUNDS		
CURRENT LIABILITIES:		
Loans and bank overdrafts	844,418	910,219
Accounts payable	911,229	773,150
Grants received in advance	451,773	–
Accruals and other liabilities	134,719	201,394
Total current liabilities	2,342,139	1,884,763
SEVERANCE INDEMNITY LIABILITY, net of advances of US$18,593 in 1983 and US$15,771 in 1982	379,242	185,980
CAPITAL AND UNEXPENDED FUNDS:		
Funds invested in fixed assets (Note 5)	7,336,468	6,707,572
Unexpended funds –		
Working funds	786,000	745,000
Operations	544,264	191,562
Special projects	593,523	473,521
Funds for additions to fixed assets	–	57,000
	1,923,787	1,467,083
	9,260,255	8,174,655
	11,981,636	10,245,398

The accompanying notes to the financial statements are an integral part of these balance sheets.

INTERNATIONAL POTATO CENTER – CIP

STATEMENT OF SOURCES AND APPLICATION OF FUNDS FOR THE YEARS ENDED DECEMBER 31, 1983 AND 1982

(Expressed in U.S. dollars)

	1983	1982
SOURCES OF FUNDS:		
Operating grants –		
Unrestricted	3,728,624	3,716,094
Restricted	5,704,450	5,271,601
	9,433,074	8,987,695
Special project grants	1,425,965	971,894
Working fund grants	786,000	745,000
Grants for fixed asset additions	525,629	563,049
Other income, net	230,930	124,253
	12,401,598	11,391,891
APPLICATION OF FUNDS:		
Operating costs –		
Potato research program	2,351,533	2,453,021
Research services	1,098,865	883,620
Research program and training	2,864,073	2,549,481
Library and information services	389,051	423,829
Other operating costs	1,289,060	1,331,698
Administrative costs	1,127,158	967,697
TAC revision and symposium	–	254,041
	9,119,740	8,863,387
Special projects –		
Costs	832,442	467,720
Grants returned	–	30,652
	9,952,182	9,361,759
ADDITIONS TO FIXED ASSETS	525,629	563,049
	10,477,811	9,924,808
Unexpended funds	1,923,787	1,467,083

The accompanying notes to the financial statements are an integral part of this statement.

INTERNATIONAL POTATO CENTER – CIP

STATEMENT OF CHANGES IN FINANCIAL POSITION FOR THE YEARS ENDED DECEMBER 31, 1983 AND 1982

(Expressed in U.S. dollars)

	1983	1982
FUNDS WERE PROVIDED BY:		
Operations –		
Unexpended funds	1,923,787	1,467,083
Provision for severance indemnities	207,323	28,074
Total funds provided from operations	2,131,110	1,495,157
Decrease in long-term loans to executives and employees	42,380	–
Increase in funds invested in fixed assets	628,896	693,969
	2,802,386	2,189,126
FUNDS WERE APPLIED TO:		
Fixed asset acquisitions –		
Additions	525,629	563,049
Net cost of replacements	103,267	130,920
Increase in long-term loans to executives and employees	–	66,015
Payments and advances of severance indemnities	14,061	10,017
Prior year's unexpended funds	1,467,083	999,487
	2,110,040	1,769,488
INCREASE IN WORKING CAPITAL	692,346	419,638
INCREASE IN WORKING CAPITAL DUE TO CHANGES IN THE FOLLOWING ACCOUNTS:		
Cash	243,604	568,950
Accounts receivable	791,744	(158,431)
Laboratory and other supplies	109,388	(58,255)
Prepaid expenses	4,986	(16,593)
Loans and bank overdrafts	65,801	(26,296)
Accounts payable	(138,079)	(147,529)
Grants received in advance	(451,773)	389,887
Accruals and other liabilities	66,675	(132,095)
INCREASE IN WORKING CAPITAL	692,346	419,638

The accompanying notes to the financial statements are an integral part of this statement.

INTERNATIONAL POTATO CENTER – CIP

NOTES TO THE FINANCIAL STATEMENTS AS OF DECEMBER 31, 1983 AND 1982

(Expressed in U.S. dollars)

1. Activities of the CIP

The International Potato Center – CIP is a non-profit organization incorporated in Peru in 1972 through a scientific cooperation agreement signed in 1971 (which expires in the year 2000) between the Peruvian government and North Carolina State University, U.S.A. The CIP is a member of the group of International Agricultural Research Centers and receives support from the Consultative Group of International Agricultural Research.

The objective of the CIP is to contribute, through the execution of research programs and training, to the worldwide potato production and development.

Besides its headquarters in Lima, Peru, the CIP also has regional offices located in South America, Europe, Asia and Africa.

In accordance with present legal dispositions the CIP is exempt from income and other taxes.

2. Significant accounting principles and practices

a. The CIP's accounting records are kept in U.S. dollars, and all transactions, both in U.S. dollars or other currencies, are recorded in U.S. dollars. Current assets and liabilities in other currencies are expressed in U.S. dollars at the year end exchange rate. Net exchange gains or losses originating during the year are included in the results of each period as other income, net in the statement of sources and application of funds.

b. Grants are recorded as income on the basis of commitments made by the donors.

c. Laboratory and other supplies are stated at average cost.

d. Fixed assets are stated at cost. No depreciation is applied to fixed assets.

   Additions to fixed assets are reported in the statement of sources and application of funds as incurred; however, replacements are reported as operating costs.

   Fixed assets sold or retired are eliminated from the asset account and from the related capital and unexpended funds account. Maintenance, repairs and minor replacements are charged to costs as incurred.

e. The severance indemnity liability is recorded under the accrual method for the estimated amount the employees would receive should they retire at the balance sheet date.

Certain amounts in the financial statements as of December 31, 1982 have been reclassified to make them comparable to those in the December 31, 1983 financial statements.

3. Loans to executives and employees

The CIP grants loans to its principal and support staff which are substantially financed by a line of credit of US$1,000,000 from Citibank N. A.–New York for the acquisition of homes and vehicles to be repaid in a maximum period of 10 years and 3 years, respectively. Such loan is guaranteed by US$500,000 deposited in said bank, earning a yearly interest of approximately 8.5%.

The amounts drawn down from such credit line carry an annual interest based on New York PRIME rate plus 1-1/2% on the aggregate unpaid principal balance. The outstanding balance as of December 31, 1983 and 1982 from such line of credit amounted to US$843,742 and US$899,428, respectively. These loans are made at no cost for the CIP. Also, loans are secured by first mortgages on properties acquired in favor of CIP.

A breakdown of loans to executives and employees as of December 31 is as follows:

	1983	1982
Current portion of loans to executives and employees	150,911	144,425
Long-term loans to executives and employees	712,147	754,527
	863,058	898,952

4. Fixed assets

This account consists of the following:

	1983	1982
Buildings and construction in progress	2,260,788	2,169,648
Vehicles and aircraft	1,724,334	1,672,133
Installations	919,151	742,801
Research equipment	858,391	771,235
Furniture, fixtures and office equipment	573,196	536,180
Site development	431,635	317,026
Operating equipment	301,823	249,925
Communication and other equipment	267,150	248,624
	7,336,468	6,707,572

5. **Capital and unexpended funds**

Funds invested in fixed assets relate to the cost of fixed assets acquired by the CIP for carrying out its operations. This account is increased annually through charges to income of amounts equivalent to the total acquisitions of fixed assets for the period. On the other hand, this account decreases by the cost of the fixed assets retired.

In the event of dissolution of the CIP, all its property, after the liquidation of liabilities, shall be turned over to the Peruvian Ministry of Agriculture.

6. **Donation commitments**

As of December 31, 1983 the donations committed by third parties to the CIP, to be applied to special projects from 1984 to 1987 are as follows:

Donor	1984	1985	1986	1987
Swiss Development Cooperation and Humanitarian Agency	307,000	326,000	306,000	335,000
United Nations Development Program	138,000	199,000	181,000	155,500
International Development Research Center – Canada	46,935	55,887	41,129	–
Federal German Government	32,250	64,500	42,750	–
W.K. Kellogg Foundation	69,100	–	–	–
	593,285	645,387	570,879	490,500