CIP 86-87

International Potato Center

Annual Report 86-87

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

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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.

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Foreword

This *Annual Report* covers research carried out during 1986, discussed during the annual review at the end of the year, and published during 1987. Thus, to make the transition from using the date of research on the cover to the date of publication, we will show on this year's report the years 1986 and 1987. In the future, only the year of publication will be used.

Biotechnology is receiving a great deal of attention today in the CGIAR system and in national agricultural programs. This technology is not new to institutions such as CIP, which has already been doing modern day, innovative research with vegetatively multiplied crops for which meristem culture and in vitro maintenance and propagation are standard practices. Both of the commodities with which CIP is working lend themselves to improvement by the use of the modern day tools of biotechnology; thus, CIP is fortunate in being able to apply these new tools when justified and to keep abreast of the latest methods in biotechnology research. But, with potato breeders having utilized, up until now, less than 10% of the wild tuber-bearing species in the production of potato varieties, there is a tremendous amount of work still to be accomplished through conventional research methods. There is an old adage that states "do not be the first to take on the new or the last to put off the old." Taking from this old adage, we can be and are among the first to take on the new in biotechnology, but we will not put off the old approaches as we continue to exploit our most valuable asset, the world potato germplasm collection. The developing world, with its scarce resources, cannot afford to be led astray by a possible over-selling of the potential of biotechnology. However, those of us committed to supporting developing country agriculture must not let applicable and relevant new science bypass developing countries.

Periodically, new sets of catch phrases come onto the scene in scientific research, which point toward a potential and stimulating involvement of staff and facilities. Two new words on the scene today are "up-stream" and "down-stream," which refer to basic and applied research, respectively. In these days, the guardians of national and international research institutions are frequently asking the direction toward which research should be moving. For CIP, my answer has been that the average of our research should be where the real action is, in "mid-stream." At CIP headquarters our research is moving up-stream towards more basic research. This is possible since many national programs are now conducting good applied, production-type research. CIP is in the advanced stages

of solving some of the present priority problems of warm climate potato production. CIP's regional programs are moving further down-stream and becoming more client-oriented through support to the country networks and to national programs in their help to farmers. But when measured by the yardstick of up-stream and down-stream research, our average will remain about where it is right now.

CIP has moved quietly but strongly into sweet potato research. Scientists attending an early 1987 planning conference on CIP's sweet potato involvement were amazed at how much we had done in a short time with still practically no specific core funding being provided for sweet potato work. The reason for so much with so little is simple—most of our potato research program has direct application to sweet potato. Thus, our work on collection and maintenance, transfer to in vitro culture, identification of viruses, and development of cleanup procedures are equally applicable to both commodities. CIP's research with potatoes is as advanced in most areas as anywhere else in the world, and we are ready to make the same application to another similar important commodity. The TAC's recent priority paper for the CGIAR system clearly indicates that sweet potatoes have been under-attended up until now for the Third World. At the 1987 planning conference, staff from AVRDC and IITA as well as senior researchers from many institutions in the developed and developing world helped plan the next five years of CIP activities in accordance with needs of developing countries and CIP's comparative advantages. The results of the conference indicated clearly that our present activities fitted very well with CIP's advantages for research and the needs of developing countries. These activities are the following: putting together a world collection of sweet potato genetic material, learning how to identify and eliminate viruses so that genetic material can be distributed safely, exploiting the collection for the major traits in which breeders are interested, and using CIP's regional stations and the country networks for the transfer of technology and training.

The research that is to be done now must fill the needs of the future for sweet potatoes in the developing world. Many countries with over a 3% annual population growth are already using all of their good soils, and the less fertile and more fragile soils are being brought into production. The sweet potato, a highly nutritious food, is an ideal crop for these marginal soils. Furthermore, the number of resource-poor farmers will increase in many developing countries over the next two decades. A recent World

Bank Atlas shows that the average incomes are decreasing in many of the countries with which we work. Under such conditions, the sweet potato probably has an advantage over other commodities presently being addressed within the CGIAR system, since it requires very low inputs, has high nutritional value, the total biomass is usable, and it is an excellent crop for subsistence and small-farm production. We at CIP are already addressing this challenge of developing the sweet potato for the Third World. And we will not forget that we are working with a commodity specifically well suited to the resource-poor farmer with marginally productive land who is probably more concerned with early ground cover and a long harvest period than early maturity and an upright vine-type for mechanization. With only a modest increase in our present level of funding, we can give sweet potato the same attention being given to potato. Two for almost the price of one is still a pretty good bargain as we approach the end of the twentieth century.

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Netherlands, Ministry of Foreign Affairs
Rockefeller Foundation
Swiss Development Cooperation and Humanitarian Agency
United Kingdom, Overseas Development Administration (ODA)
United States, Agency for International Development (USAID)

List of Abbreviations and Acronyms

a.i.	active ingredient
AMV	alfalfa mosaic virus
APLV	Andean potato latent virus
APMV	Andean potato mottle virus
avg	average
AVRDC	Asian Vegetable Research & Development Center (Taiwan)
BARI	Bangladesh Agricultural Research Institute
BPI	Bureau of Plant Industries (Philippines)
BW	bacterial wilt
CDH	Centre pour le Developpement de l'Horticulture (Senegal)
CEC	cation exchange capacity
CGIAR	Consultative Group on International Agricultural Research
CIAAB	Centro de Investigaciones Agrícolas "A-Boerger" (Uruguay)
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIP	Centro Internacional de la Papa (Peru)
cm	centimeter
CNPH	Centro Nacional de Pesquisa de Hortaliças (Brazil)
CPE	centrally planned economy
CPRA	Centre de Perfectionnement et de Recyclage de Pratiques Agricoles de Saïda (Tunisia)
CPRI	Central Potato Research Institute (India)
cv	coefficient of variation
cv.	cultivar
d	day
DLS	diffused-light stores
DNA	deoxyribonucleic acid
EB	early blight
EBN	endosperm balance number
ELISA	enzyme-linked immunosorbent assay
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria (Brazil)
ENEA	Comitato Nazionale per la ricerca e per lo sviluppo dell'Energia Nucleare e delle Energie Alternative (Italy)
FAO	Food and Agriculture Organization of the United Nations
FDR	first division restitution
FONAIAP	Fondo Nacional de Investigaciones Agropecuarias (Venezuela)
g	gram
GA	gibberellic acid
GCA	general combining ability

h	hour
ha	hectare
IBPGR	International Board for Plant Genetic Resources
ICA	Instituto Colombiano Agropecuario (Colombia)
ICAR	Indian Council for Agricultural Research
IDRC	International Development Research Centre (Canada)
IITA	International 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)
INPT	Institut National de la Pomme de Terre (Togo)
INRA	Institut National de la Recherche Agricole (Senegal)
INRAT	Institut National de la Recherche Agronomique de la Tunisie
INTA	Instituto Nacional de Tecnología Agropecuaria (Argentina)
IPO	Research Institute for Plant Protection (Netherlands)
ISABU	Institut des Sciences Agronomiques du Burundi
L	liter
lat.	latitude
LB	late blight
LER	land equivalent ratio
long.	longitude
LSD	least significant difference
LUE	light use efficiency
m	meter
meq	milliequivalent
min	minute
MJ	megajoule
ml	milliliter
mm	millimeter
mo	month
NASH	nucleic acid spot hybridization test
ND	not determined
nm	nanometer
ns	not significant
NS	not studied
OP	open-pollinated
Pf/Pi	final population density/initial population density
PCARRD	Philippine Council for Agriculture and Resources Research and Development
PLRV	potato leafroll virus
PNAP	Programme National de l'Amelioration de la Pomme de Terre (Rwanda)
ppm	parts per million
PRACIPA	Programa Andino Cooperativo de 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
PTV	Peru tomato virus
PVM	potato virus M
PVS	potato virus S
PVV	potato virus V
PVX	potato virus X
PVY	potato virus Y
RH	relative humidity
RNA	ribonucleic acid
SAPPRAD	Southeast Asian Program for Potato Research and Development
SD	standard deviation
sec	second
SED	standard error of difference
t	ton
TPS	true potato seed
UNA	Universidad Nacional Agraria (Peru)
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
var.	variety
vol	volume
vs.	versus
wk	week
wt	weight
yr	year

CIP and Biotechnology

Probe preparation for the NASH test

The overall goal of CIP's research is to remove priority constraints on global production and utilization of potatoes and sweet potatoes when CIP has a comparative advantage to do so. Biotechnological approaches are already helping to achieve this goal and are likely to play an even more important role in the future. The purpose of this article is to describe CIP's biotechnological activities and to discuss our philosophy toward present and future biotechnological research.

But first, what is biotechnology? It has been defined by the United States Congressional Office of Technology Assessment as: "any techniques that use living organisms (or parts of organisms) to make or modify products to improve plants or animals, or to develop microorganisms for specific uses."

But "biotechnology" is used in various ways, embracing many applied aspects of biochemistry, molecular biology, cell biology, microbiology, and even organic chemistry and chemical engineering. At CIP the term encompasses the exploitation of biochemical molecular biological and cellular techniques for crop improvement. It is in this context that CIP's biotechnological activities will be discussed.

Some Biotechnological Activities within CIP

Germplasm management and distribution. For several years CIP's potato germplasm collection, the focal point of CIP's activities to date, has been in the process of transfer to in vitro culture. Potato nodes are introduced to in vitro culture and plantlets are produced. This approach has assisted greatly in genome conservation by avoiding natural disasters that could affect the field-grown collection and in reducing pathogen load. The latter is due to the fact that meristems are low in pathogens and that thermotherapy can be used in combination with in vitro culture to reduce the load further.

Micropropagation for multiplication and distribution also plays a very important role at CIP. Here, techniques include the culture of single nodes and shaken shoot

cultures and production of in vitro tubers. These techniques are very rapid, prevent reinfection of pathogen-tested materials, ensure availability throughout the year, and facilitate easy storage and retrieval. Table 1 illustrates the importance of these biotechnological methods by summarizing 1986 statistics on in vitro germplasm management and distribution.

Maintenance (and utilization) of the potato collection has been streamlined by the use of biochemical methods. Electrophoresis of soluble tuber proteins and isoenzymes has been used to distinguish between morphologically similar plants. Such identifications have resulted in the reduction from approximately 12,000 to 5,000 potato accessions in CIP's potato collection. This has greatly reduced the cost of germplasm maintenance and of breeding programs based on the germplasm collection.

Table 1. Numbers of in vitro cultures produced by CIP's tissue culture laboratory, 1986.

In vitro plantlets in storage:	
1,000 clones (5 tubes/clone)	11,000
In vitro plantlets exported:	
2,500 tubes (3 plants/tube)	7,500
1,650 in vitro tubers	1,650
In vitro plantlets produced for use in CIP	12,700
Clones undergoing pathogen elimination	20
Somatic embryos cultured	1,000

Germplasm improvement. Embryo culture and management is playing an important role in potato improvement. Work on somatic embryo culture is helping to overcome crossability barriers, thereby reducing hybrid generation time, and is assisting in the development of rapid micropropagation techniques.

The ability to regenerate haploid plants from pollen grains is one of the success stories of plant tissue culture. In a collaborative research project with the Italian Nuclear Research Agency (ENEA), an explanation is being sought as to why in some potato genotypes it is easy to obtain dihaploids while in others it seems impossible. This so-called "tissue culture ability" has been shown to be under genetic control, and present data indicate that it may now be possible to move this characteristic from one genotype to another. Tissue culture ability also appears to control other aspects of tissue culture regeneration, including regeneration of somatic tissues such as leaves and stems.

The search for optimal conditions to regenerate plants from tissue explants, single cells, or protoplasts in vitro is of considerable importance at CIP. There are many novel techniques of germplasm improvement such as protoplast fusion and

genetic engineering where success or failure depends on the ability to regenerate plants for evaluation. There is an enormous variation of genotype response and CIP is currently attempting to standardize these regeneration methods.

Quarantine and pathogen identification. Nucleic acid spot hybridization (NASH) is a highly sensitive, rapid detection test to aid in the elimination of potato spindle tuber viroid (PSTV). The technique is based on hybridization or annealing of nucleic acids with complementary sequences. Complementary DNA sequences to PSTV have been synthesized and cloned in plasmids or bacteriophages from where these sequences can be produced at will. Plasmid or bacteriophage DNA that are carrying PSTV sequences are labeled with ^{32}P and used as probes for detection. The NASH test was developed through the collaboration of Beltsville Agricultural Research Center, U.S. Department of Agriculture, in Maryland.

Screening by NASH is arranged in such a way that the simple part of the test (extraction of the plant sap and spotting the extract onto a test filter) can be done in CIP's regions and by national programs, whereas the hybridization of PSTV with a radioactive nucleic acid probe is performed in laboratories at CIP headquarters.

Virus detection by enzyme-linked immunosorbent assay (ELISA) is a highly sensitive, rapid assay to aid in the elimination of potato viruses. The technique has been in use at CIP since 1978 and it has been adopted in several developing countries with CIP's technology and active participation. Reagents and supplies in the form of a simple kit have already been distributed to many national programs in developing countries.

ELISA is also used for the detection of bacteria including *Pseudomonas solanacearum*. Reagents and kits for diagnosis of *P. solanacearum* directly on potatoes have been developed and distributed to several countries. In addition, for detection of other important bacteria on potatoes (e.g., *Erwinia carotovora*), antisera have already been produced.

Some Collaborative Biotechnological Activities

Potato protein improvement by genetic engineering. This work has been performed in collaboration with Louisiana State University in the United States. A synthetic gene, which produces high quality protein, has been incorporated into the potato genome using *Agrobacterium* as the gene vector. We have proved that the gene is transcribed and produces a corresponding messenger RNA molecule, which is then translated in the plant to produce the synthetic protein.

Cytoplasmic male sterility. In collaboration with the Weizmann Institute in Israel, CIP is developing a potato protoplast fusion program to transfer nuclei of one genotype to the cytoplasm of another genotype (donor-recipient approach). This technique has already proved useful in the transfer of cytoplasmic characters in several plants, (e.g., cytoplasmic male sterility in tobacco). Efforts are now aimed at manipulating cytoplasmic sterility in the potato. Fusion of protoplasts between a male sterile and non-male sterile line should allow us to produce female parent lines for production of true seed with male sterility; thus, the need for emasculation of female plants is eliminated.

Genetic stability of in vitro systems. The use of tissue culture methods to produce somaclonal variation (genetic variation induced by regeneration of somatic cells that have undergone chromosomal changes) has drawn attention to the overall suitability of tissue culture methods for propagation and conservation of potato genetic resources. In collaboration with Rothamsted Experiment Station in the United Kingdom, CIP is investigating the genetic stability of all of these in vitro methods. Potato plantlets propagated and regenerated by a wide range of in vitro methods are being tested to determine the levels of somatic mutation in tissue culture material. A number of biochemical methods, some conventional and some nonconventional, are being used to look for major or minor genetic changes. Plants can appear to be unchanged morphologically, but more detailed biochemical analyses can detect minor genetic changes. For example, electrophoresis of soluble proteins from potato tubers is a very useful approach. A more sensitive method is restriction fragment length polymorphism (RFLP), which involves enzymologically cutting the DNA of potato chromosomes into small fragments, separating the fragments by electrophoresis, and comparing the separation patterns. This project helps us to develop methods that will ensure the genetic stability of potato germplasm held by CIP and other national potato programs.

Pathogen elimination. The present routine system of pathogen elimination at CIP and in many national programs is thermotherapy of plants for four to six weeks at 36° C followed by meristem culture. In collaboration with the University of Wisconsin in the United States, CIP is developing new in vitro methods of thermotherapy and chemotherapy. Plants already in an in vitro germplasm collection, but still contaminated with viruses, are cleaned in vitro by chemotherapy and thermotherapy. Tubes of in vitro plantlets are placed into heat treatment for three to five weeks at

37° C in continuous light. The plantlets are then removed and meristems dissected and cultured. The plantlets regenerated are then indexed by standard indexing methods.

Results from Wisconsin indicate that the method is highly efficient as a method of virus eradication. Adoption of this methodology at CIP will allow an increase in the amount of material that can be treated for virus eradication. Consequently, CIP will be able to provide more material much more quickly to national programs for both breeding and seed programs.

Future projects. Biotechnological approaches will continue to be used in several important research areas at CIP. For example, highly sensitive rapid techniques for identifying duplicates in the new sweet potato collection will be needed. Improved technology for induction of somatic embryos and the development of clonal seeds may be useful. Protoplast fusion and other organelle transfer techniques, such as electroporation, may become important for characters other than male sterility (e.g., heat tolerance and nematode resistance). Through selection in vitro it may be possible to break the linkages into the specific hybrids between the highly desirable presence of glandular trichomes, which confer resistance to several insect pests, and undesirable agronomic traits associated with the wild, trichomed parents. Here, somaclonal variation may play an important role. New, highly sensitive biochemical methods for nematode identification could be very important.

The implications of genetic engineering go far beyond the improvement of protein quality in potato discussed earlier. With this approach it may be possible to genetically engineer potatoes to improve resistance to pests and diseases. Through additional collaborative links, CIP hopes to genetically engineer potato plants for resistance to viroid and virus infections by inserting gene sequences that interfere with viroid and virus replication. This approach will allow potato plants to be grown for more generations in the field before being regenerated to eliminate virus infection. CIP's primary interest is to insert resistance to potato leafroll virus (PLRV) and PSTV. There may be possibilities of engineering resistance in the potato to diseases caused by bacteria such as *Pseudomonas* and *Erwinia*. Theoretically, the genetic engineering approach may permit production of plants with increased resistance to biological stresses without making major changes in existing agronomically acceptable characters.

Despite this, application of genetic engineering to potato and sweet potato will be modest in scope for the foreseeable future.

Synthetic genes can be used only in a limited number of cases and the ability to isolate and utilize natural genes is still in its infancy. Also, many useful characters in potato and sweet potato are polygenically determined and are thus presently out of range of the genetic engineer.

CIP's General Philosophy on Biotechnology

This review of CIP's current and future biotechnological activities demonstrates that such activities are already helping us to achieve our institutional goals and will continue to play an important role. Two major issues will continue to dominate our thinking on the use of biotechnology. First, which of the rapidly developing new biotechnological methodologies should be attempted and which might be fruitless? Second, how can we finance biotechnological approaches, which often require heavy investments? Collaborative research is the key to resolving both issues. CIP's collaborative biotechnological research with other institutions has already been illustrated. Collaborative linkages with experts worldwide are, and will be, extremely important in helping us to pursue the most appropriate experimental approaches. Such linkages will continue to be cost-effective for CIP because they involve institutions that have already made large financial commitments in personnel and capital equipment so often necessary to make substantive biotechnological progress.

Through collaboration, CIP also maintains a "window" on biotechnological advances, keeping us aware of developments that might be useful in solving practical problems facing potato and sweet potato agriculture in developing countries.

Potato Production From True Seed: A New Alternative

Present Status of Potato Production

The potato (*Solanum tuberosum* L.) from the time of its domestication in the Andes of South America, where it originated, was traditionally an asexually propagated plant. After its introduction into Europe in the late sixteenth century, and into North America in the early eighteenth century, crop improvement technologies were developed but asexual propagation of the potato using seed tubers was preserved. The ecological conditions in the temperate latitudes favor high tuber yields in a spring summer crop, followed by a crop-free severe winter which also limits the survival of insects, fungi, and bacteria. These conditions permit high-quality seed production by early plantings, when no aphids are present, and by early haulm killing, before aphid population buildup, to avoid virus transmission. After harvesting, tubers are stored at low cost in air-cooled stores until the next planting season. Under these proper production and storage conditions, seed tubers will have an excellent sanitary status and an optimum physiological age to express their entire genetic potential for high performance. The inherent sanitary problems related to asexual propagation have been solved, without the need to select virus-resistant varieties. The potato in the temperate latitudes has therefore become a high-yielding, low-cost staple food.

In the last 100 to 150 years, the cultivated potato developed in the temperate latitudes spread to most tropical and subtropical regions of the world. In these new ecological niches, the crop met with several problems: 1) introduced varieties might not have had an optimum adaptation, and being susceptible to main pests and diseases they required costly pesticide protection; and 2) ecologic and/or economic factors might have limited or made it more difficult to establish programs for high-quality seed production. Most of these problems stem from the fact that potatoes can be grown almost year-round and from the continuous presence of growing plants that harbor diseases and aphids, which begin attacking the potato at an early stage. A seed crop, therefore, will produce infected tubers that when planted in the next season will have their inherent yield potential already diminished. Also, due to warm to hot temperatures, seed tubers must be kept in expensive refrigerated stores to avoid fast deterioration. To overcome these problems and to obtain adequate yields, many countries use costly seed imported from temperate countries, which may not have the adequate physiological age to fit into their potato-growing seasons. As a consequence, the cost of consumer potato production is very high—50% to 60% of which is rep-

resented by imported seed cost—and the market retail price becomes too expensive for low-income groups in the developing world. The potato, then, is still an expensive vegetable in many tropical countries instead of a low-cost, nutritious staple food as in the temperate countries.

Since its foundation, CIP has been creating or adapting technologies to help increase potato production in developing countries. In the area of asexual propagation (seed tubers), important advances have been made. Improved seed production schemes by using tissue culture combined with rapid multiplication and rapid disease detection techniques, low-cost seed storage, and disease-resistant genetic materials have been developed and introduced into developing countries. In spite of these improvements, some of the inherent problems to asexual propagation still exist and limit, in certain countries or regions within countries, an increase in potato production.

In its constant search for technologies to help solve these problems, CIP started in 1976 to use sexual propagation (true potato seed) as an alternative to the asexual propagation of potatoes.

Comparison Between Asexual (Seed Tubers) and Sexual (TPS) Potato Propagation

In spite of the same final objective—high production—these two alternatives are different in their genetic and agronomic aspects, each having strong and weak points which should be compared objectively (*see* Table 1). This comparison has been made on the basis of available asexually propagated commercial potato varieties with TPS hybrid progenies selected at CIP. In some countries, these progenies have reached the farmers' fields; however, in others, they are still at the stage of on-farm trials or at the experiment station level (this topic will be discussed later).

From the comparison, one can see that true potato seed (TPS) is a competitive alternative for developing countries, and it has significant advantages over asexual propagation when good quality seed tubers are not available or beyond the farmers' reach. In many developing countries today, where food scarcity is a reality, the use of TPS could prevent the loss of 1000 to 2000 kilograms of usable food (about 220-440 kg of energy and 8.8 to 17.6 kg of protein), which would have to be used to produce one hectare of the next crop.

Table 1. Comparison of potato production using sexual (TPS) and asexual (seed tuber) propagation.

True potato seed (TPS)	Seed tubers
1. 80-120 g TPS/ha according to field sowing or transplanting density.	1. 1000-2000 kg seed tubers/ha according to tuber size and planting density. As a reference, seed/ha for cereals: rice, 60-75 kg: wheat, 40-50 kg; and corn, 30-50 kg.
2. Free from nematodes, insects, bacteria, fungi, and most viruses. Can be infected by PSTV.	2. Can be infested by economically important nematodes and insects, and infected by bacteria, fungi, viruses, and PSTV.
3. Requires more labor in the initial phase of the crop.	3. Requires less labor and planting can be fully mechanized.
4. In the early stages of plant growth, either from direct seed sowing or transplanting, more vulnerable to weed competition, pests, diseases, and stresses. At this stage, artificial irrigation is required.	4. In the early stages of plant growth, less vulnerable to stress factors due to a more vigorous and uniform initial growth.
5. Tendency to mature 10-20 days later. Comparable or higher yield than seed tubers. Larger number of smaller size tubers. Relatively less uniform in tuber quality factors.	5. Earlier maturity and clonal uniformity, both physiologically and in tuber quality.
6. Tubers are less adequate for processing for fast-food industry.	6. Well adapted for processing for fast-food industry.
7. Cost of storage and transportation is extremely low.	7. Cost of storage and transportation is very expensive.
8. Total cost of production is reduced by eliminating costly seed tubers, storage, and transportation.	8. Total cost of production is much higher.

What Is A Potato Variety Versus A TPS Progeny

Let us first consider that the cultivated autotetraploid potato ($2n = 4x = 48$) is a highly heterozygous biological entity. When it is subjected to sexual reproduction the individuals forming the progenies display a wide segregation for most attributes. In this heterogeneous genetic background,

selection starts by isolating an individual genotype (varietal selection) or an individual progeny (progeny selection).

A *potato variety* is a large collection of genotypically identical individuals that originated from the asexual propagation of a single heterozygous plant. The genotypic identity of all individuals will be maintained unless a mutation occurs. The performance of a variety in a given environment will be the result of the addition of its unique genotypic effect, the effect of the given environment, and the interaction of its unique genotype with the given environment. It is likely that a single genotype growing under several environments will interact strongly with them, and its performance will not be stable.

All variety breeding programs use a pragmatic approach—the pedigree breeding method—by crossing progenitors with complementary attributes to combine them in a single genotype. The magnitude of success depends on the population size and the "eye" of the breeder to identify and isolate a superior genotype from a large number.

A *TPS progeny* is a large collection of individuals, genotypically different but with sufficient phenotypic uniformity in tuber characteristics, that originated from sexual propagation. The performance of a TPS progeny in a given environment will be the result of the addition of the average effect of its genotypes, the effect of the given environment, and the average interaction of its genotypes with the given environment. Genetically, it is expected that the mixture of different genotypes in a TPS progeny will have a "buffering effect" in its interaction with the environment, resulting in a more stable performance when grown under several environments when compared with the stability of a variety (single genotype). The breeding program for TPS progenies is more orthodox in its strategy and has different selection requirements than the varietal selection. Since progenies are rated by the mean performance of all individuals which compose them, the breeding strategy should be conducted accordingly.

Selection of TPS Progenies at CIP

The use of TPS to produce potatoes has imposed the need to select for a number of characteristics that are not necessary for traditional potato breeding: seedling vigor and uniformity in the nursery, ability to recover from transplanting, plant vigor and uniformity in the field, uniformity of

maturity, and tuber uniformity (color, shape, and number). The following characteristics are selection criteria for both TPS and variety breeding: earliness, yield, yield components (tuber number and tuber size), resistance to early blight, late blight, and viruses, and, more recently, to bacterial wilt. The breeding method to select TPS progenies is recurrent selection with progeny testing.

A large number of potential progenitors are tested for general combining ability (GCA) for the transmission of all of these attributes. So far, CIP has selected at least 20 superior progenitors to produce TPS progenies, i.e., LT-7, LT-8, LT-9, TS-1, TS-2, DTO-28, R-128.6, Atzimba, Serrana, Atlantic, Maine-28, CFK-69.1, etc. These progenitors flower well and produce large amounts of seed.

Each year CIP tests the field performance of at least 600 hybrid progenies at its experiment stations at San Ramon and Lima. From the selected group, a sample of 25 to 30 are sent every year to 12 to 15 countries for field evaluation. This is called the International Progeny Testing Trials. These trials, which were started in 1985, are providing important information not only about the performance of the progenies, but also about the value of the progenitors utilized. With the results obtained, CIP produces large quantities of the best progenies for large-scale distribution.

Several types of progenies are produced from the progenitors selected for GCA.

- *Hybrids*: These result from the cross of two given progenitors, i.e., Atzimba x DTO-28, Serrana x LT-7, LT-8 x LT-7, Atlantic x LT-7, and Atzimba x R-128.6.
- *Open-pollinated clones or varieties*: A clone or variety grown in the field produces open-pollinated (OP) fruit. Under field conditions, about 15% to 20% of the seed formed will originate from cross-pollination while the other 80% to 85% will be from selfing.
- *Open-pollinated TPS progenies*: A TPS progeny growing in the field will also produce fruit, and as in the previous type, a large part of the seed will be from selfing and the rest from cross-pollination. Progenies from both OP clones and OP TPS progenies have a certain amount of inbreeding. In spite of this, repeated open-pollination of certain progenies has not decreased yields with respect to the original hybrid.

- *Synthetic progenies*: Selected progenitors are planted together, under isolation, in the field and allowed to intermate. A variable number of progenitors can be used (2, 3, 4, 5, 6, or more), but it has been found that a lower number (2, 3, 4) produces the best synthetics for TPS utilization. CIP is now producing larger amounts of these progenies for regional testing.

Comparisons made at CIP among the three first types of TPS progenies have shown that, in general, the hybrids have a superior yield and tuber uniformity over those of OP progenies. However, some OP TPS progenies do not decrease their yield after three generations of open pollination compared to the yield of the original hybrid, e.g., Atlantic x TS_2, 379643.3 x C83.551, and 378015.25 x 377250.7.

Seed Production

The production of large quantities of TPS must be achieved to facilitate faster adoption of TPS technology by farmers. Research on methods to improve TPS production from both a genetic and physiological aspect is an active part of CIP's TPS program. Potato flowering and fruit production, strongly influenced by daylength and temperature, require daylengths of 15 to 17 hours with mean temperatures of 15° to 18° C for abundant production of TPS. Under tropical latitudes, however, these conditions are not present as the days are shorter (12-13 hr) and temperatures range from medium to high (20°-28° C). Consequently, the production of hybrid seed diminishes or ceases to be produced. Within its TPS breeding work, CIP is emphasizing the selection of progenitors that flower well and produce TPS under the tropical conditions at San Ramon (12.5 hr daylength and 24° C mean temperature).

Use of TPS Progenies in Potato Production

There are three alternatives for the use of TPS: 1) direct seed sowing into the field, 2) transplanting, and 3) use of seedling tubers.

Direct sowing into the field. This is the least expensive way of using TPS, but there are many problems that restrict its use as a viable alternative for the developing world. Under warm to hot conditions, seed germination is poor, seedlings in the field have a slow initial growth, weeds

cause serious damage, and seedlings are easily attacked and destroyed by insects.

Transplanting. TPS is sown in trays or in seedbeds containing a substrate with adequate moisture, fertilizer, and pesticides, which favor fast and healthy germination. Both trays and seedbeds can be shaded to lower the temperature and protect the emerging seedlings from high radiation. Ten days after sowing, practically all seedlings have germinated, and 20 to 25 days later they are ready for transplanting to the field. An extra number of seedlings are also grown to select the most vigorous ones for transplanting. Extreme care is taken in the following ten days after transplanting to avoid transplanting shock. To overcome this problem, proper irrigation of seedlings and insect control must be carefully managed. After the seedlings are well established in the field, agronomical management is similar to that for a standard tuber crop.

Production of seedling tubers from TPS. This method is based on growing seedlings at close spacing in nursery beds (10 x 10 cm spacing or 100 plants/m^2) until tuber maturity. Seedlings are established either by direct sowing or by transplanting from seedling nurseries. At maturity, tubers are harvested and stored as usual until planted for production of consumer potatoes or for use as seed tubers. At the density of 100 plants per m^2 of bed, several TPS families have produced, on the average, 1100 usable tubers per m^2 (larger than 1 gm), with a total tuber weight of over 10 kilograms. In 30 m^2 of nursery bed one can produce enough tubers to plant one hectare of potatoes in the field. The use of seedling tubers combines the advantages of potato production from true seed with those of the traditional planting method. A grower or a national agency using this method can produce seedling tubers intensively in a small and easily controllable area that permits the elimination of abnormal plants and off-type tubers. Seedling tubers from TPS can also be produced during off-season periods. For farmers accustomed to planting seed potatoes, the use of seedling tubers produced from TPS presents an acceptable alternative. Plants produced from seedling tubers have greater vigor than seedlings and usually give better yields than transplants.

Collaborative Research With National Programs, On-Farm Evaluation, and Farmer Adoption

Through CIP's regional research programs, TPS technology has been tested and demonstrated in more than 40 developing countries (Table 2).

Table 2. Research and use of TPS in developing countries.

Research and use	Countries
Experiment station research	Chile, Argentina, Peru, Colombia, Jamaica, Venezuela, Uruguay, Costa Rica, Cuba, Mexico, Burundi, Rwanda, Ethiopia, Senegal, Cape Verde, Zimbabwe, Ghana, Cameroon, Kenya, Malawi, Zambia, Egypt, Turkey, Iraq, Iran, Tunisia, Morocco, India, Sri Lanka, Bangladesh, Bhutan, Nepal, Philippines, Vietnam, West Samoa, Thailand, Indonesia, South Korea, China, Fiji.
On-farm evaluation	India, South Korea, Sri Lanka, Rwanda, Bangladesh, Philippines, Peru, Venezuela, Egypt, West Samoa, China, Vietnam, Rwanda.
Farmer use	China, Philippines, Sri Lanka, West Samoa, Bangladesh, Vietnam.

Many national programs are now going through the phases of adaptive experimental research and on-farm evaluation. Some have progressed to the point that farmers have adopted the technology and are using it in the commercial production of seed tubers and consumer potatoes. Table 2 summarizes the different phases that this technology has reached in the countries collaborating with CIP.

Commercial use of TPS by national programs and farmers. The potato is a very profitable crop in *Sri Lanka*, but is limited by an insufficient and expensive seed tuber supply, storage requirements that are difficult to meet, and the incidence of major seed tuber-transmitted diseases. At present, TPS seedlings are produced on a government farm and sold to farmers for production of seed tubers. Further, farmers have now produced consumer potatoes from their own-produced seed tubers. Some farmers are using their own OP seed produced from standard varieties growing in their fields.

In the *Philippines*, TPS is considered to be an alternative on the islands of Mindanao and Negros, where potato yields are low due to poor seed tuber quality. Moreover, an extra problem is the remoteness of these islands from a better seed source. Both methods of transplanting seedlings

and planting seedling tubers are being used for commercial production in Mindanao and Negros by a few farmers who have obtained yields as high as 20 to 40 tons per hectare.

Importation of seed tubers in *West Samoa* has been prohibited because of the high cost. The lack of imported seed has forced farmers to use TPS commercially. Locally produced OP seed is used at present for potato production from transplanted seedlings. The larger tubers produced are sold for consumption and the smaller sizes for seed tubers the following season.

TPS technology in *Vietnam* has been evaluated and rapidly adopted by farmers. During 1986, over 20 kilograms of OP TPS were produced and distributed in 500-gram packets to 35 cooperatives in 10 provinces. Seedlings were transplanted to 50 hectares to produce seedling tubers for the following season. The crop from the seedling tubers outyielded that of the local variety. Future plans are to increase seedling tuber production to more than 100 hectares.

In *Rwanda*, on-farm trials have been carried out to compare the yield potential of seedling tubers produced from hybrid and OP TPS progenies to that of farmers' own seed. The mean yield of all plots with farmers' seed was 16.3 tons per hectare compared to a yield of 22.3 tons per hectare of the seedling tuber crop. Furthermore, in more recent studies, crops from seedling tubers have yielded 25% higher than the traditional crop.

Evaluation of TPS technology started in *Egypt* in 1983, and appropriate agronomic methods and higher yielding progenics have been selected. Uniform production of consumer potatoes is obtained using seedling tubers from TPS with yields ranging from 20 to 30 tons per hectare. Based on these results, the government will start an extensive program of on-farm evaluation and demonstration in 1987.

In *India*, TPS research and on-farm evaluation of agronomic technology and TPS progeny selection has been successfully tested for three years, and significant progress has been achieved. Presently, three locally bred hybrid TPS progenies have been selected, and several kilograms of seed of these progenies are being produced for extensive farmer evaluation in more than 25 locations throughout the country. The yields from transplanted seedlings and seedling tubers ranged from 20 to 35 tons per hectare, with good tuber uniformity and acceptability for table consumption.

The development of methodologies for producing TPS on a commercial scale requires a major effort to continue advancing this technology. Col-

laborative research with national scientists in *India* and *Chile* has been effective in producing large amounts of TPS. In these two countries, effective techniques were enhanced by optimum daylengths and temperatures. In *Chile*, about 14 kilograms of TPS of seven selected TPS hybrid progenies for distribution to countries was produced by means of hand emasculation of the flowers. In *India*, however, the availability of varieties with a flower type with an extended style makes emasculation unnecessary and therefore reduces the cost of TPS production.

Prospects for the Use of TPS Technology in the Future

As more farmers in the developing world become exposed to TPS technology, it is likely that the use of TPS will spread significantly and contribute to increased potato production. The quality of the TPS progenies is continuously improving by the accumulation of pest, disease, and stress resistance factors, which will widen the range of progeny adaptation. The use of this new alternative has high production potential and can efficiently complement or replace the use of traditional seed tubers of the common varieties. As potato production increases, by means of a more efficient and low-cost technology, the potato as a staple food will become within the reach of large majorities of populations in the developing world.

Summary of Research and Regional Programs

World Potato Germplasm Collection

A new potato species was discovered and described as *Solanum donachui* Ochoa. This species is of the taxonomic series Conicibaccata and was found in Colombia. New sources of resistance to bacterial wilt (*Pseudomonas solanacearum*) have been found by screening 10,000 seedlings from seven inter- and intra-specific hybrid combinations. None of the species that has accessions with high levels of resistance occurs in areas where *P. solanacearum* has been found. This strongly suggests that the evolution of such resistance has not occurred through natural selection.

Ten thousand seedlings, representing twenty species from the taxonomic series Commersoniana and Tuberosa, were screened for resistance to potato leafroll virus (PLRV). Immunity to PLRV was found in five accessions of the species *S. chacoense* and high levels of resistance were found in three accessions of an unclassified species from the series Tuberosa. Utilization of these species should present no major problem if most of the germplasm enhancement is carried out at the diploid level. These clones are already being stored in vitro.

Duplicates of CIP's cultivated in vitro collection have been taken regularly to Ecuador for maintenance, and the Ecuadorian national potato program of INIAP provides quarterly reports on the general status of the material.

There has been good progress in the selection of aluminum-resistant genotypes in vitro. Callus and protoplasts cultures of clones LT-2, Revolución, DTO-2, and DTO-33 were subjected to aluminum stress. Cell lines that grew in the presence of certain aluminum concentrations were regenerated and the regenerated plantlets were again propagated in the presence of aluminum. The plantlets are currently being grown in pots under conditions of high pH and high aluminum concentrations for analyses of growth and yield.

Promising results have been obtained in an attempt to genetically manipulate male sterility at the protoplast level. In a collaborative research contract with the Weizmann Institute in Israel, asymetric fusions were made to transfer nuclei of two clones (Atzimba and Atlantic) into cytoplasm that confers male sterility. Plantlets regenerated from these fusions indicate that male sterility has indeed been transferred.

Sweet Potato Collection

Thirteen expeditions to collect sweet potato germplasm were carried out in 1986. A total of 1079 accessions were collected in 521 localities, and centers of great genetic variability were identified in five of the six countries explored.

CIP's sweet potato gene bank now contains 3140 accessions which are maintained as clones and seed. Of these, 1967 belong to *Ipomoea batatas*, 814 to wild *Ipomoea* species, and 359 are breeding lines. Routine methods have been established that allow single nodes and buds of screenhouse-grown material to be introduced to in vitro culture. About 300 Peruvian sweet potato clones have already been cultured.

Maintenance, Breeding, and Distribution of Advanced Clones

There was intensive selection of parental clones to be used for variety selection and true potato seed utilization. Six clones were introduced to the seed program for cleanup and regional distribution. These clones are progenitors with high general combining ability for yield and tuber uniformity as well as earliness and heat tolerance. One clone, 379706.34, has been code-named LT-9. In addition to the attributes mentioned above, it is also immune to potato viruses PVX and PVY.

New sources of resistance to early blight (*Alternaria solani*) were introduced to the lowland tropical populations, which resulted from research contracts with North Carolina State University and Cornell University (U.S.). Results indicate that it is not only possible to combine good levels of disease resistance with high yield and heat tolerance, but it is also possible to shorten the growing period of the material to 90-100 days. The latter finding represents a major advance in CIP's breeding program.

Following two years of field evaluation and selection of potato clones with salt tolerance (electrical conductivity = 3.5 mmhos/cm or more), clones with yields ranging from 9 to 20 tons per hectare have been identified. Of a large sample of genotypes grouped in 49 families, 107 clones from the lowland tropical population were shown to exhibit resistance to *Erwinia* spp. These clones represented only 1.8% of the original popu-

lation and will be inoculated in the laboratory to select progenitors for the next cycle of selection. Clones exhibiting high yield, medium maturity, and resistance to late blight (*Phytophthora infestans*) have been selected in several countries. At least two have been released as new commercial varieties.

Research has led to a new approach for parental line selection for general combining ability (GCA) for yield. It has been found that the evaluation of open-pollinated progenies of prospective parental clones is an efficient method to select those with GCA. This method is simpler and more economical than traditional methods such as bulk pollination, clone x tester, and complete or partial diallels. In Bangladesh, six highly selected clones from CIP breeding populations have shown great potential for becoming new varieties. The national program of Vietnam has also selected five clones introduced in 1982 for testing.

During 1986, CIP distributed potato genetic materials to 69 countries (15 developed and 54 developing) worldwide. The CIP Region III germplasm distribution center in Kenya exported 60 clones to various countries in Africa, and the regional germplasm station in the Philippines distributed a total of 2880 cuttings, 15,372 tubers, 21,000 true seeds, and 60 test tubes of in vitro plantlets to eleven countries.

Disease Research

A new population with bacterial wilt resistance, derived from several species, was crossed to heat-adapted, early maturing materials for use in the lowland tropics. Maturity time was reduced from 126 to 86 days. The new materials have already shown promise in Mindanao, Philippines. A new and more efficient method for inoculating potato plants and seedlings with *P. solanacearum* has been developed, which involves cutting a terminal leaflet with scissors dipped in a suspension of the bacterium. An antiserum against *P. solanacearum*, which was effective in identification of the bacterium in plants or tubers, is now in use in 16 countries. Twenty-two new sources of resistance to bacterial wilt have been identified, eleven in contract work at the University of Wisconsin (U.S.) and eleven in Peru.

Irrigation water at San Ramon, Huancayo, and Lima was found to be contaminated with large numbers of *Erwinias*, the causal agents of soft rot; however, filtering the contaminated water through sand reduced the numbers by 94%. Resistance to *Erwinia* can be increased by calcium fertilization, which results in a thicker tuber periderm. Also, resistance to soft rot was correlated to increased calcium in medullary tissues, higher dry matter and greater tuber polyphenol content. Tuber rotting in San Ramon, Peru, was shown to be the result of interaction between several fungi and the *Erwinias*. In storage, tuber rotting was significantly reduced by a prestorage treatment with calcium fertilizer and Cidial insecticide.

In studies on late blight disease, zoospores of *P. infestans* were found to be more effective than sporangia in inoculation procedures. Intensive efforts continue in the development of populations with general resistance to *P. infestans*. There have been successes in selecting clones with resistance to late blight, high yield, earliness (110 days), and desirable agronomic traits. Some clones with high GCA have also been selected.

Seedling screening for early blight conducted under screenhouse conditions did not correlate well with adult plant field tests in San Ramon. However, a reasonable correlation resulted between seedling tests under screenhouse conditions in Lima and field tests of the same seedling populations in San Ramon when they were inoculated 45 and 55 days after planting and final readings were taken at 75 days.

Fifteen clones with resistance to *Verticillium dahliae* were found in Cañete on the coast of Peru. Eighteen weed species in eleven families were found to be infected by *V. dahliae* in fields of the central Peruvian highlands. A survey of 255 potato fields in Pakistan led to the identification of 18 fungal and 3 bacterial diseases.

The best control of damping-off and premature death, both caused by *Rhizoctonia solani*, was achieved by incorporating the fumigant Basamid with Rizolex fungicide into the soil which was covered immediately with plastic sheeting.

Interaction between PLRV and other potato viruses was shown to decrease the level of resistance to PLRV multiplication in clone B-71-240.2. It seems feasible that this interaction is caused by a synergism between PLRV and the viruses tested, and it might explain the rapid loss of PLRV resistance in some cultivars under field conditions. Rapid screening of stem cuttings from agronomically superior progenies of TPS families has been developed to speed up selections of clones with good agronomic performance and resistance to viruses PVX and PVY. Studies under natural conditions confirmed the hypothesis that immunity to PVX and PVY would give stable resistance to these viruses and, in general, would decrease the degree of degeneration of new cultivars due to virus infections.

More efficient detection of potato spindle tuber viroid (PSTV) by nucleic acid spot hybridization (NASH) has been facilitated by new procedures developed for preparing and labeling PSTV nucleic acid probes. The NASH test may be used also to detect PVX, PVY, and PLRV, which are normally detected by ELISA. This work, in collaboration with the Plant Breeding Institute in Cambridge (U.K.), could lead to more sensitive and easier analyses of large numbers of samples. Improvements in serological tests for viruses include the preparation of an antiserum for potato virus A, replacing reagent grade latex by cheap industrial latex or bacterial cells as carriers of antibodies, and the development of immunobinding assay on nitrocellulose cultures.

Microcrystals related to PLRV have been found in embrionary aphids in the abdomen of viruliferous mothers. The significance of these findings on PLRV ecology in the tropics, where multiplication of aphids occurs almost entirely by parthenogenesis, is under study.

Integrated Pest Management

Intensive effort was continued on screening potato genotypes for resistance to nematode and insect pests and on finding nonchemical control methods. Large-scale screening for resistance to root-knot nematode revealed resistance in 8% of 150 potato clones and in 4% of a segregating population of 3000 genotypes. Use of the nematode parasitic fungus *Paecilomyces lilacinus* in the presence of aldicarb looked promising in controlling root-knot nematode at one quarter of the recommended rates of aldicarb. Tests are being conducted to verify these results under field conditions.

Screening trials for resistance to potato cyst nematode (*Globodera pallida*) revealed the presence of resistant clones in early and advanced materials. Forty-three selected clones were passed on to the Peruvian national potato program for tests on adaptation to different localities. One clone (G3) is being released as a new variety in Peru, and other promising clones are in advanced selection trials.

Of sixty species of potatoes, four showed various degrees of resistance to potato tuber moth (PTM) damage in the foliage. There appears to be some association between this resistance and the presence of glandular trichomes. New sources of resistance have been identified in clones derived from wild diploid material.

Of 144 clones in a germplasm collection screened for resistance to leafminer fly *Liriomyza huidobrensis*, 19 were found to be resistant. Promising results have been obtained in the biological control of potato insect pests. A granulosis virus, infecting potato tuber moth larvae, was identified in colonies reared at CIP, Lima. Initial trials with this virus for PTM control in stores and in the field have been successful. Isolates of virus from PTM obtained from other countries have been tested. The fungus *Beauveria bassiana* showed moderate action against the Andean potato weevil in the field.

In Tunisia, the population dynamics of potato tuber moth was studied in relation to potato planting dates, plant growth, tuber maturity, and timing of harvest. As a result, recommendations were given to manage this pest through proper timing of planting and harvesting practices. In Egypt, the combined use of light and sex pheromone traps, and the use of phosphine as a fumigant were both effective in controlling PTM in stores. Aphid populations were monitored in three areas in Colombia; *Myzus persicae* was the most predominant of the 13 species recorded.

Warm and Cool Climate Production

Results confirm that splitting nitrogen applications during the dry season in San Ramon results in no yield benefit relative to single application. In contrast, during the San Ramon rainy season, splitting nitrogen applications significantly increased final tuber yield relative to a single application.

Intercropping with potatoes has received considerable attention in several countries. A number of potato clones tolerant to shade have been identified in Peru. Intercropping experiments in the Philippines with potato:maize in the proportion 9:1 have been very successful. Relay cropping in Egypt, where potatoes are planted in the shade of maize, has permitted planting of potato at a time considered too hot for the potato crop. In Bangladesh, potatoes have been grown successfully with sugarcane, providing almost double the income of other sugarcane intercrops.

The poor yield potential of warm-produced seed tubers, especially those stored in diffused-light stores (DLS) in warm climates, has been confirmed. Yield decline of these tubers over seasons and years was site- and clone-dependent. Cold storage was almost ineffective in offsetting the yield decline.

Alternatives to warm climate field-produced seed tubers were studied. Rooted stem-cuttings of some clones gave yields similar to those of cool-produced seed tubers. TPS transplants also gave comparable yields, but were characterized by large numbers of small tubers. Various alternative systems to reduce the high cost of good quality planting material are being evaluated.

It was found that heat tolerance in potato plants is probably not related to one specific character and that various laboratory or screenhouse tests may be necessary to quantify heat tolerance. In contrast, salt tolerance may be quantified more simply by using in vitro techniques.

Good progress continues in the identification of heat-tolerant clones. Certain clones (e.g., LT-7) are known to provide good selections. Screening of pathogen-tested clones in San Ramon has also identified new sources of heat tolerance. The yields of the heat-tolerant clones, which matured two weeks later than the early LT and DTO clones, were significantly higher than those of the controls.

In population development for cool climates, emphasis was placed on materials for the non-Andean region. Early maturing clones immune to PVY and PVX were crossed to selected frost-tolerant clones and the resulting segregating progenies were screened for frost tolerance.

Efforts have continued to widen the adaptability of the frost-resistant populations. A new sample of this population was sent to southern Chile

to be tested for performance under natural long daylengths. The work was carried out in collaboration with the Chilean national potato program. This new sample, which involved 252 clones grouped in 16 families, was the result of the use of a new methodology to screen potato plants for long-day performance in Lima. The methodology consisted of growing potato plants under natural short days in Lima, supplemented with artificial light to simulate long days from planting to harvest. The Chilean program has provided information showing that, for the second consecutive year, selected clones from the frost-resistant population have exhibited high yield performance as compared to that of local varieties.

The search for clones efficient in the use of nitrogen continues. Studies have confirmed that clones that yield well under low levels of nitrogen have a general tendency not to respond to additional nitrogen. Unfortunately, some of the experiments in the greenhouse to identify nitrogen-efficient clones did not show the same trend as the field experiments.

Postharvest Technology

Storage research focused on methods to reduce losses of consumer potatoes in warm areas. Four new stores, divided into 10 units (500 kg each), have been built in San Ramon. In these stores, methods to control potato tuber moth, soft rots, and sprouting will be integrated with technologies on store design and low-cost cooling systems.

In research on the storage of seed tubers, the focus has been on storage behavior and subsequent field performance of small seed tubers, such as seedling tubers and clonal tubers obtained from rapid multiplication techniques. The studies conclude that despite high weight losses in small seed tubers during storage at elevated temperatures, these tubers can be stored successfully in DLS at such temperatures. Experiments on desprouting of seed tubers stored in DLS showed that in most of the non-desprouted tubers, the sprout number increased little with increasing storage period. However, desprouting considerably increased sprout number in all tuber sizes and at all storage intervals. The effect of desprouting on sprout number was greater in large tubers than in small tubers due to the greater number of eyes per tuber. Observations on desprouting also showed that desprouting should be done before sprouts become too old, since this may cause tuber wounding and subsequent dehydration.

The variability in storage behavior of seedling tubers was generally similar to that observed in clonal seed tubers during storage in diffused light, particularly when desprouting was carried out. Thus, possible differences in variability in plant growth observed between the two types of seed tubers probably did not result from differences in storage behavior.

Fifty advanced clones were evaluated for storability as seed tubers and as consumer potatoes. There were considerable differences in length of

dormancy, incubation period (the time between tuber initiation in the field and tuber formation on sprouts during dark storage at 18° C), rate of sprout growth, number, length and weight of sprouts, and tuber weight loss.

In potato processing research, emphasis was placed on the transfer of technology used in the production of dehydrated food mixes based on potatoes. The CIP processing plant in Huancayo was made available to researchers of national institutions to gain experience with this technology. In 1986 this plant was used by collaborating institutions for a total of 539 man-days to experiment with potato-based food mixes.

Some researchers have modified the original mix that was developed by CIP (code-named M6) into a food mix that is based exclusively on Andean crops. This would probably simplify the preparation of the mix in Andean communities. In addition, several researchers concentrated on the use of discarded potatoes for preparation of the mix. Several national institutions have demonstrated considerable interest in using potato-based food mixes in their programs. Centro IDEAS of Peru has almost completed the construction of a small potato-processing plant, which will have a capacity to produce 21 tons of dehydrated food mix per month. The Peruvian Ministry of Health has expressed strong interest in such mixes, and the National Institute for Agricultural Research and Extension (INIPA) has developed construction plans for a processing plant for Andean crops, including potato. In India, CIP continues to support a village-level processing project in Bareilly that has been set up by Compatible Technology, Inc. This project involves making potato slices, sun-drying them, grinding the dry slices, packaging them, and marketing the product.

In addition to working on food mixes, CIP has been carrying out research on dehydrated French fries. A low-cost, simple method was used to produce this product which has shown excellent consumer acceptability. The product has the potential to be used in small restaurants that at present must rely on fresh tubers for making French fries, as frozen fries are too expensive or not available in developing countries.

An in-depth anthropological study of household potato processing technologies was continued in Peru, Bolivia, and Argentina. The diversity of potato processing techniques found in the Central Andes may well provide essential information on appropriate techniques for low-cost processing in other developing countries.

Seed Technology

Efforts were concentrated on incorporating resistances to late blight, early blight, and PVY into TPS progenies, and on identifying improved genetic combinations for vigorous seedling growth under adverse environments. Selected progenitors with high levels of resistance to late blight and immunity to PVY were able to transfer these traits to a high percentage

of their progeny. Using the system of raised beds (as is used for vegetable production), and increasing transplant density, researchers were able to improve the proportion of marketable-sized tubers for TPS. Control of damping-off in potato seedlings caused by *Rhizoctonia solani* was achieved by use of appropriate rates of Benomyl, Tolclofos, and Dazomet. It was found that seedling tuber production in nursery beds could be improved by growing seedlings in square rather than in rectangular patterns. In this way, hilling problems were reduced, the number of small tubers was decreased, and production was maximized.

Good progress was made on improving the efficiency of large-scale TPS production as well as on methodology to ensure the production and maintenance of high quality seed. Twelve kilograms of selected hybrid TPS was produced in Chile and distributed to approximately 50 countries. Significant increases in TPS vigor were obtained through supplemental nitrogen applications during seed development. Optimal berry loads, stem number per hill, and planting densities of mother plants were defined for selected progenitors. The treatment of seed with gibberellic acid to promote vigorous and uniform emergence has now been replaced by improved management practices, which lead to increased berry maturity prior to harvest, and improved TPS extraction methods. It was found that TPS quality could be maintained by drying mature TPS at 20° C followed by immediate storage under low moisture.

Seed tuber research concentrated on the evaluation of diverse propagation methods appropriate to self-sustaining potato production systems in warm environments. It was confirmed that faster field establishment is obtained from tubers, followed by rooted cuttings or TPS transplants. However, rooted cuttings showed a favorable tendency to produce lower number of tubers, and hence larger and more uniform tubers. Seed tubers produced in warm environments showed a marked reduction in yields as compared to yields of those produced in cool areas. TPS transplants, however, do not show this yield reduction when produced under warm environments, which represents a considerable advantage.

Potato and Sweet Potato in Food Systems

CIP's computerized data bank of potato statistics was expanded to cover all major root crops. Contrasting patterns and trends of potato and sweet potato production and use were analyzed. Although only about 30% of the world's potatoes are grown in the developing regions, almost all sweet potatoes are produced in these regions. Potato production has tripled in developing countries since 1960 and has remained about constant in developed countries. Sweet potato production has only increased by 20%. China alone produces nearly 60% of the potatoes in the developing world and 85% of the sweet potatoes.

Use of potato varieties in Bhutan, Peru, and Rwanda was studied at the farmer level. Although commercial potato production is expanding rapidly in many areas, farmers maintained older varieties for home consumption because of their preferred culinary qualities or storability. The higher-yielding improved varieties are generally grown for the market. Work in Rwanda indicates the desirability of decentralizing and encouraging greater farmer participation in variety selection, maintaining genetic diversity, and exploring alternative systems for seed distribution. Research in the Peruvian central highlands has confirmed the feasibility of involving small-scale farmers in seed distribution systems.

A marketing survey in Bangladesh revealed several important points: there has been a rapid expansion of potato production and use, accompanied by increases in farmers' incomes as well as declining real potato prices at the consumer level. The study has contributed to the Bangladesh government's planning of its potato production and marketing programs.

A study of the Tunisian seed program identified several factors that have contributed to the program's extraordinary high rate of return. Research in South Korea pinpointed the well-organized application of tissue culture and virus testing methods as being crucial to the success of the national seed program.

The potential benefits of the lowland potato project in the Philippines were highlighted in a recent study. The project is now focusing on solutions to three major constraints: inadequacies of the Philippines' present seed systems, the need for a dual-purpose variety that performs well in both high and low areas, and financing to allow poor farmers to undertake potato production, which is more costly than production of most traditional lowland crops.

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

Agroecological Zones of CIP's Experiment Stations in 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 experiment stations located between latitudes 6° and 12°S that represent the four major agroecological zones of Peru: Lima-La Molina, arid; Huancayo, highlands; San Ramon, mid-elevation tropics; and Yurimaguas, low, humid tropics. The 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 the potato-growing seasons, with meteorological data for 1986.

Site:	Lima-La Molina		Huancayo	San Ramon		Yurimaguas
Latitude:	12°05'S		12°07'S	11°08'S		5°41'S
Altitude:	240 m		3280 m	800 m		180 m
Growing season:	Jan-Mar	May-Nov	Oct-May	Nov-Mar	May-Aug	May-Aug
Air max (°C)	27.60	20.09	20.47	29.65	30.01	30.47
Air min (°C)	18.88	13.97	6.06	18.61	15.94	21.25
Evaporation (total mm)	505.59	538.40	1203.41*	780.8	564.62	377.40*
Rainfall (total mm)	1.50	6.5	799.53	976.60	337.10	693.00
Solar radiation (daily MJ/m^2)	18.52	6.76	20.82	18.76	17.86	no data

* Evaporation using Piché evaporimeter.

Collection, Maintenance, and Utilization of Unexploited Genetic Resources

A new potato species was discovered and described as *Solanum donachui* Ochoa. In the continuing search for new sources of resistance to *Pseudomonas solanacearum*, about 10,000 seedlings from seven hybrid combinations involving four wild and one cultivated species were tested for resistance. None of the species having accessions with high levels of resistance has its natural habitat in areas where *P. solanacearum* has ever been found. In another 10,000 seedlings (representing 20 species) screened for resistance to potato leafroll virus, immune as well as highly resistant accessions were found.

A second potato collecting expedition went to Ecuador and collected 208 samples of native cultivars and three populations of wild species. An inventory of 650 native Andean potato cultivars with an array of resistances to pests and diseases and other traits has been prepared for distribution to interested breeders worldwide. CIP now has 2035 accessions of potato germplasm in vitro and more than 1200 accessions were cultured in 1986.

In an effort to select aluminum-resistant genotypes, in vitro cultures of several clones were subjected to aluminum stress. The regenerated plantlets are being grown under conditions of high pH and high aluminum concentration for further analysis. The Weizmann Institute in Israel, with whom CIP has a research contract, transferred nuclei of two *tuberosum* cultivars into cytoplasm conferring male sterility.

Thirteen expeditions to collect sweet potato germplasm in 1986 resulted in 1079 accessions being collected in 521 localities. Centers of great genetic variability were identified in five of the six countries explored by these expeditions. CIP's sweet potato gene bank now contains 3140 accessions, which are maintained as clones or seeds. Of the total, 1967 accessions belong to *Ipomoea batatas*, 814 to wild *Ipomoea species*, and 359 are breeding lines. Routine methods have been established that allow single nodes and buds of sweet potato to be introduced to in vitro culture.

Planting stem cuttings of Peruvian accessions from CIP's sweet potato collection, Lima, Peru.

BIOSYSTEMATIC STUDIES

A new potato species, belonging to the taxonomic series Conicibaccata, was found in Colombia in 1986 and described as *Solanum donachui* Ochoa. It has not been possible to retain living material of the original collection of this species for CIP's germplasm bank; however, new collections of this species will be made in the near future.

The endosperm balance number (EBN) was confirmed for the species *S. lignicaule* (1 EBN) and *S. circaeifolium* (1 EBN), and was newly determined for *S. abancayense* (2 EBN) and *S. wittmackii* (2 EBN). In their range of natural variation, *S. lignicaule* and *S. circaeifolium* have genotypes with resistance to the potato cyst nematode *Globodera pallida*. In the past it was difficult to cross *S. circaeifolium* with any other potato species; however, with the determination of the EBN of *S. circaeifolium*, it is now possible to hybridize this species with other potato species that have the same EBN. It was also shown that some of the species that hybridize with *S. circaeifolium*, such as *S. commersonii*, can serve as bridging species for further hybridization steps. Thus, one more source of resistance to *G. pallida* has become accessible to breeders.

During 1986, major effort and resources went into the completion of a manuscript on wild and cultivated Andean potatoes, which will be copublished by CIP and Cambridge University Press in 1988.

UTILIZATION STUDIES

The search has continued for new sources of resistance to the bacterial wilt pathogen *Pseudomonas solanacearum*. Approximately 10,000 seedlings from a total of seven inter- as well as intraspecific hybrid combinations were tested for their resistance to this pathogen. The screening process consisted of three sequential steps: 1) inoculation of seedlings, 2) reinoculation of the transplanted survivors from inoculation 1, and 3) retesting of the new clonal material.

Combinations involving accessions of *S. bukasovii*, *S. boliviense*, and *S. sogarandinum* have consistently given the best results (Table 1). The material is now at various stages of multiplication and is ready to go into the regular breeding program for resistance to bacterial wilt. It is of particular interest that none of the species

Table 1. Potato wild species crosses selected as resistant to *Pseudomonas solanacearum* by sequential inoculations in a hot house (25°-31°C).

Progenitor species and accession numbers	Percent (%) survival				
	Inoc. 1	Transplant	Inoc. 2	Inoc. 3 (clones)	Final
BUK 13856 x PHU 10199	56.1	56.5	46.2	100.0	14.6
BUK 13166 x PHU CCC4731	59.5	63.6	32.1	100.0	12.1
BLV 11935 x BLV 11938	92.0	58.7	63.0	95.0	32.3
BLV 11938 x BLV 11935	79.4	53.4	51.6	82.5	18.0
BLV 11938 x BLV 11937	72.6	55.5	68.0	100.0	27.4
PLQ 13231 x PLQ 13230	95.1	97.4	23.7	100.0	21.9
SGR 13336 x SGR 13006	100.0	36.2	41.2	80.0	11.9

BUK = *S. bukasovii;* PHU = *S. phureja;* BLV = *S. boliviense;* SGR = *S. sogarandinum;* PLQ = *S. peloquinianum.*

that has accessions with high levels of bacterial wilt resistance has ever occurred in areas where *P. solanacearum* has been found. The observed resistance must therefore be due to factors different from natural selection pressure.

Another 10,000 seedlings representing twenty species from the taxonomic series Commersoniana and Tuberosa were screened for resistance to potato leafroll virus (PLRV). Five accessions of the species *S. chacoense* were found to be immune to PLRV, and three accessions of an unclassified species from the series Tuberosa were found to be highly PLRV-resistant. Experience with species from the series Commersoniana and Tuberosa suggests that the utilization of these sources of virus resistance should be relatively easy, particularly if most of the germplasm enhancement is carried out at the diploid level.

Biosystematic studies in the *altiplano* region of Bolivia revealed the existence of more genetic variability in the diploid cultivated species *S.* x *ajanhuiri* than previously reported. Some cultivars that strongly resemble *S. megistacrolobum*, the wild diploid ancestor of *S.* x *ajanhuiri*, were discovered. This discovery has improved our understanding of the evolution of *S.* x *ajanhuiri*.

POTATO GERMPLASM COLLECTION

A second potato collecting expedition, conducted jointly by CIP, the National Institute of Agricultural Research of Ecuador (INIAP), and the International Board for Plant Genetic Resources (IBPGR), went to the provinces of Loja, Azuay, and Cañar in southern Ecuador. A total of 208 samples of native cultivars and three populations of the wild species *S. colombianum* were collected. The cultivated material, collected in a maize-growing area, represents about 109 genotypes. Most of the samples were identified as the diploid species *S. phureja*.

The CIP cultivated potato collection was reduced by another 651 duplicate accessions, which will be discarded after true seed samples have been obtained from them. Good progress was made during 1986 in transferring CIP's cultivated potato germplasm to in vitro culture. More than 1200 accessions were cultured in 1986, bringing the total of the in vitro germplasm collection to 2035 accessions (5 replicate test tubes per accession). This reduces the number of the clones grown annually in the field as fewer replicates have to be maintained of the clones already in culture. Duplicates (4 test tubes per accession) of the cultivated in vitro collection are taken regularly to Ecuador, and the Ecuadorian program (INIAP) sends quarterly reports to CIP on the general condition of the material.

CIP's computerized data file on the in vitro collection is updated routinely so that information on transfer dates of in vitro cultures can be easily retrieved. This collection is monitored at monthly intervals for bacterial or fungal contaminants, and contaminated cultures are removed. The question of the genetic stability of potato germplasm stored in vitro is receiving attention in a research contract with Rothamsted Experimental Station in the United Kingdom.

An inventory of 650 native Andean potato cultivars with an array of resistances to pests, diseases, and other useful traits has been prepared and is ready for distribution to potato breeders and breeding institutions worldwide. This publication, entitled *Inventory of Andean Potato Cultivars with Resistance to Some Pests and Diseases and Other Desirable Traits*, lists 85 diploid, 29 triploid, 531 tetraploid, and 5 pentaploid accessions.

IN VITRO TECHNIQUES FOR POTATO GERMPLASM IMPROVEMENT

Anther culture. In a collaborative project with the Italian National Institute of Nuclear and Alternative Energy Sources (ENEA), several hundred pollen-derived plantlets were produced from a range of potato genotypes. Apparently some of these genotypes contain genes controlling "tissue culture ability," while others lack this character. There are still problems in the management of pollen-derived embryoids, and experiments are currently aimed at increasing the total number of intact plantlets regenerated.

Selection for aluminum tolerance. In an effort to select aluminum-resistant genotypes in vitro, callus and protoplast cultures were produced from the clones LT-2, Revolución, DTO-2, and DTO-33. The cultures of these clones were subjected to aluminum stress, and plantlets were regenerated from cell lines that grew in the presence of certain aluminum concentrations. The regenerated plantlets were again propagated in the presence of aluminum. These plantlets are now growing in pots under conditions of high pH and high aluminum concentration for analysis of overall growth and yield.

Protoplast fusion. In a collaborative contract with the Weizmann Institute in Israel, funded by the U.S. Agency for International Development, asymetric fusions were made to transfer nuclei of the clones Atzimba and Atlantic into cytoplasm that confers male sterility. During 1986, plantlets regenerated from these fusions were received at CIP and are now under evaluation for male sterility.

SWEET POTATO GENETIC RESOURCES

During 1986, there were thirteen additional expeditions to collect cultivated sweet potato germplasm and related wild species: six in Peru, two in Bolivia, two in Colombia, two in Ecuador, and one in the Dominican Republic. All expeditions were conducted in collaboration with the respective national institutions of these countries.

A total of 1079 accessions were collected in 521 localities; of these, 753 accessions belong to *Ipomoea batatas*. In the rest of the material, 28 wild *Ipomoea* species and four natural hybrids have been identified. Five of the wild species are related to *I. batatas*. The expeditions identified centers of great genetic variability in five of the countries that were explored.

Some cultivated accessions were received as donations from several national institutions during these expeditions. The Universidad Nacional de la Amazonía Peruana at Iquitos, Peru, donated 46 accessions, and various institutions in the Dominican Republic donated 112 accessions.

At present, a total of 3140 sweet potato accessions are maintained in CIP's gene bank either as clones or botanical seed. Of this total, 1967 accessions belong to *I. batatas*, 814 to wild *Ipomoea* species, and 359 clones represent breeding lines. These breeding lines were selected from 722 introductions from Peru, the Dominican Republic, and the United States. Selections were made on the basis of yield, other agronomic characters, and root-knot nematode resistance.

A total of 1967 accessions of *I. batatas* from six Latin American countries are maintained clonally at CIP in Lima, Peru. The cultivars from Peru are maintained in the field, and those from Bolivia, Colombia, the Dominican Republic, Ecuador, and Venezuela are maintained in pots in quarantine greenhouses. Progress has been made in the morphological charac-

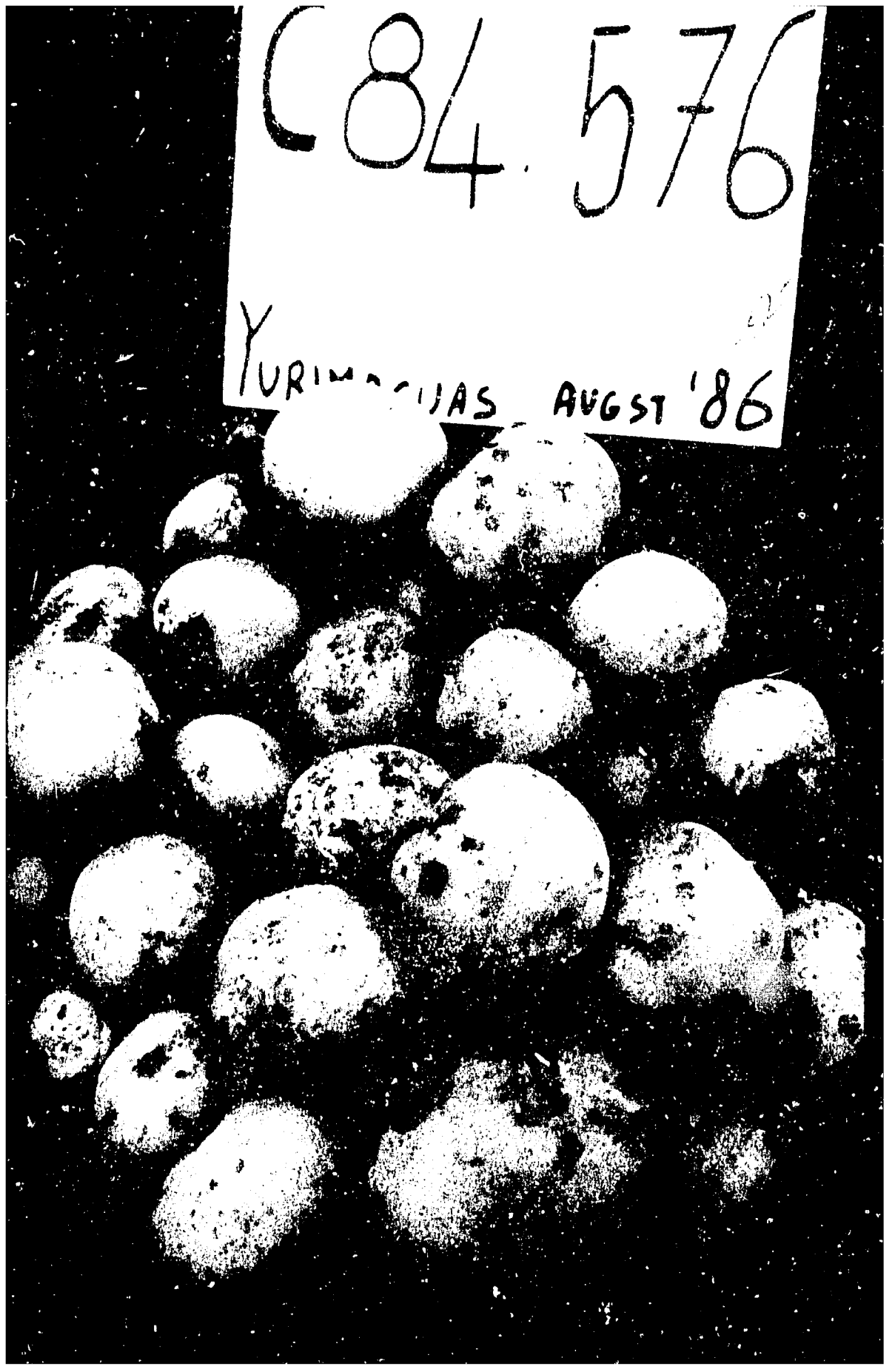
Figure 1. Sweet potato accessions made from a field trial for good potato [illegible] tions of excess soil moisture [illegible]

terization of the Peruvian cultivars, and numerous accessions of potential duplicate samples have already been identified. Traits such as palatability and cooking quality have also been identified and recorded.

Field data on the yield potential of all Peruvian accessions have been obtained at Lima, and representative samples have been grown at San Ramon (mid elevation tropics) and Yurimaguas (lowland tropics) (Fig. 1) to assess the performance of this material under warm and hot conditions during the dry and wet seasons. Some materials with heat tolerance combined with tolerance to excess soil moisture have been identified.

All available data on origin, taxonomic identification, morphological characterization, and the other evaluations carried out on the sweet potato germplasm are available in a computerized data bank.

The in vitro collection. Routine methods have now been established that allow single nodes and buds of screenhouse-grown material to be introduced to in vitro culture. Media that do not induce callus formation are used for the in vitro culturing of sweet potato. About 300 Peruvian sweet potato clones have already been cultured. Efforts are underway to locate a site outside Peru where duplicate in vitro samples can be deposited. Presently, cultures introduced to in vitro culture are, for technical reasons, kept at 28°C. Previously, the optimum temperature for in vitro storage of sweet potato was considered to be 15°C. A number of chemical compounds have been tested to evaluate their potential as growth retardants. As in potatoes, it appears that mannitol, at reduced temperatures, will be highly effective for storing sweet potatoes in vitro.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Production and Distribution of Advanced Breeding Material

In 1986 six clones were introduced into CIP's seed program for disease cleanup and regional distribution. These clones are progenitors with high general combining ability (GCA) for yield and tuber uniformity as well as for earliness and heat tolerance. They are to be used in breeding for variety selection and true potato seed utilization. One of the clones (379706.34), code-named LT-9, is also immune to potato viruses X and Y. When this clone is mated to another progenitor, which is susceptible to both viruses, one fourth of their progenies will be PVY and PVX immune.

Selection for resistance to early blight (*Alternaria solani*) has continued and reevaluation of selected clones from previous seasons has shown adequate levels of resistance, high yields, heat tolerance, and a growing period of 90-100 days. After two years of field evaluation and selection for salt tolerance (electrical conductivity of 3.5 mmhos/cm or more), four clones with yields ranging from 9 to 20 t/ha have been identified. Clones with resistance to *Erwinia* spp. have been identified within the population for the hot, humid tropics. In crosses between *andigena* and resistant cultivars, the frequency of resistant genotypes ranged from 3% to 40%. There has been continued progress in selection for medium maturity and resistance to late blight. Clones with these attributes have been selected in several countries, and at least two have been released as new commercial varieties.

Three years of experiments on comparing methods of parental line selection for GCA for yield have been concluded. Results indicate that the evaluation of open-pollinated progenies of prospective parental clones is an efficient method to select clones with GCA. This method is simpler and more economical than traditional ones, i.e., bulk pollination, clone x tester, and complete or partial diallels. In Bangladesh, six highly selected clones from CIP breeding populations have the potential of becoming new varieties—one clone, 720088 (B-240-2.1), gave the highest yields in trials. The national potato program in Vietnam has also selected five clones introduced in 1982 for testing. CIP genetic materials were distributed to 69 countries (15 developed and 54 developing) in 1986.

Advanced CIP clone being evaluated for heat tolerance, yield, earliness, and tolerance to aluminum toxicity, at Yurimaguas, Peru.

DEVELOPMENT OF ADVANCED CLONES

Intensive work was carried out on selecting parental clones to be used for variety selection and for true potato seed (TPS) utilization. In early 1986, clones 378015.13, 378015.16, and 379706.34 (immune to both potato viruses X and Y) were submitted for disease cleanup and for use by national programs. Later, three more clones, which had been tested for several years, were submitted for cleanup: C83.119 (377887.17 x LT-7), 377964.5 (DTO.2 x Atlantic), and Maine-28 (AF303.5) which was made available to CIP by Dr. A. Reeves from the University of Maine in the United States. Clone C83.119 has a high general combining ability (GCA) for yield and tuber uniformity. Clones 377964.5 and Maine-28 are excellent combiners for heat tolerance, earliness, and tuber uniformity.

A CIP clone from the heat-tolerant and early maturing family 382081 (377964.5 x P_2C_6.1) being evaluated in Cuba by the national potato program.

A sample of 31 selected female clones from a *tuberosum* background and a group of CIP hybrids were tested for parental value by using a line x tester analysis. The results indicated that the *tuberosum* clones did not transmit a high-yielding capacity to their progenies but did transmit earliness and, in some, good tuber uniformity. Conversely, most CIP hybrids transmitted a very high-yielding capacity to their progenies.

In Venezuela, the National Agricultural Research Institute (FONAIAP) has tested 63 advanced clones introduced by CIP, for good high-yielding capacity and tuber quality; of these, 25 were selected for further evaluation. In FONAIAP regional trials, CIP clone 380670.1 (India 853 x Atlantic) showed good agronomic characteristics such as high yields and earliness, as well as tolerance to late blight and possible tolerance to golden nematode. To date, 1500 kg of basic seed of this clone have been produced for on-farm testing prior to varietal release. A second possible varietal release is the Colombian clone 80-428-2 (Greta x (diacol Monserrate x India 1058)), which was originally selected from CIP tuber family 378051. This clone gave excellent yield performance (1.7 kg/plant) without chemical control of late blight in the eastern zone of Venezuela at an altitude of 1000 meters. The control variety in this trial (Sebago) yielded 0.7 kg/plant.

POPULATION DEVELOPMENT

Early blight (Alternaria solani). *Peru.* The introduction of early blight resistance into the lowland tropical populations was continued at San Ramon. In general, the

most resistant families were late to very late in maturity. Early blight attack was also negatively correlated to yield (Table 1).

New sources of resistance to *A. solani* were introduced into the lowland tropical populations, which originated from research contracts with North Carolina State University (*phureja-stenotomum*) and Cornell University (*neo-tuberosum*) in the United States. Good levels of resistance and acceptable yields were found in some of these families (Table 2). Despite the positive correlation between length of the growing period and resistance to early blight, the family Maine-47 x 378015.16 of medium maturity yielded 694 g/plant (about 22 t/ha) in 90-100 days. This indicates that the correlation is not absolute and that it would be possible to shorten the growing period while still maintaining an adequate level of resistance.

Table 1. Phenotypic correlation matrix for early blight (EB) infection at 60 and 75 days after transplanting and for earliness and tuber yield. San Ramon, 1986.

Trait	EB 60	EB 75	Yield
Earliness	0.08	0.44*	−0.46*
EB 60		0.31	−0.53**
EB 75			−0.49*

*Significant at the 5% level; **significant at the 1% level.

Late blight (Phytophthora infestans). ***Colombia.*** Trials continued in Colombia on the international testing and selection of clones with late blight resistance. After 25,000 seedlings grouped in 125 families were screened by the national potato program of ICA, 1738 clones were selected and field-tested at ICA's research station at Rionegro. Of these, 116 were retained that combined high yield, medium maturity, and resistance. Clones selected in 1985 were reevaluated at Rionegro, and several highly resistant clones with medium maturity and high yield were identified (Table 3).

Kenya. The procedure followed in Kenya in 1986 for screening clones for late blight resistance had four stages: 1) 10-hill plots, 2) 20-hill plots, 3) preliminary yield trials, and 4) yield trials.

Table 2. Evaluation of *Alternaria* (EB) resistance 60 and 75 days after transplanting and other traits in families from North Carolina State University (NC), Cornell University (NY), and CIP. San Ramon, 1986.

Family	EB 60	EB 75	Yield/plant (g)	Earliness
Sacco x EB81P3.11 (NC)	3	2	124	2
71C15.20 x EB72P4.B133 (NC)	3	3	398	4
Sacco x EB66P1.B2 (NC)	3	2	438	2
NDD277.2 x 378676.6 (CIP)	3	3	657	4
NY59 x NY72 (NY)	3	3	677	4
BL2.9 x 378015.16 (CIP)	3	3	727	2
Maine-47 x 378015.16 (CIP)	4	4	694	5
NY59 x T53.26W (NY)	4	4	542	5
NY59 x ADG.LB (NY)	4	4	590	5

Early blight (EB) rating: 1 = immune, 9 = susceptible.
Earliness rating: 9 = very early (maturity 75-80 days), 1 = very late (maturity >120 days).

Table 3. Disease evolution and yield performance of the best five late blight resistant clones and three controls at Rionegro, Colombia, 1986.

Clone	Intervals of late blight readings					Yield (kg/plant)
	1	2	3	4	5	
382397.9	3	2	4	2	2	3.73
383081.27	1	4	2	2	2	2.32
383042.9	1	1	1	3	2	2.21
383119.14	1	1	1	3	2	2.18
383105.6	1	1	1	2	2	2.15
Picacho (control)	1	3	7	9	9	0.40
Purace (control)	3	6	6	7	9	0.23
Capiro (control)	5	7	8	9	9	0.03

CIP late blight rating scale: 1 = no damage; 9 = 100% damage.

In stage (1), 46 clones were planted in the highlands at Molo (2400 m) and Mau Narok (3100 m). For most of these clones it was their first field evaluation in East Africa for general performance. The best 15 clones at Molo and Mau Narok included 12 and 9 selections, respectively, from CIP tuber families. In the stage (3) trial at Molo, the two controls (commercial varieties Kenya Baraka and B.53) yielded 12.5 and 15.2 t/ha, respectively. The highest-yielding clone (tuber family selection 379417.11) gave 53.3 t/ha. The majority of clones showed better late blight resistance than the controls.

In the stage (4) trial at Molo, control varieties Kenya Baraka and B.53 both yielded 15.8 t/ha with late blight scores of 5 and 6, respectively (scale: 1 to 9). Similar results were obtained with the stage (4) trial at Mau Narok. The control variety B.53 yielded 17.9 t/ha with a blight score of 6 (Table 4). At both locations, clone 720084 occupied either first or second place for yield giving 35.4 t/ha at Molo and 42.5 t/ha at Mau Narok with blight scores of 2 and 3.

Bhutan. The national potato program evaluated 16 introduced cultivars, principally for yield and resistance to late

Table 4. Screening for late blight resistance and yield trials in Kenya, 1986.

Site	Yield of control (t/ha)	No. of clones better than control	Yield of best clone (t/ha)	Blight score[a] for control	Blight score[a] for best clone
Category 3					
Molo	12.5	18 (36)[b]	53.3	6	4
Category 4					
Molo	15.8	19 (21)	36.0	6	2
Mau Narok	17.9	17 (20)	42.5	6	3

[a]CIP late blight rating scale: 1 = no damage; 9 = 100% damage.
[b]Numbers in parentheses indicate total number of clones in the trial.

blight. Among the group of five clones with supposed late blight resistance, clone 800949 (Sangema) was the most promising, with maturity in 140 days and good resistance. Two other clones were also retained but matured in 160 days. None of five French varieties gave acceptable yields, although they were slightly earlier maturing at 140-150 days. Selected cultivars will be reevaluated in 1987.

In a preliminary yield trial with four replications at Yusipang, clone 800949 was the highest yielder among 17 entries. Several other clones were also selected for further evaluation, with two originating from tuber family selections supplied by CIP. Of these, several showed a high level of late blight resistance 92 days after planting, but it was suspected that the resistance might be vertical.

The main objective of the national program is to find a suitable substitute for the variety Kufri Jyoti widely grown in Bhutan. In on-farm trials with clones that had already passed preliminary and multilocational tests, the two clones 720088 (B-71-240.2, Argentina) and 720122 (MEX 750815) were preferred by farmers over Kufri Jyoti.

Erwinia spp. Sources of resistance to *Erwinia* spp. (bacterial soft rot) were sought in hybrid families adapted to the lowland tropics as well as in a highland population of families from crosses between resistant *andigena* cultivars. In the lowland tropical population, the initial sample was 5880 genotypes grouped in 49 families. Of these, 107 selections not showing tuber rot were retained after two seasons of field exposure at San Ramon, Peru. Tubers of these clones, which represent 1.8% of the original population, will be inoculated in the laboratory to select progenitors for the next cycle of selection. The highland population comprised 22 families obtained from crosses between *andigena* cultivars exhibiting resistance to soft rot after tuber inoculation in the laboratory. ubers from 1980 genotypes field-grown in Huancayo were inoculated by the infectivity titration method with a concentration of 8.8 x 10^5 cells/ml. Distribution of resistance in the 22 families ranged from 3% to 40%.

Salt tolerance. In the last two years selection of clones for salt tolerance has been carried out through a research contract in Tacna, Peru, located 1300 km south of Lima. In the testing site at La Yarada, the soil has an electrical conductivity of 3.5 mmhos/cm or more, and only salt-tolerant crops are cultivated. In the first year, 500 clones were tested and 60 were retained for further observation. In the second year, 4 clones were selected, representing 0.8% of the original population. These clones, with a medium to late growing period, had good plant survival and did not show foliar burning, which is characteristic of susceptibility. The best performing clone (78.9.4 F_2 x Bk Pr HM).32 yielded 785 g/plant (about 20 t/ha).

USE OF SELFED, OPEN-POLLINATED, OR HYBRID FAMILIES

In CIP's breeding program, selection for yield of superior progenitors is based on the use of bulk pollination of phenotypically selected clones or the use of the clone by tester analysis. In previous years, experiments were initiated to investigate open-pollination and selfing as alternative methods to select for GCA. To do this, a random sample of 50 *andigena* cultivars was taken, and from each, four types of families were obtained, including selfed, open-pollinated (OP), and hybrid to a pollen bulk of 10 cultivars and to a pollen bulk of 20 cultivars. The 50 groups with four families each were field-evaluated for

two seasons. Results indicated that in some cultivars there was no difference between the yield performance of their selfed and OP families compared to yield performance of hybrid families produced by bulk pollination. In other cultivars there was a superiority in yield from mild to very high of the hybrids over the selfed and OP families due to the inbreeding effect.

The yield performance of some cultivars (mentioned earlier) that did not depress by inbreeding and some that did was field-evaluated by means of an 11 x 11 diallel experiment without reciprocals. The diallel analysis indicated that the highest estimates of GCA ($\hat{g}_i$) corresponded to the cultivars that did not depress by inbreeding, while the $\hat{g}_i$ values not different from 0 or significantly negative corresponded to the cultivars that showed strong inbreeding depression. These results would indicate that the yield performance of either selfed or OP families would permit selection of progenitors with high GCA for yield. It would be much more economical, however, to test the OP families of the clones undergoing selection.

USE OF DIHAPLOID CLONES

Since one of the goals of the population breeding at CIP is to increase the frequency of genes controlling desirable attributes, a new approach involving selection of superior progenitors for tetraploid breeding was started in 1985. Dihaploids were extracted from highly selected clones with attributes such as earliness, heat tolerance, and resistances to potato leafroll virus (PLRV), PVX, and PVY (Table 5). The dihaploid clones segregating for virus resistance were screened and some clones with immunity to PVX and PVY were identified. These are in the process of doubling to obtain autotetraploid clones, which will be duplex at the loci controlling immunity to the two viruses. The use of such clones in breeding can be illustrated by the following example. If the clone LT-8, which is immune to PVX and PVY, being

Table 5. Dihaploids extracted from 12 selected tetraploid clones.

Clone	Attribute or resistance	No. of dihaploids	
		Expected[a]	Confirmed
LT-1	Heat tolerant, early	133	27
LT-5	Heat tolerant, early	16	10
LT-7	Heat tolerant, early	59	20
LT-8	Heat tolerant, early, PVX, PVY	67	32
Maine-28	Early	148	24
PW 31	PVX, PVY, PLRV	16	9
377887.35	Tuber yield	10	4
377888.8	Early	5	3
377904.10	Tuber yield, early	126	9
379706.34	Heat tolerant, PVY, PVX	71	21
575049	Late blight	281	21
7XY.1	PVY (duplex for PVY)	20	14
Total		952	194

[a] Expected as a function of absence of seed spot.

both loci at the simplex condition (YyyyXxxx), is used as a progenitor and crossed to a susceptible clone, LT-8 would transmit PVX plus PVY immunity to 25% of its progeny. If a doubled dihaploid, which has become duplex at both loci, from LT-8 (YYyyXXxx) is crossed to a susceptible progenitor, it would transmit PVX plus PVY immunity to 69% of its progeny. Since doubled dihaploids per se are not suitable as commercial varieties, the inbreeding (F=0.333) generated in the process of doubling will be dissipated by crossing these progenitors to unrelated and highly heterozygous partners. The average inbreeding coefficient of a progeny like YYyyXXxx x yyyyxxxx will be decreased to F=0.055, which is very small and should not have a major influence on the performance of the hybrids.

Table 6. Results from evaluations for resistance to various pests and diseases of diploid clones from October 1985 to October 1986, Lima.

Pest/disease	Number of clones	
	Screened	With resistance
Cyst nematode		
GP4	48	5
GP5	47	8
Potato virus Y	39	9[a]
Potato virus X	8	3
Potato leafroll virus	43	25
Root-knot nematode		
population 1	108	10
population 2	66	11
population 3	53	4
Total	368	75

[a] Four clones were hypersensitive.

PLOIDY MANIPULATION

In research on ploidy manipulations, 368 selected diploid clones were screened at Lima for resistances to specific pests and diseases (Table 6), and 75 were selected for specific resistances. Since some of the 2x clones produce unreduced pollen, they can be used in 4x-2x crosses to transfer the resistance factors to the tetraploid level. These selected clones will also be used in 2x-2x crosses to create a new population with combined resistances.

Kenya. Now that a CIP potato breeder is based at CIP's regional headquarters in Kenya, it is possible to concentrate the breeding program on producing clones better adapted to East African agroclimatic conditions. From past experience, it has been found that although a clone may have potentially good resistance to diseases such as late blight and bacterial wilt, the expression of this resistance is frequently masked by poor adaptation. The new breeding program based in Kenya will produce progeny derived from crosses between the best of CIP's new disease-resistant genetic materials and certain local varieties with good adaptability to local conditions. The first testing of these new materials will be in 1987.

South Asia. In Pakistan, a bilateral potato research program, funded by Switzerland, works directly with the national potato program. One of the projects initiated in 1986 was the selection of improved clones adapted to the northern hill area, with resistance to late blight and cyst nematode and sufficiently early maturing for use in a double-cropping system. Genetic materials derived from CIP, Belgium, Scotland, India, and the United States are in the process of evaluation.

In Bangladesh, the Potato Research Institute continues to test a wide range of genetic materials from many sources. Priorities are for earliness—an important consideration in the short Bangladesh season—and virus resistance. Among the CIP selections and imported varieties, it was

observed that there were some cultivars with heat tolerance—a very important character for Bangladesh potato production.

The Argentinian variety Huinkul showed excellent storage characteristics throughout the hottest part of the year (March-June) during which time no sprouting was observed when tubers were kept in diffused light storage (DLS) for eight to nine months.

Through the CIP contract with the Plant Research Institute in Victoria, Australia, pathogen-tested stocks of 13 advanced CIP introductions were supplied to Bangladesh. CIP clone 720088 (B-240-2.1), bred by INTA in Argentina, gave the highest yield in trials. In addition to this clone, five highly selected clones from CIP breeding populations with potential to become new varieties have been selected and are in the process of cleanup from diseases. The characteristics of these materials, tested at the Mushiganj and Joydepur research stations of the Bangladesh Agricultural Research Institute, are presented in Table 7. In Table 7 it is noticeable that four of the five clones selected from CIP breeding material have as the male progenitor the cultivar Marie Tropical, which had transmitted to them its earliness and heat tolerance.

Table 7. Principal characteristics of CIP highly selected clones in Bangladesh.

Cultivar no.	Pedigree	Characteristics
CIP 720088	(MPI 61375.23 x B-2565)	Main season variety (90 days); moderate yield; field-resistant to late blight, bacterial wilt and leafroll; low degeneration rate; heat tolerant; excellent storability in farmer's store; white round tubers.
CIP 379666.501	[(BR63.65 x Katahdin) x Maria Tropical]	Early (70-90 days); fast growing; consistently high yield; low degeneration rate; white oval tubers.
CIP 379688.230	[(BR63.65 x Atlantic) x CGN-69.1]	Medium maturity (80-100 days); quick growing; field-resistant to insect-transmitted viruses; red round tubers.
CIP 379667.421	[(BR63.65 x Katahdin) x Maria Tropical]	Medium early (80-90 days); fast growing; high yield; low degeneration rate; field-resistant to late blight; white round oval tubers.
CIP 379659.657	(Atzimba x Maria Tropical)	Very early (60-80 days); excellent yield; very low degeneration rate; white oval tubers.
CIP 379673.150	[(BR63.74 x Anita) x Maria Tropical]	Early (70-90 days); high yield; very low degeneration rate; white oval tubers.

Selections had been made in Bangladesh in 1985 of *neo-tuberosum* clones received from Cornell University. Seventy-one clones were retested in 1986 and 38 were selected for further trials in 1987.

Southeast Asia. Most areas in Region VII have planting dates and growing periods with short-day conditions. The CIP cultivars P-3 and DTO-2, planted as cuttings, appeared to be adapted to this type of photoperiod in a trial planted at Pangasinan State University, Philippines. Under lowland conditions at Canlubang, seven trials were planted to study the performance of heat-tolerant materials. Twenty of these were second generation tubers of selections grown on the same site, the rest were supplied through CIP's contract with the Plant Research Institute, Australia, and direct from CIP, Lima. Generally, all cultivars did well except DTO-2 and LT-2, which suffered from virus degeneration. Cultivars P-3 and B-71-240.2 had the lowest level of virus degeneration, the latter is known to have tolerance to PLRV. In a similar degeneration trial planted at Pangasinan State University, B-71-240.2, P-3, and also Sequoia gave high yields.

Forty cultivars were evaluated by national scientists in countries of the Pacific Basin for adaptation to warm growing conditions and longer daylengths. The countries were Cook Islands, New Caledonia, Vanuatu, and French Polynesia. The highest yields were given by Sequoia, Red Pontiac, B-71-240.2, Serrana, and N-565.1. The two introductions from Argentina (B-71-240.2 and Serrana) showed that first generation seed stored in DLS for six to seven months gave consistently good performance. Of the cultivars with bacterial wilt resistance, only BR-112-113 showed good yield and adaptation to warm growing conditions and increasing daylength. No cultivars were identified as being resistant to *Alternaria solani*, the major fungal parasite encountered in the Pacific area.

In Thailand, the same two introductions from Argentina mentioned above gave excellent yields from second generation seed after storage for eight months in DLS. The locally grown control variety Spunta did not store well in DLS and gave relatively poor performance. In Vietnam, five clones introduced in 1982 were selected by the national program after being evaluated over four seasons of cultivation in the lowlands. These clones are selections from tuber families of B-71-240.2 x DTO Bulk, BR 69.84 x Atzimba, BR 69.84 x Atlantic, and Serrana x 14XY.4.

In the Red River Delta of Vietnam, potato varieties are needed with long dormancy coupled with short-day adaptation. Three CIP clones, P-3, 381064.12, and 381064.7, continue to show good adaptation under these conditions. Commercial propagation for planting materials is obtained by sprout cuttings, and regula *S. tuberosum*-type cultivars tend to tuberize too early under short-day conditions to permit this type of propagation. The above mentioned materials, which have either *S. andigena* or *S. phureja* in their parentage, are better adapted to these requirements.

In the southern hills of Laos, the first CIP clones were introduced in 1984. After four generations of testing in replicated trials by national scientists, only clones BR 63.15 and Cruza 148 have survived the combined selection pressure of bacterial wilt, *Erwinia*, and late blight. These clones are now being rapidly multiplied by cooperative groups of farmers who urgently need improved seed of superior cultivars.

West Africa. The potato program of the Agricultural Research Institute (IRA) in Cameroon compared 45 cultivars for

general yield performance and late blight resistance. These cultivars originated from CIP (1985 introduction, multiplied once in Cameroon), imported seed of varieties from the Netherlands, and older local varieties. The highest yields were obtained from the varieties Escort and Condor (25 t/ha), which had no late blight symptoms, and from CIP introduction 573275 (ASN 69-1) (22.3 t/ha), which showed slight symptoms of late blight.

In Senegal, cultivars introduced in 1985 were grown in a replicated trial in 1986 and selected for heat tolerance at the Center for Horticultural Development (CDH) at Dakar. Warm conditions prevailed at planting in October 1985 and summer-type temperatures continued until mid-November (35° C). Locally produced seed of Desirée gave the best yield, but among the CIP clones, CFK-69-1, LT-6, DTO-33, and DTO-28 gave good yields. The clone DTO-28 performed especially well considering it had a long storage period in diffused light at summer temperatures.

TRUE POTATO SEED

In research on the use of true potato seed (TPS), experiments were carried out in San Ramon to compare the performance of hybrid families (F_1) with their respective open-pollinated OP_1 and OP_2 generations. This research included 27 families from each generation. In the comparisons, F_1 vs. OP_1, F_1 vs. OP_2, and OP_1 vs. OP_2, the following results were obtained. In 22% of the cases, $OP_1 > F_1$, and in 30% $OP_1 = F_1$. In 30% of the progenies, $OP_2 > F_1$, and in 18% $OP_2 = F_1$. Furthermore, in 30% of the progenies, $OP_2 > OP_1$, and in 40% $OP_2 = OP_1$. In only 33% of the families was the F_1 superior to both OP_1 and OP_2. These results suggest that in this population the effect of inbreeding on yield performance may not be very severe. It can be assumed that in the F_1 hybrids the coefficient of inbreeding (F) was F = 0. In the OP_1, the F value would be variable with a maximum value of 0.1667, depending on the amount of selfing. In the OP_2, the F value should still be greater considering that selfing and sib mating would be taking place. The results discussed could be due to two reasons: 1) this population has been, for several cycles, selected for GCA and this may have increased the frequency of additive genes, consequently decreasing inbreeding effects; 2) it is possible that the infertility produced as an effect of inbreeding may eliminate from the next generation the most inbred genotypes, and thus minimize their contribution to the generation mean. These findings are important as they indicate that it is feasible to select families that will permit the use of open-pollinated generations to produce potato from TPS. These types of families could be used by farmers in the developing world who could repeatedly use OP seed from their own crops.

Trials to evaluate yield and earliness of 4x-2x progenies were carried out at San Ramon, Lima, and Huancayo. As usual, these progenies were high yielding and superior to the controls in the trials; however, their growing period still tended to be late. The 4x-2x progenies resulted from crosses between selected tetraploid females with high GCA for yield and earliness and 2x progenitors with medium earliness and high total yield.

GERMPLASM DISTRIBUTION

CIP tested 4456 samples from the seed program (Gen II) with an indicator host range and ELISA for PVS, PVX, PVY, PLRV, Andean potato latent virus (APLV), and Andean potato mottle virus (APMV). All samples were virus-free, indicating that

Table 8. Distribution of germplasm from CIP headquarters in Lima, Peru, during 1986.

	Clones		Tuber families		In vitro plants		True potato seeds		Seed progeny		In vitro tubers	
CIP region	Accessions	Units	Accessions	Units	Accessions	Units	Accessions	Units	Accessions	Units	Accessions	Units
I (5)[a]	639	8,795	112	1,145	19	57	27	5,400	16	137,650	-	-
II (17)	505	6,448	231	9,542	147	351	125	19,446	62	366,200	13	1,425
III (7)	252	1,154	283	6,575	32	64	30	7,000	13	249,530	-	-
IV (4)	102	2,489	101	9,074	-	-	25	5,000	8	30,000	-	-
V (8)	55	716	15	511			25	5,000	16	58,400	-	-
VI (5)	96	3,477	24	2,271			26	6,750	20	1,353,400	-	-
VII (7)	137	835	375	17,008	78	165	96	14,280	14	44,220	14	1,353
VIII (1)			28	359	40	80				-	-	-
Others (15)	47	216	-	-	81	160	70	24,545	20	78,000		-
Total (69)	1,833	24,130	1,169	46,485	397	877	424	87,421	169	2,417,400	27	2,778

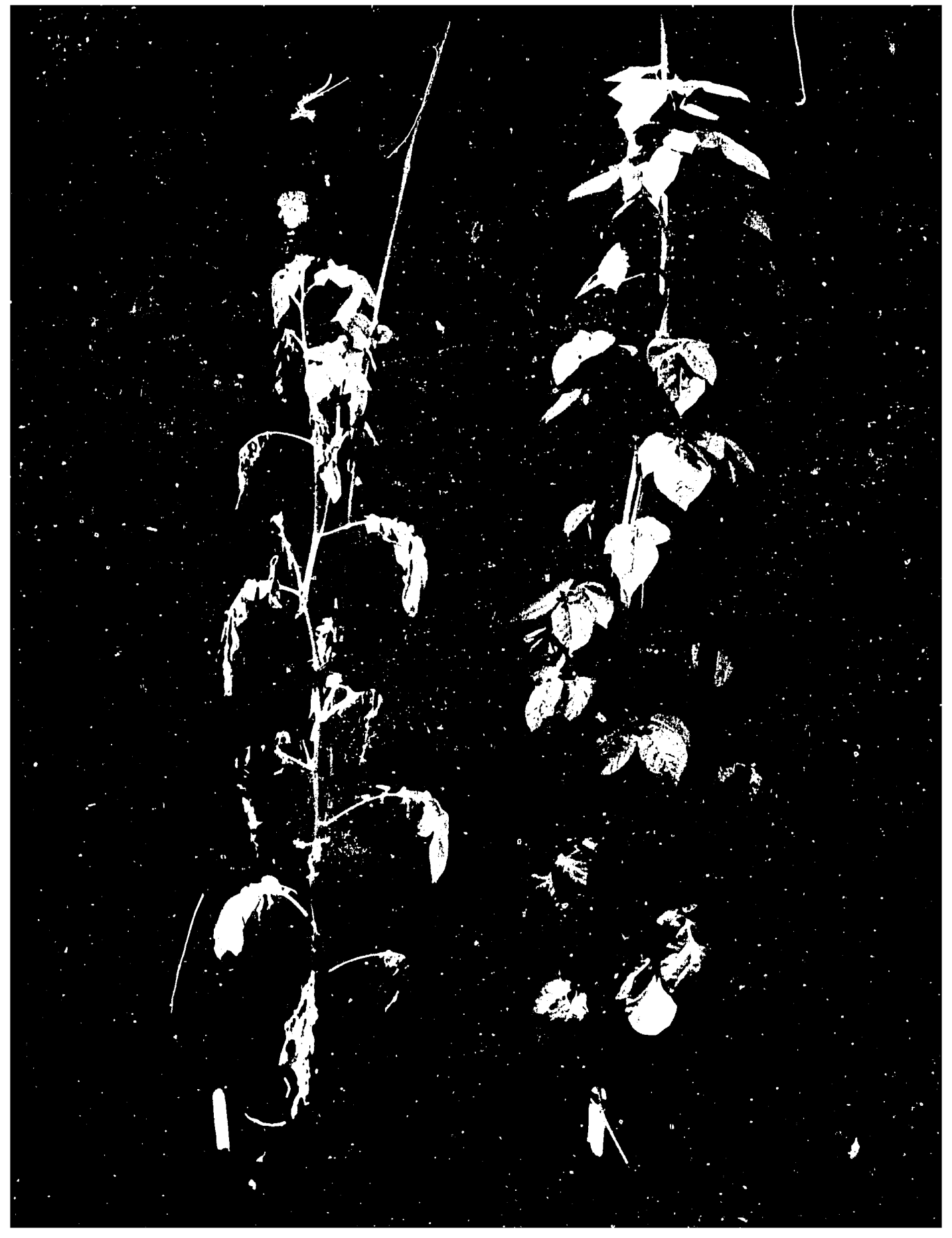
[a] Numbers in parentheses indicate the number of countries within each region, and for "Others" the number of developed countries to which shipments were made.

eradication measures taken to prevent contamination in export materials have been successful.

During 1986 CIP distributed genetic materials to 69 countries worldwide (Table 8). The CIP Region III germplasm evaluation and distribution center in Nairobi, Kenya, exported 60 clones to various countries in Africa. A large ongoing program of germplasm evaluation for Southeast Asia has been organized at CIP's regional germplasm station at St. Lucia, Philippines. All recently introduced and promising clones are maintained and multiplied in vitro and materials are distributed to other countries for evaluation in the form of in vitro plantlets, cuttings, and small tubers. The Sta. Lucia station distributed in 1986 a total of 2880 cuttings, 15,372 tubers, 21,000 true potato seeds (TPS), and 60 test tubes of in vitro plantlets to eleven countries.

TRAINING

Due to the increasing quantities of in vitro germplasm being exported annually from CIP, training activities have concentrated on tissue culture techniques. Seven scientists from Europe, South America, and Asia completed a total of 32 weeks of training that emphasized rapid propagation in vitro and the transfer of in vitro plantlets to the glasshouse. A germplasm management course was held in Turkey, the second one to be held there after a gap of four years, and was attended by scientists from Egypt, Sudan, and the Middle East.



Control of Bacterial and Fungal Diseases

A new population, derived from several potato species with resistance to bacterial wilt, was crossed to a heat-adapted, early maturing potato population, and the maturity time of the hybrids was reduced from 126 to 86 days. Some of these hybrids have shown promise in fields infested with *Pseudomonas solanacearum* in Mindanao, Philippines. A scissors-cut method proved to be an efficient means of inoculating potato plants and seedlings with *P. solanacearum*. An antiserum effective in identifying *P. solanacearum* in infected plants or tubers is in use in 16 countries.

Large numbers of *Erwinias* (Ecc), the causal agent of soft rot, were detected in irrigation water at three sites in Peru, but filtering the contaminated water through sand reduced the numbers of Ecc by 94%. Calcium fertilization resulted in a thicker tuber periderm with greater resistance to *Erwinia*. Tuber rots in San Ramon were shown to be a result of interaction between several fungi and *Erwinias*. The greatest plant loss in the field was due to *P. solanacearum* and early dying caused by different fungi.

In studies to improve inoculation procedures with *Phytophthora infestans*, zoospores were found more effective than sporangia. When R-gene-free populations were screened for general resistance to *P. infestans*, lower concentrations of race 0 zoospores were needed. The inoculum was more effective when grown on potato leaves than on agar medium. Screening 31,000 seedlings with a complex race of *P. infestans* resulted in 29% seedling survival. When another 10,000 seedlings were screened with race 0, 70% immunes were discarded plus 22% susceptibles, the remaining 8% had general resistance. A second population of 30,000 seedlings, based on *S. tuberosum* subsp. *andigena*, was screened for general resistance to *P. infestans* with race 0, and 22% expressed resistance.

Early blight (*Alternaria solani*) seedling screening did not correlate well with adult plant field tests in San Ramon but an acceptable correlation resulted between Lima screenhouse screening and San Ramon plants inoculated at 75 days. Field evaluations of 65 clones for resistance to *Verticillium dahliae* on the coast of Peru yielded 15 resistant clones. The best control of *R. solani* damping-off and premature death of transplanted seedlings was achieved with the fumigant Basamid plus Rizolex fungicide, and a plastic cover over the soil.

Potato plant *(left)*, showing symptoms of chlorosis and wilt, infected with *Verticillium dahliae*, causal agent of *Verticillium* wilt.

BACTERIAL DISEASES

Breeding for resistance to bacterial wilt (Pseudomonas solanacearum). A new breeding population which had been developed in Peru during the last five years and which combines four different sources of resistance to bacterial wilt had a late maturity of 126 days. This population was crossed with CIP's best heat-adapted and early maturing materials, and the resulting hybrid population matured in 86 days in San Ramon. True seed of this cycle of selection were sent to the Philippines where they were planted in the field in Mindanao and exposed to natural field infestation of *P. solanacearum* and high temperatures. This work in Mindanao was carried out in collaboration with the Philippine Bureau of Plant Industry (BPI). Clones were selected for resistance and agronomic characters and planted again in a field with higher inoculum potential. During this second exposure, most clones succumbed to wilt, but the 20 best clones were selected, some of which had no wilted plants. Another group of clones, slightly more advanced genetically, of the same population was exposed to the bacterial wilt pathogen once at midyear, and 35 clones were selected under low inoculum potential. These clones were to be retested under conditions of heavy inoculum pressure later in the year.

Although superior in wilt resistance to the *S. phureja*-derived populations, which were developed four to five years ago and which had only one source of resistance, this new population has demonstrated that much progress can be made at the diploid level before making the tetraploid x diploid cross; it does, however, lack resistance to late blight. The postponed objective of combining late blight with bacterial wilt resistance will now be tackled using the currently available general resistance (free of race-specific R-genes) for *Phytophthora infestans*.

Latin America. Seven advanced clones from CIP with reported resistance to bacterial wilt were tested in the laboratory by the National Agricultural Research Institute (FONAIAP) in Venezuela. Only Cruza 148, now named as a variety in Burundi and other countries, appeared to be resistant. These clones will be tested in field trials next season.

In Brazil and Uruguay, the testing of breeding materials with bacterial wilt resistance has continued at the National Center of Horticultural Research (CNPH) in Brasilia, and at the Center of Agricultural Research (CIAAB) experiment station in Uruguay in a special field house with inoculated soil. As the natural level of field inoculum was low in Brazil, a high percentage (56%) of clones passed the field test. In Uruguay, however, good levels of infection were obtained in the field house. Three clones showed zero field symptoms, but when the tubers were tested by latex serology no clone was completely free of latent infection. The levels of resistance to *P. solanacearum* still need improvement as symptomless plants could still be a source of disease spread due to latent infection. None of these materials has resistance derived from the wild species used in the multiple hybrid combinations reported in Thrust I.

Tropical Africa. In Burundi, the principal requirement of the potato crop planted during the third cropping season (June-July) is resistance to bacterial wilt, since the crop is sown in the valley bottoms on residual moisture where the disease is most prevalent. During January-April 1986, in conjunction with the Crop Protection Department of ISABU, clones were multiplied for subsequent bacterial wilt evaluation. A total of 1147 clones, which according to their breeding parentage had

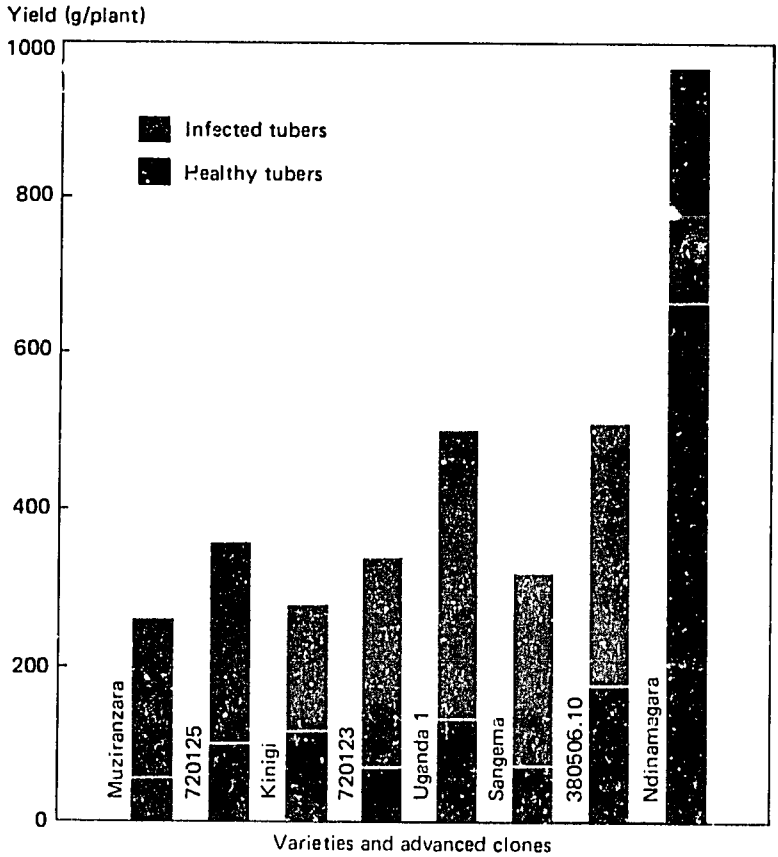


Figure 1. Yield (healthy and infected tubers) for varieties and advanced clones in a bacterial wilt evaluation in Burundi.

wilt tolerance, were multiplied in a wilt-free environment at Munanira. They were given only light fungicide protection against late blight, and as a result, 468 clones were eliminated because of extreme susceptibility to this disease. The remaining 679 clones will receive one more multiplication at the same site before being screened for bacterial wilt.

Wilt-tolerant varieties and advanced clones were planted at Gisozi in September 1985 and harvested in January 1986. There were six replications, and visual wilting symptoms were recorded weekly until harvest 14 weeks after planting. Figure 1 shows the yield of the various genotypes. The new variety Ndinamagara (Cruza 148) continued to give the highest yield under severe wilt conditions and is now being distributed in large quantities throughout the different development projects in Burundi.

In Kenya, 20 advanced clones were evaluated for resistance to bacterial wilt through contract work with the National Agricultural Laboratories in Nairobi. The trial was replicated and test plants were inoculated artificially with a suspension of the bacteria. No clones were completely resistant (zero wilting), but a few

showed apparent tolerance, i.e., out of a total of forty plants per clone, six clones had five wilted plants or less after 45 days of inoculation.

Southeast Asia. Resistance to bacterial wilt is so essential throughout CIP's Region VII, that a major collaborative research program has been continued annually in an attempt to identify resistant or tolerant genotypes. The most resistant selections, all produced locally, had Cruza 148 in their parentage. However, bacterial wilt resistance alone may not be sufficient for conditions where root-knot nematodes are present in the soil. Root-knot nematodes are known to injure roots which in turn provides entrance for the *P. solanacearum* bacteria into the plant. This is why resistance to root-knot nematodes will eventually have to be combined with resistance to the bacterial wilt pathogen.

True potato seed (TPS) families from the newly combined hybrids incorporating bacterial wilt resistance from wild species, developed at CIP, were evaluated by CIP and the Bureau of Plant Industries in the Philippines at Dalwangan, Mindanao, and transplanted to the field at Intavas, Mindanao. A total of 714 clones were harvested and 225 were selected for general agronomic characters. It is of special interest that among the clones selected at both sites, CIP family 384015, which has AVRDC 1287.19 as the male parent, was predominant. One clone, 384015.3, was the highest yielder at both sites and showed 0% bacterial wilt ten weeks after planting. The selected clones will be used as parents to combine with locally adapted varieties.

Comparison of inoculation methods. Soil infestation with suspensions of *P. solanacearum* is the method presently used at CIP in screening for resistance and for other inoculation studies. This method, however, requires large numbers of bacteria and results are not highly consistent. Therefore, an experiment was conducted in which four different methods of artificial plant inoculation were compared with plant infection resulting from artificial soil infestation. Inoculum for all methods consisted of 1×10^8 colony forming units (CFU)/ml of Peruvian race 3 strain 204 grown for 48 hours on Kelman's agar medium without tetrazolium. Plants used for testing the effectiveness of the prepared suspension were cuttings of the susceptible variety Ticahuasi four weeks after being transplanted to one-liter plastic pots. Ten plants were used per treatment, and the test was repeated twice at temperatures averaging 25.3° and 27.6° C, respectively.

The four methods that were compared with soil infestation were 1) stem puncture, 2) scissors-cut method, 3) leaflet infiltration, and 4) carborundum injury. Soil infestation was done by drenching the soil around the stem with 40 ml of inoculum. Stem puncture consisted of inserting a dissecting needle through a drop of inoculum into the axil of the third leaf below the apex. A scissors-cut method involved cutting the terminal leaflet of the third leaf below the apex with a dissecting scissors dipped in inoculum. Infiltration was performed by using a needleless disposable syringe fitted with an additional perforated plunger end piece from an identical syringe. Pressure was applied with the plunger so that the inoculum passed through the perforated plunger end piece onto the underside of the leaflet (where most stomates are located). The other side of the leaflet rested against the hand. Inoculation with carborundum was done by first dusting carborundum 600 mesh onto the topside of the leaflets and then rubbing the dusted side of the leaflet with a cotton tip immersed in the inoculum. This method is identical to the one

Table 1. Evaluation of five methods for inoculating plants of the variety Ticahuasi with *Pseudomonas solanacearum*. Averages for two tests, ten plants per treatment.

Method	8 days		12 days	
	% Diseased plants	Index[a]	% Diseased plants	Index
Stem puncture	100	4.0	100	4.9
Scissors-cut leaflet	100	3.2	100	4.8
Leaflet infiltration	100	2.2	100	2.8
Carborundum injury	40	1.6	75	2.3
Soil infestation	35	1.4	90	2.9

[a] Disease intensity index: 1 = healthy; 5 = dead.

used for virus inoculations. The effectiveness of the various inoculation methods after 8 and 12 days is shown in Table 1. After 12 days the stem-punctured and scissors-cut inoculated plants were all severely wilted. The carborundum and infiltration methods were inconsistent, as the percentage and the rate of wilting in the susceptible material was clearly lower than in the material inoculated with the stem-puncture or scissors-cut method. Soil infestation produced initial wilting in nine out of ten plants. The symptom expression in these tests is shown in Figure 2. The scissors-cut inoculation method seemed the most promising for a rapid and standardized inoculation of individual plants.

Figure 2. Symptoms resulting from potato plants with *P. solanacearum* by four methods (*left* to *right*): stem puncture, scissors-cut, rubbing with carborundum, and infiltration.

Antiserum production and distribution. A broad spectrum rabbit antiserum that reacts with all races of *P. solanacearum* was produced at CIP in 1983. A latex kit is now prepared routinely with the antiserum stock and distributed to national potato programs. However, when a program's demand for antiserum supply is heavy, CIP provides training to national program staff for the preparation of their own antiserum. The amount of sensitized latex sent to different countries during one year is shown in Table 2.

At the University of Wisconsin in the United States, contract research has resulted in the production of several hybridomas that produce monoclonal antibodies against a race 3 strain of *P. solanacearum*. However, one hybridoma produced antibodies that had activity against all strains tested. The latter hybridoma will be tested against the CIP collection of isolates to determine if it could serve as a substitute for the rabbit antiserum, with the advantage that hybridomas can be maintained indefinitely, whereas rabbit antiserum once exhausted cannot be duplicated precisely in another rabbit.

Resistance in wild species. Further attempts to find resistance to *P. solanacearum* took place at Wisconsin and at CIP. At Wisconsin the support of a CIP contract and a grant from the U.S. Department of Agriculture facilitated screening of 1573 accessions for the Inter-Regional (IR-1) Potato Collection at Sturgeon Bay, Wisconsin. This group represented 102 species, and each accession was tested as an approximately 50-seed lot in trays containing jiffy mix. Two 50-seed lots were planted in one tray. Seedlings grew for 21 days in a greenhouse at 22° C. Prior to inoculation they were not watered for three days. The soil was drenched with five liters of *P. solanacearum* strains 8 (race 1) and 81 (race 3) at concentrations of 6.0×10^5 and 1.2×10^6 CFU/ml, respectively. A knife was then pushed between rows to injure roots. Seedlings were incubated for 21 days at 28° C, and survival rates ranged from 0% to 100%. The forty-one most resistant accessions included nineteen *S. demissum*, six *S. phureja*, four *S. acaule*, three *S. commersonii*, two *S. polytrichon*, two *S. raphanifolium*, and one each *S. berthaultii*, *S. blanco-galdosii*, *S. boliviense*, *S. brachycarpum*, and *S. chacoense*. Future plans are to test the high-temperature stability of the resistance of these clones.

At CIP 85 intra- and interspecific crosses between 31 tuber-bearing *Solanum* spp.

Table 2. Amount of sensitized latex for the detection of *Pseudomonas solanacearum* sent to different countries between October 1985 and September 1986.

Country	Amount (ml)	Country	Amount (ml)
Brazil	10	Nepal	10
Burundi	40	Pakistan	5
Colombia	10	Papua New Guinea	10
Costa Rica	100	Philippines	30
Cuba	50	Samoa	5
Guatemala	5	South Africa	5
Malagasy	10	Trinidad	5
Mauritius	5	United States	10

Figure 3. *Solanum boliviense* families inoculated with *P. solanacearum*. *Left:* tray contains family 42 (in Table 3) with a few susceptible individuals. *Right:* tray contains an unselected family with mostly susceptible individuals.

were screened by planting two trays with 50 seeds each from each cross combination. The trays were placed in in a screenhouse and kept at a 24° to 38° C temperature range. After four weeks the soil mix was drenched with a suspension of 1 x 10^8 CFU/ml of Peruvian strain 204 (race 3). As plants developed initial wilt symptoms, they were pulled out, and survival ranged from 0% to 100% (Fig. 3). Nonwilted plants were transplanted at eight weeks to one-liter plastic pots, many dying soon therafter due to the expression of latent infection. Survivors (3 to 48 per family) were again inoculated after four weeks with 40 ml of inoculum per pot. Survivors of the best 16 families were grown for tuber production in the greenhouse with many failing to tuberize. The clones that did tuberize were inoculated with 1 x 10^9 CFU/ml Rwandese strain 122 (race 3). Seventeen families that had high levels of resistance involved 11 confirmed parental tuberiferous *Solanum* species (*acaule*, *bukasovii*, *boliviense*, *candolleanum*, *coelestispetalum*, *leptophyes*, *phureja*, *peloquinianum*, *raphanifolium*, *sogarandinum*, and *sparsipilum*) and one species tentatively identified as *S. tapojense*. Three of the families were of intraspecific crosses involving different accessions of *boliviense*, *peloquinianum*, and *sogarandinum*. Selected clones could not be maintained, but seven families representing the most vigorous in growth and with a high frequency of resistance were screened again. The best clones have been placed in tissue culture for maintenance and future testing for high-temperature stability and general resistance to *P. solanacearum*.

Bacterial soft rot (Erwinia spp.). Large populations (10^5-10^6 cells per liter) of *Erwinia carotovora* pv. *carotovora* (Ecc)

Tubers harvested from one plant at CIP's San Ramon experiment station. Left: *tubers with* Erwinia *soft rot.* Right: *non-rotted tubers that carried latent infection.*

vere detected throughout the year in irrigation water at San Ramon (800 m), similar numbers were also recorded at Huancayo (3200 m) and Lima (240 m). The bacteria were not detected in well water from the three sites. Neither *E. carotovora* pv. *atroseptica* nor *E. chrysanthemi* were detected in irrigation water. The ability of Ecc isolates to multiply rapidly in San Ramon water, but not in distilled water, was demonstrated. Filtering contaminated water through a 75-cm depth of fine river sand or adding sodium hypochlorite to the water (final concentration: 5 ppm active chlorine) reduced the concentration of *Erwinia* cells by 44.4% and 99.9%, respectively.

During the San Ramon dry season (June-Sept. 1986), soil samples from around tubers of TPS transplants (Desirée OP) that were irrigated with chlorinated water contained significantly less *Erwinia* throughout the growing season (6.7% of samples contaminated) than soil samples in control plots irrigated with untreated water (70.0% of samples contaminated). The treated water, however, was phytotoxic to the growing potato transplants. Phytotoxicity was not observed during the previous wet season (Nov.-Feb. 1985-86) in potatoes grown from seed tubers. Contamination by Ecc of the soil surrounding tubers in plots irrigated with chlorinated water was not observed initially; whereas with untreated water, the soil was contaminated immediately following the first irrigation. All plots, however, were subsequently contaminated to an equal extent following prolonged rainfall later in the growing season, probably due to bacteria coming from rotting seed tubers.

Calcium nutrition and resistance to soft rot. Contract research at the University of Wisconsin had shown that increased calcium fertilization of potato plants increased the calcium content of tubers, and that

higher calcium tubers of a given cultivar were more resistant to soft rot. Furthering this research, observations were made on the effect of calcium on tuber surface structure. Russet Burbank tubers harvested from plots with four different soil levels of calcium, 200 tubers per treatment from four replications, were examined for surface netting. A higher percentage of tubers with well-developed netting was obtained from plots fertilized with calcium sulphate as a preplant strip application (47.0% to 56.0%) than from the control plots (20.5%). Furthermore, a lower percentage of tubers from calcium-treated plots had smooth skins with the netting absent.

The periderm thickness of 20 tubers with well-developed netting (over 80% of the surface well-netted) and 20 with smooth skins was examined by scanning electron microscopy. At midpoint of the tubers with well-developed netting, the number of cells in the periderm ranged from 6 to 20 with an average of 13.6, but in tubers with a smooth skin, the periderm depth ranged from 7 to 16 cells with an average of 9.1 (this difference was significant at the 0.1% level).

To determine if these changes induced by calcium nutrition would result in a decreased susceptibility to wounding, an Instron Universal Testing Instrument Model 1132 was used. The averages of periderm rupture forces for tubers with well-developed netting versus those with smooth skins were 47.2 and 42.1 Newtons, respectively ($P<0.001$). The periderm rupture force for well-netted tubers was about 10% higher than that for smooth ones.

The possible relationship between bacterial soft rot susceptibility and dry matter content of potato tubers among different cultivars was also evaluated at Wisconsin. The percent dry matter was determined by the hydrometer method. The average percent dry matter at two sites during two years ranged from 14.5% to 21.1%. The cultivars Atlantic, Neoksack, Butte, and Russet Burbank were relatively high in dry matter content, whereas it was relatively low in Norland, Pontiac, and Redsen. The negative correlation, however, between bacterial soft rot susceptibility and dry matter content of tubers of different cultivars was not significant. Neither dry matter content nor calcium concentration in medullary tissues of tubers alone could explain the variation in susceptibility to bacterial soft rot among potato cultivars. When both variables were considered for tubers of 12 potato cultivars evaluated in both 1983 and 1986, the regression model describing bacterial soft rot susceptibility in relation to calcium concentration in medullary tissues and dry matter content of tubers was significant. Tubers from cultivars with high calcium and dry matter were less susceptible to bacterial soft rot than tubers from cultivars with low calcium concentration and dry matter content.

To explore the possibility that the polyphenol content of tubers may be related to soft rot resistance, researchers at Wisconsin assayed tubers from seven cultivars, which had been stored for seven months, for polyphenols in peel tissues. The cultivars Butte, Norgold, and Russet Burbank, which are the least susceptible to tuber soft rot, had relatively high concentrations of polyphenols (1.23, 1.20, and 0.95 mg/g fresh weight, respectively); whereas the more susceptible cultivars Norchip and Redsen had lower concentrations (0.42 and 0.56 mg/g, respectively).

The cultivar Butte was one of the most resistant to bacterial soft rot and cultivar Redsen one of the most susceptible. They contrast also in that Butte had high

calcium and high dry matter and polyphenols, whereas Redsen was relatively low in these components. It is suggested that Butte should be evaluated as a parent for resistance to tuber soft rot. These studies did not include observations on stem resistance to the blackleg phase of the disease; however, it cannot be assumed that tuber resistance is linked to stem resistance.

Interaction of bacterial and fungal pathogens. Post-transplanting wilting and early dying of potato plants grown from TPS (Desirée OP) caused a 43% loss of stand in rotation land at the CIP station in San Ramon during the wet season (Nov.-Feb. 1985-86). Losses were higher still in land that had been previously under potato for several seasons (76%) and during the following dry season (62%), which was June-September 1986. Examination of affected plants revealed a complex of causal agents involving pathogenic fungi and bacteria as well as insects and heat or drought stress. Isolations from diseased plants showed infection by *P. solanacearum*, *E. carotovora* pv. *carotovora*, *Rhizoctonia solani*, *Pythium* spp., and *Fusarium* spp. The frequency of isolations of each pathogen varied with the time from transplanting. The most consistently isolated pathogen in the wet season was *P. solanacearum*, diagnosed in 45% of the wilting plants. In the dry season, *R. solani* was more frequently isolated, from 82% of wilting plants.

Applications of several fungicides (copper oxychloride, benomyl, metalaxyl, pentachloronitrobenzene, or tolclofos-methyl) to the soil during transplanting and hilling had no significant effect on plant loss during the wet season. However, when tolclofos-methyl was applied (as Rizolex at 50 kg/ha) to transplants during the dry season, seedling survival was increased by 42%. Isolations from rotting tubers in the field at harvest time revealed mainly the presence of Ecc in 95.2% of the tubers tested. Field and storage tuber rotting, however, was reduced from 9.2% (by tuber number) for non-treated potatoes to 0.9% when metalaxyl (as Ridomil-5G at 40 kg/ha) was applied in the field. Interaction between fungal rotting agents and *Erwinia* therefore seems likely since this fungicide is nontoxic to *Erwinia* spp.

Studies on the interaction of calcium fertilization, potato tuber moth (PTM) infestation, and incidence of *Erwinia* dis-

Table 3. Percentage of tuber rot caused by different bacterial and fungal pathogens in tubers stored in diffused light for up to six months, San Ramon.

Pathogen	Storage period (months)			Average (%)
	2	4	6	
Erwinia carotovora pv. *carotovora*	23.33	12.12	2.32	11.51
Fusarium oxysporum	43.33	54.54	32.55	45.32
Fusarium solani	16.66	21.21	32.55	23.74
Pythium spp.	10.00	3.03	2.32	4.31
Rosellinia sp.	3.33	3.03	0	2.15
F. oxysporum + *F. solani*	3.33	1.51	6.97	3.59
E. carotovora + *F. oxysporum*	0	1.51	6.97	2.87
E. carotovora + *F. solani*	0	0	13.95	4.31
Fusarium spp.	0	3.03	2.32	2.15

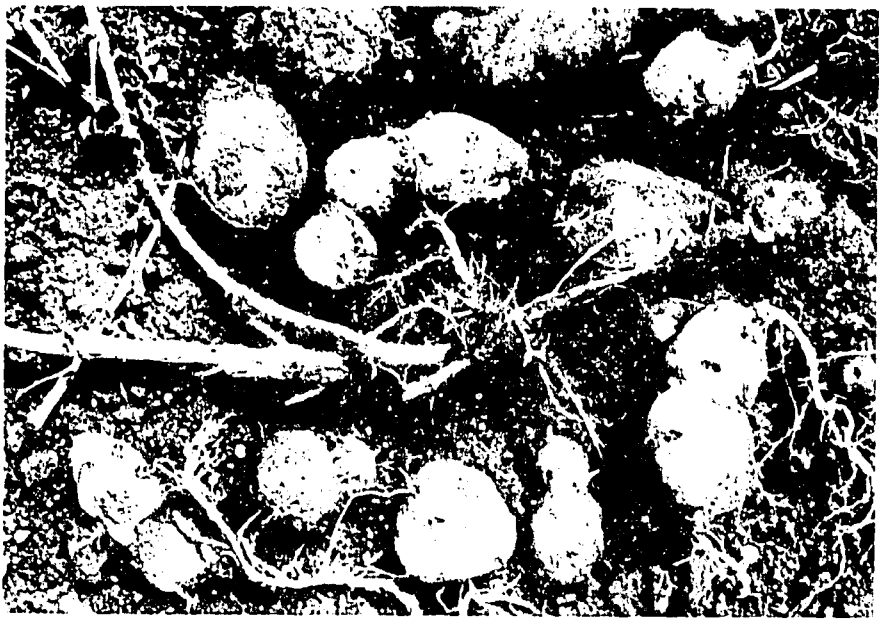


Figure 4 External symptoms of *Rosellinia* black rot detected recently in San Ramon, Peru.

cases (reported under Thrust VIII, *Ann. Rep. 1985*) were repeated in 1986. In new diffused-light stores in San Ramon, the incidence of tuber rotting was about 50% higher when prestorage dusting of tubers with calcium sulphate was not used and PTM was not controlled with Cidial insecticide. Close inspection and analysis of rotting tubers revealed less *Erwinia* soft rot than found in previous seasons and a high proportion of dry rot (*Fusarium* spp.), as well as some other diseases such as *Pythium* sp. and *Rosellinia* sp. (Table 3). This is the first detection of *Rosellinia* at San Ramon (Fig. 4).

FUNGAL DISEASES

Breeding and screening for late blight (Phytophthora infestans) resistance. In order to distinguish between race-specific resistance and general resistance to late blight in breeding populations, more precise inoculation methods had to be determined. Previously, the inoculum had consisted of mixtures of sporangia and zoospores of *P. infestans*, but it was found that zoospores used alone produced 10 to 30 times more disease than the mixture. Complex race 1, 2, 3, 4, 7, 10 was compared to a mixture of races collected throughout Peru in inoculating open-pollinated (OP) seedlings of the cultivar Renacimiento. The mixture proved to be more aggressive than the complex race. Simple race 0 was also tested on OP seedlings from the cultivars Tomasa Condemayta and Yungay, which have no race-specific R-genes; it was found that low concentrations of zoospores were needed for successful screening.

The effect of growth substrate for pathogenicity of *P. infestans* was studied. Various substrates were tested in a group of live tissue (tuber plant leaves, seedling leaves, and tuber slices) and in artificial media (3-week old V-8 cultures and 1-week old V-8 culture). The inoculum

obtained from all substrates consisted of 4000 zoospores/ml of race 0, which were sprayed on susceptible seedlings derived from the cultivar Tomasa Condemayta. The inoculum from live tissue caused 54% more disease than the inoculum produced on artificial media.

The effectiveness of different spraying equipment used for dispensing inoculum was determined. The equipment consisted of three electric vacuum/pressure pumps and one manual knapsack sprayer, each containing the same amount of zoospore concentrations. The knapsack sprayer delivered nearly 100% of the zoospores, whereas the three pumps delivered about 85%. The viability of the inoculum after being sprayed is now under study, and initial observations have indicated that over 80% of the zoospores were nonmotile after passage (they may have been dead or quiescent).

Screening for resistance to late blight in CIP's standard population containing the major genes involved 41,450 seedlings in 129 families, 75% of which were screened as in previous years with a complex race of *P. infestans*. The remaining 25% were screened with race 0. The 75% group had an average seedling survival rate among families of 29%. The 25% group had 22% R-gene-free seedling that were very susceptible and 8% that were resistant.

A second population of *S. tuberosum* subsp. *andigena* origin, which is being developed as a source of general resistance, was screened for the first time with race 0 using a low inoculum load of 2500-4000 zoospores/ml. Of 30,000 seedlings in 36 families, 22% had low infection rates or general resistance. Thus, general resistance is present in both populations. Plans are now being established to develop a general resistance population combining both sources.

Local field testing for late blight resistance was done with the Peruvian national potato program at Huánuco (northeastern highlands, 2200 m) in 10-hill observation plots. Seventy-three clones were selected among 429 for resistance, high yield, earliness (110 days), and other desirable agronomic attributes. Another 100 clones were evaluated in a simple 10 x 10 lattice design with two replications. The best 10 are shown in Table 4, which gives the infection rate (r) and percent area below the disease progress curve (ABDC), and the yield per plant. The indicators of resistance are measured by "r," the slope of the disease over time, and by "ABDC," the area below the disease progress curve determined by "r".

An additional field test of seedling progenies from 28 advanced clones was carried out in Huánuco for resistance to late blight. Eight clones were selected for high general combining ability and will be used as parents for future crosses in CIP's late blight breeding program.

The new variety Perricholi, released by the Peruvian national potato program three years ago, was compared with two other resistant clones, Rosita and 69-47-2, and the susceptible cultivar Revolución with and without fungicide treatments in Comas and Huancayo. Late blight incidence was high in Comas and mild in Huancayo. Results are shown in Tables 5 and 6 as area under the disease progress curve (ABDC) or as percent disease, yield in tons per hectare, and percent net profit over the control. The yield of Perricholi tripled that of Revolución in Comas and the profit was sixfold. In Huancayo the use of the resistant variety Perricholi resulted in a 70% profit advantage. This work was done in collaboration with the National University of Central Peru.

Latin America. Selection trials were carried out by the National Agricultural

Table 4. Yield performance of the best ten clones tested under heavy late blight field infection at Huánuco, Peru (2200 m).

CIP no.	Infection rate (r)	ARDC[a] (%)	Yield (kg/plant)
381109.160	0.071	0.31	2.536 a*
UPF 70.3	0.010	1.04	2.226 ab
381104.39	0.134	0.31	2.131 a-c
381111.150	0.004	0.30	2.040 a-d
UPP 100.4	0.001	0.20	1.961 a-e
381127.113	0.001	0.03	1.938 a-f
380389.1	0.087	1.98	1.821 b-g
381109.150	0.035	2.37	1.807 b-h
381111.151	0.013	0.25	1.802 b-h
381127.150	0.002	0.64	1.749 b-i
Yungay (control)	0.082	42.39	0.214 x-z
Tomasa Condemayta (control)	0.144	93.99	0.018 z
CV (%)			27.1

[a] ABCD = area below the disease progress curve.
*Means followed by the same letter are not significantly different at the 5% level.

Table 5. Effect of the use of late blight resistant clones and fungicide treatments on disease incidence, yield, and economics of potato production in an area with high disease incidence. Comas, Peru.

Treatment	ABDC[a]	Yield (t/ha)	% Net profit over control
Perricholi	0.10 a*	35.83 a	598
Rosita	10.21 b	17.41 b	136
69-47-2	17.68 b	15.04 b	82
Revolución no fungicide	55.24 c	11.48 c	0
Revolución + 2 appl. of Ridomil	51.97 c	17.61 b	108
Revolución + 5 appl. of Dithane	47.25 c	17.76 b	114

[a] ABDC = area below the disease progress curve.
*Means followed by different letters are significantly different at the 5% level.

Research Institute (FONAIAP) in Venezuela, at two sites close to Tachira and Merida. Of the 100 clones bred principally for late blight resistance, 55 were selected for general agronomic characters, field resistance to late blight, and yield. One of the clones, 83-207-2, is one of three possible varieties and was obtained as TPS from the Colombian Agricultural Institute (ICA). Although late-maturing (150 days), it has been selected because of its outstanding yield performance.

Tropical Africa. In Burundi, the national program of ISABU continues its selection program for late blight resistance. Large numbers of clones are screened during the two wet seasons in which blight is a major problem: September-February and March-

Table 6. Effect of the use of late blight resistant clones and fungicide treatments on disease incidence, yield, and economics of potato production in an area with mild disease incidence. Huancayo, Peru.

Treatment	Arc sine[a] $\sqrt{\%}$ disease	Yield (t/ha)	% Net profit over control
Perricholi	0.10 a	59.68 a*	70
Rosita	9.98 b	31.11 e	−21
69-47-2	9.98 b	35.31 d	−11
Revolución no fungicide	37.50 c	38.22 d	0
Revolución + 2 appl. of Ridomil	10.10 b	44.93 b	43
Revolución + 3 appl. of Dithane	20.22 b	40.57 c	5

[a] The level of disease was measured one month before harvest.
*Means followed by different letters are significantly different at the 5% level.

July. Clones evaluated for the first time in the 1985-86 season had a selection percentage of about 25%. These were reevaluated in March-July 1986 and about 50% were selected. The bacterial wilt resistance of clone 720118 (named as the variety Ndinamagara in Burundi) continues to make it a much sought after variety by local farmers. It has also shown promise in Laos and the Philippines.

Early blight (Alternaria solani). In Peru, two sets of progenies were tested to determine if a correlation existed between results of screening for resistance at the seedling stage and adult plant reaction. First, twenty-seven families were screened by inoculating them with suspensions of *A. solani* spores at 2500/ml. Later, 25 families were inoculated with 3500 spores/ml. Inoculations were done at the seedling stage (40 days) in the screenhouse at Lima in flats placed in plastic bags to obtain a high relative humidity. Inoculations were also performed in plastic-covered seedbeds in the field at San Ramon under partial shade. The same families were inoculated at 45 days and evaluated at 60 and 75 days after transplanting to the field in San Ramon. Correlation coefficients were low ($r=0.002$ to $r=0.322$) and varied between the two sets. The best correlation was between the Lima screenhouse test and the San Ramon field test when rated at 75 days ($r=0.455$). The diurnal temperature fluctuation in the Lima screenhouses is greater during the summer months; therefore, attention must be given to this since less fluctuation in temperature may improve the correlation.

The correlation was good when 47 families from 2x and 4x-2x crosses were evaluated at Lima and in seedbeds at San Ramon. Families were evaluated at 4 and 6 days after inoculation at Lima and at 3, 4, and 5 days after inoculation at San Ramon. The percentage of resistant families in the different ploidy levels is shown in Table 7, the early blight scores for the best families in Table 8, and the correlation coefficients in Table 9.

A thesis project for the University of San Marcos demonstrated that the three different species of *Alternaria* isolated at San Ramon and Huancayo responded differentially in their production of spores on different media and in their pathogenicity to certain hosts. A second thesis at the same university involved the screening of accessions from CIP'S germplasm bank for resistance to *A. solani*. So far, 267 accessions of the 800 for which true seed was collected have been screened (100

Table 7. Early blight evaluation of 2x-2x and 4x-2x families at the seedling stage (40 days old) in a screenhouse at Lima and in large seedbeds at San Ramon as compared to a resistant (R) and susceptible (S) control. Seedlings were inoculated with an inoculum suspension of 3500 spores/ml.

Genetic matarial	No. of families	Percent resistant[a]	
		Lima	San Ramon
2x-2x level			
R x R	4	100	25
R x S	20	60	35
S x R	12	17	0
S x S	4	25	0
4x-2x	7	0	0
Resistant-OP (control)	2	100	100
Susceptible-OP (control)	3	0	0

[a] Resistant = families with an early blight score of less than 4 (25%) in a scale of 1 = 0% leaf area infected to 9 = 97-100% leaf area infected.

seeds per tray) at Lima. The frequency of resistants (ratings 1-3 on a scale of 1 = no infection to 9 = 100% infection) was 27.5%. Eighteen accessions rated as resistant were retested, with 14 resulting in similar ratings; whereas 4 were slightly more susceptible (ratings of 4-6).

Latin America. Collaborative research with EMBRAPA in Brazil to select for resistance to *A solani* continued at the National Center of Horticultural Research (CNPH) in Brasilia and near Anapolis. True seed of possible resistant genotypes was supplied by CIP, Lima, and multiplied. Of 295 clones obtained from this multiplication, only 23 (7.8%) were selected after field exposure to the disease. Some clones with good tuber characteristics and high levels of resistance have been selected for the soil conditions of the "Cerrado" area, which have high aluminum toxicity and phosphate deficiency. TPS of additional families have

Table 8. The most resistant early blight families from 2x-2x and 4x-4x crosses evaluated at the seedling stage at Lima and San Ramon four days after inoculation.

Families	Early blight scores (1 to 9)				
	Lima (screenhouse)		San Ramon (field seedbeds)		
	4 days	6 days	3 days	4 days	5 days
2x-2x					
EB66P14-R1 x 381 Bulk	3.5	4.0	2.0	3.0	3.2
EB72P4-R9 x 381 Bulk	4.0	4.0	2.5	3.5	3.5
EB66P8-11 x 381348.7	3.5	3.5	3.0	3.5	3.5
EB66P32-B12 x 381348.7	3.5	5.0	3.2	3.5	3.5
EB70P8-P1 x 381348.7	3.0	3.0	2.2	2.7	3.0
EB66P1-B2 x 381348.7	4.0	4.0	2.0	3.2	3.5
FH-130 x BW-1	3.0	3.0	3.2	2.7	3.0
HB2-15 x FH-202	3.5	4.0	3.0	3.2	3.5
FH-168 x FH Bulk	3.5	3.5	2.2	2.7	3.0
4x-4x					
I-1150 (Resist.- control)	4.0	4.0	3.0	3.0	3.0
I-931 (Resist.- control)	3.5	4.0	2.0	3.0	3.5
DTO-33 (Suscept.- control)	4.0	4.5	5.0	5.5	6.0

Table 9. Spearman rank correlation coefficients between early blight evaluations carried out at the seedling stage (47 families) at Lima and San Ramon on 2x-2x and 4x-4x crosses involving resistant germplesm.

	San Ramon-3[a]	San Ramon-4	San Ramon-5
Lima-4[b]	0.449**	0.436**	0.481**
Lima-6	0.390**	0.465**	0.464**

[a]Test conducted at San Ramon and families evaluated three days after inoculation, and so on.
[b]Test conducted at Lima and families evaluated four days after inoculation, and so on.

been multiplied in a greenhouse to produce tubers for similar tests during the 1986-87 season.

Similar genotypes were tested by national program scientists in Uruguay at the Las Brujas experimental station of the Agricultural Research Center (CIAAB). Clones from the two tuber families 384063 (WCN-521.2 x Gloria) and 384072 (NDD-277.22 x DTO-33) registered a mean early blight infection of less than 15%; and from these, 35 clones were selected with acceptable agronomic characters. Although the blight attack in Uruguay was very severe, some clones such as CFS-69.1 showed a good level of resistance (13%) similar to their performance at San Ramon, Peru. The climate and facilities in Uruguay are excellent for screening for this disease and greater emphasis will be placed on this project in 1987.

SOIL-BORNE DISEASES

Verticillium wilt (Verticillium dahliae). In Peru, on the coast at Cañete, further evaluations for field resistance to *Verticillium* wilt were performed with 65 clones from CIP's pathogen-tested collection and other projects. Tubers were inoculated at planting time with microsclerotia in perlite. Each clone was also planted without inoculum. Three replications of five tubers per plot were used in a randomized block design. The incidence of the disease was relatively low. The final evaluation at 110 days after planting resulted in 15 clones being rated (on a scale of 1 = no infection to 5 = 100% infection) as resistant (rated 1-2), 22 moderately susceptible (rated 2-3), and 10 as susceptible (rated 3 or higher).

A thesis project for the National University of Central Peru, Huancayo, determined that 18 weed species were infected with *V. dahliae* in the field (Table 10). Sometimes they were without symptoms, serving as alternate hosts or reservoirs for this pathogen.

Rhizoctonia solani. A field trial similar to the one conducted during the Lima summer (19°-28° C) in 1984-85 was again repeated in the winter (14°-20° C) to control damping-off and premature death of seedlings transplanted to the field. Only the most effective fungicide treatments were repeated. As before (*Ann. Rep. 1985*), the best results were obtained with the combination of Basamid fumigation + Rizolex + plastic cover.

Lanosa disease. In Ecuador, a collaborative study between CIP and the National Institute of Agricultural Research (INIAP) on the disease known as "lanosa" was started in 1985. The three main objectives were to 1) identify the pathogen, 2) determine host range, and 3) to identify possible sources of genetic resistance. During

Table 10. Weed hosts growing in farmers' fields in the Mantaro Valley (central highlands) of Peru from which *Verticillium dahliae* was isolated.

Plant family and species	Samples collected (no.)	Isolation frequency (%)	External plant symptoms
COMPOSITACEAE			
Bidens pilosa L.	80	11	None
Senecio vulgaris L.	80	20	Chlorosis, wilt, defoliation
Tagetes elliptica L.	10	20	None
Tagetes foeniculacea L.	15	13	None
Tagetes multiflora L.	35	6	None
CRUCIFERACEAE			
Brassica campestris L.	80	11	Chlorosis, wilt, defoliation
Capsella bursa-pastoris (L.) Medik.	60	28	Chlorosis
Diplotaxis muralis D.C.	40	28	Chlorosis, wilt, defoliation
GERANIACEAE			
Erodium cicutareum (L.) L'Herit	90	6	None
LABIATAE			
Lamium amplexicaule L.	10	50	None
Stachys arvensis L.	45	4	Chlorosis, wilt, defoliation
LEGUMINOSACEAE			
Medicago hispida Gaernt.	95	5	None
MALVACEAE			
Malva sylvestris L.	100	4	None
PRIMULACEAE			
Anagallis arvensis L.	10	20	Chlorosis
PORTULACACEAE			
Calandrinea ciliata Kunth	5	20	None
CHUENOPODIACEAE			
Chenopodium quinoa Willd[a]	85	4	Chlorosis, wilt
SCROPHULARIACEAE			
Veronica persica L.	65	4	Chlorosis
SOLANACEAE			
Solanum nigrum L.	5	20	None

[a] Not a weed, but a crop mentioned as such in the rotation system.

microscopic identification of the fungus, fruiting bodies (synnemas) were observed for the first time. When grown on agar media these bodies produced mycelia identical to *Rosellinia*. Pathogenicity tests produced symptoms with the virulence of "lanosa," suggesting that these bodies were a possible sexual stage of the fungus. The cultivar Esperanza was the most resistant, but cultivars J-16-16 and Chaucha had resistant foliage, although this was not correlated with tuber health. Twenty

weed species were examined to determine the host range of the fungus. Only *Lupinus* sp. appeared completely healthy and seven of the weed species died from fungal infection. Among other cultivated crops, the most susceptible were peas, squash, beans, radish, and certain herbs. No symptoms were found on wheat and barley or on Andean crops such as mashua (*Tropealum tuberosum*), and quinua (*Chenopodium quinoa*).

Rust disease (Puccinia pittieriana). A cooperative research project with the National Institute of Agricultural Research (INIAP) in Ecuador was started to study the rust fungus *Puccinia pittieriana*, which can be severe in specific microclimatic zones. There were 130 clones from INIAP and CIP tested for reactions in the field at two disease-specific sites, El Belen and Sabañag. Results were not identical at each site and only one clone gave the same susceptible reaction. The same erratic behavior was noted at two other sites, suggesting the existence of fungal races. This work will be continued in 1987, and a new test site at Pillaro, where the disease has economic importance, will be included.

SURVEY OF DISEASE INCIDENCE

A survey of diseases of the potato in the hilly potato-growing area of Pakistan was conducted from August 14 to September 11, 1985. The project was carried out as part of an agreement with the Research Institute for Plant Protection (IPO), Netherlands, in collaboration with the Pakistan-Swiss Potato Development Project and the Pakistan Agricultural Research Council. After the inspection of 255 fields, eighteen fungal and three bacterial pathogens were identified plus four fungi commonly associated with potato crops.

The main problem was soil-transmitted fungi associated with the lack of rotation in most of the regions visited. *Verticillium albo-atrum* was widespread causing severe wilting. This disease could be readily controlled by rotation and by planting clean seed, since this organism does not remain in the soil for long periods. *V. dahliae* was found in most fields and is less damaging, but is not readily eliminated by short crop rotations as it remains in the soil for several years. *Fusarium solani* was less frequent but still significant. The presence of the seed-transmitted strain was not verified and should be investigated. *Sclerotinia sclerotiorum* wilt was found mainly in the Swat District of Pakistan and was associated with foliar damage by farms animal or field workers during spraying for late blight.

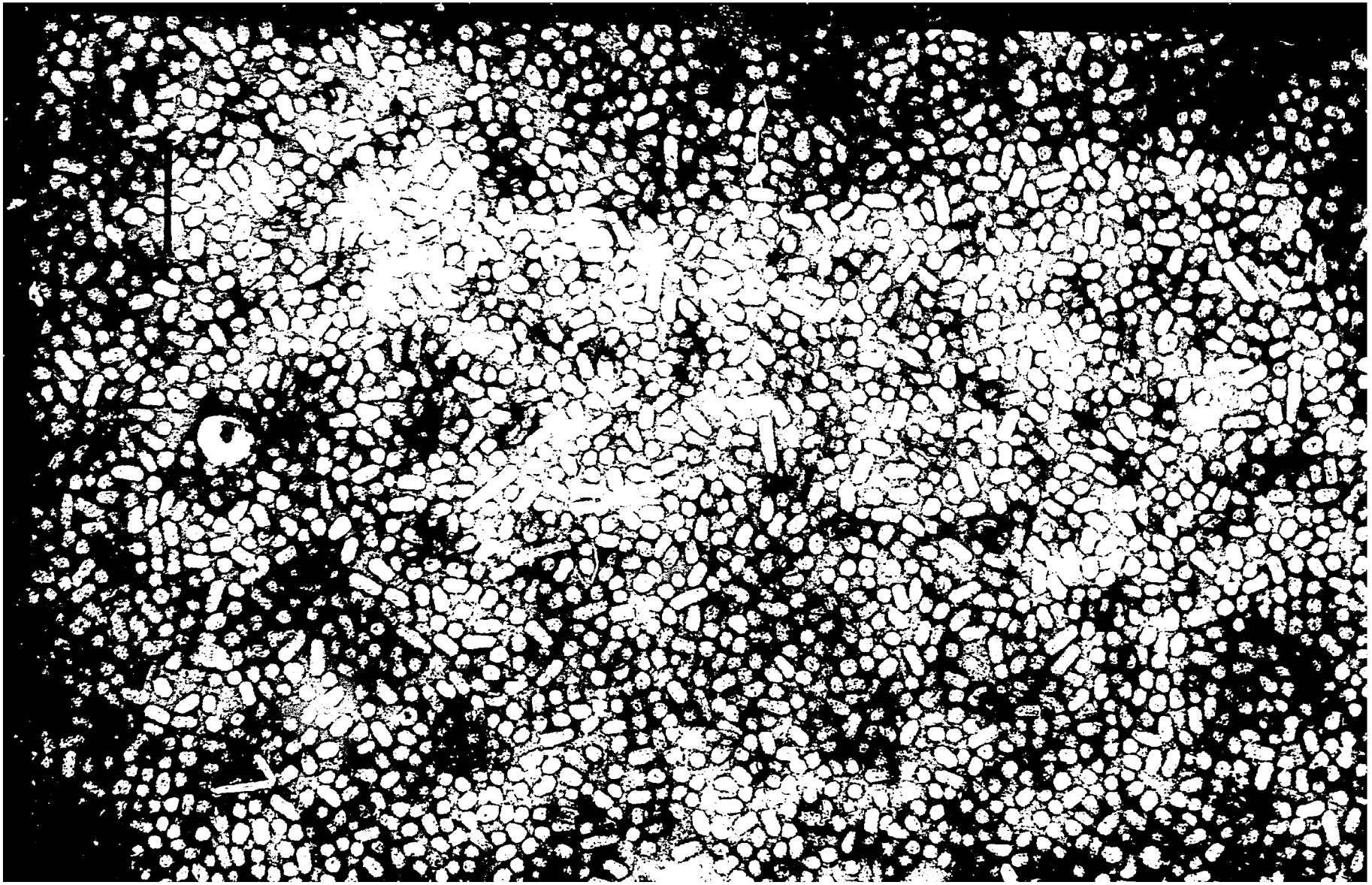
Late blight (*P. infestans*) was a problem throughout the country, except in the Gilbit region, and causes severe damage to potato crops in areas with heavier rainfall. To better control this disease, farmers need to be trained in fungicide application. Other leaf-infecting fungi were of lesser importance, as were other soil-borne fungi.

Bacterial diseases, though common, were of relatively low incidence in the country. They are, however, a potential serious threat to seed production programs. Bacterial wilt occurred at the lower elevations (around 2000 m) and will probably limit potato production at these elevations. Apparently the movement of seed tubers from the lower to higher areas is occurring and can lead to latent infection and subsequent severe losses in potato crops.

TRAINING

At CIP headquarters, four visiting scientists from Peru, Brazil, and Burundi were

trained on various aspects of late blight, bacterial wilt, and *Erwinia* diseases to assist their work on basic research problems, screening for varietal resistance, and seed tuber production in areas where bacterial wilt is endemic.



Control of Virus and Virus-Like Diseases

Different levels of interaction between potato leafroll virus (PLRV) and other potato viruses were shown to decrease the level of resistance to PLRV multiplication in clone B-71-240.2 This interaction might explain the rapid loss of PLRV resistance in some cultivars under field conditions. A rapid screening in stem cuttings from agronomically superior progenies has been developed to speed up the selection process of clones with good agronomic performance and resistance to PVX and PVY. Testing for virus resistance under field conditions was continued in Peru, Colombia, Chile, Argentina, Uruguay, and Tunisia. It is worth noting that clone 381371.81, selected in Uruguay, has excellent agronomic characteristics, good virus resistance, and an 80-day dormancy period which is suitable for a two-crop regime. The success of CIP's recurrent breeding program can be supported from the selection in Uruguay of families that showed approximately 60% of virus-resistant selections. Studies under field conditions confirmed the hypothesis that immunity to potato viruses X and Y will reduce the degree of degeneration of new cultivars due to virus infections. Studies in Tunisia have shown that four generations of imported seed is the maximum number of multiplications possible at present without a serious drop in seed quality supplied to the farmer. The development of new procedures for preparing and labeling potato spindle tuber viroid (PSTV) nucleic acid probes allowed more efficient detection of PSTV-RNA. Radioactive probes (^{32}P) are now used routinely, and the use of ^{35}S or nonradioactive labels now seems possible.

An extension of the NASH test for detecting PLRV, PVX, and PVY has been studied in collaboration with scientists at the Plant Breeding Institute in Cambridge, United Kingdom. Plasmids containing inserts from portions of virus genomes are being multiplied and transformed into new vectors at CIP. Improvements in serology include preparation of a potato virus A antiserum, replacing reagent grade latex by a cheap industrial latex or bacterial cells, and the development of immunobinding assay on nitrocellulose filters. The demonstration of PLRV-related microcrystals in embrionary aphids located in the abdomen of viruliferous aphids is intriguing. The significance of these findings on virus ecology in the tropics is under study.

Purified preparation of SB-22 virus showing three basic types of nucleoprotein particles. Bar represents 200 nm.

RESISTANCE TO VIRUSES

Interaction of potato viruses. Since it has been demonstrated that potato viruses X and Y (PVX, PVY) interfere with the rate of multiplication of potato leafroll virus (PLRV) in potato clones, major studies were initiated to investigate the mechanisms of virus interaction. Experiments were conducted on clone B-71-240.2, which is known to have resistance to PLRV multiplication. Interactions were studied between PLRV and the most common potato viruses such as PVX, PVY, PVS, Andean potato mottle virus (APMV), Andean potato latent virus (APLV), and a virus code-named SB-22. Results showed that all viruses tested, except PVS, reduced the resistance to PLRV multiplication in clone B-71-240.2. Virus SB-22 showed the greatest effect since the concentration of PLRV in B-71-240.2 also infected with SB-22 was always higher than the control (Fig. 1). PVX and PVY showed a similar synergistic effect that can be detected immediately after inoculation. In the case of APMV and APLV, however, the increase in concentration of PLRV occurred at least four weeks after PLRV inoculation. In contrast, PVS showed an opposite effect on PLRV multiplication, since in plants infected with PVS, the concentration of PLRV was lower than in plants infected only with PLRV. These studies seem to explain why PLRV-resistant clones rapidly become susceptible to PLRV under field conditions in the absence of variability in the virus. Experiments are in progress to determine the biochemical/physiological basis of virus interference.

Development of virus resistance. ***Peru.*** Work is still in progress to determine the type of resistance to PLRV found in clones from CIP's germplasm collection (*Ann. Rep. 1985*). Experiments to compare the efficiency of PLRV inoculation of clones in the greenhouse with the efficiency of natural field infection have now been established.

Screening for resistance to PVY and PVX was performed with clones from CIP's pathogen-tested program and with superior breeding lines. CIP clone 379706.27 (LT-8), selected because of earliness, high yield, heat tolerance, and immunity to PVY and PVX, has been tested against a broad spectrum of PVY strains and related potyviruses. This clone was immune to 3, 8, and 9 isolates selected from the PVY^C, PVY^N and PVY^O group of strains, respectively. It was also immune to wild potato mosaic virus (WPMV), Peru tomato virus (PTV), and to the isolates PVY^C-AB, PVY^C-GL, and UF of the potato strain of PTV (all of these isolates were previously reported in the literature as potato virus V). However, like other sources of immunity to PVY derived from *Solanum tuberosum* ssp. *andigena*, LT-8 was hypersensitive to the four isolates of potato virus A (PVA) that were tested. This hypersensitivity will have to be considered in the strategy of CIP's breeding program for virus resistance to assure that the desired field durability of PVY-resistant clones is maintained.

Nineteen true potato seed (TPS) families that showed a high percentage of agronomically superior progenies in previous tests at Lima were propagated under quarantine conditions in the screenhouse. Stem cuttings from the mother plant of each genotype were tested for resistance to PVY. From a total of 2707 cuttings tested, 1375 resistant genotypes (51%) were selected. Tubers from resistant genotypes, grown under quarantine conditions, will be sent to CIP regions for agronomic evaluation. This procedure has been adopted to speed up the selection process of clones with good agronomic characteristics and resistance to PVY.

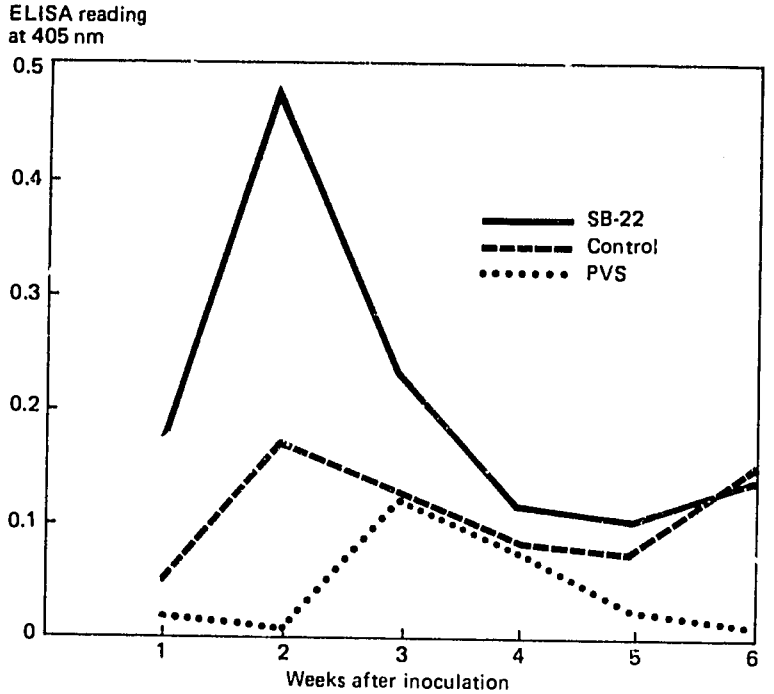


Figure 1. Concentration of potato leafroll virus (PLRV) in clone B-71-240.2 infected with virus SB-22 and potato virus S (PVS). PLRV was detected by ELISA at weekly intervals after plant inoculation.

Sixty-nine families with a total of 11,040 cuttings are now being screened for PVX and PVY resistance according to the procedure described above. Twenty-two of these families will also be evaluated for PLRV resistance.

Colombia. The third consecutive season of testing for general virus resistance in clones from CIP and the Central Colombian Potato Collection (CCC) was completed at the national potato program research stations at Tibaitata and La Selva, Colombia. As the results between the field symptoms and serology tests were contradictory, seven clones of the CCC set were eliminated. A fourth cycle of selection will be initiated in 1987. A further set of crosses was made between two clones of the CCC set and three CIP selections. The progeny will be grown in early 1987 for field exposure to viruses at the early seedling stage.

Argentina. Tuber families with virus resistance were multiplied in 1985 by the national potato program of INTA at the San Pedro research station and 83 clones were selected. These were planted in the fall 1986 and 16 (19%) were selected for further agronomic evaluation. These clones, together with 31 tuber families, will be exposed to virus infection in spring 1987.

Chile. Work by the national potato program of INIA has continued on the selection of both INIA and CIP breeding lines for resistance to PLRV. In these trials the breeding lines tested had been exposed previously to virus infection during the 1984-85 season. Readings obtained in this second season of infection indicated that

Serrana (INTA, Argentina) and Linea 76 (INIA, Chile) had the lowest infection percentage (8%). Several lines and clones were intermediate, but the controls (Pentland Crown, Urgenta, and Spartan) varied between 48% to 64% infection. In a second trial, which mainly comprised CIP clones together with Serrana and Desirée, very little infection occurred even after the second exposure. Most clones, including Serrana, showed zero infection. Yields were good, but acceptable agronomic characteristics suitable for the sophisticated Chilean market were difficult to obtain.

Uruguay. Virus infection in Uruguay, particularly by PLRV, was extremely severe in 1986, making it an excellent site for selection of resistant materials. The national scientists have selected many promising clones even after the second exposure to field infection. Clone 381371.81 has excellent agronomic characteristics, good virus resistance, and an 80-day dormancy period and would be suitable for the two-crop regime (spring-fall) currently being considered. The yields of the 1986 trials were severely reduced as a frost killed the crop at 55 days. In two other trials, clones that had already been exposed twice to PLRV were reduced from 21 to 6. and 4 will be passed to national trials. Several other clones with a dormancy period of 90 days will be tested in a cropping system of three crops in two years. Two other clones with a dormancy of 70-80 days will be used in the system of two crops per year. It is important to analyze the percentage of resistant clones arising in different families, as this will indicate the success of CIP's recurrent breeding program. Some families, such as 382018 (378703.11 x 7XY.1) and 382021 (Serrana x 7XY.1), showed approximately 60% of resistant selections.

Tunisia. CIP and national scientists have now completed the fourth multiplication of imported seed. Only 6.5% PVY was detected by ELISA serology after 8% of diseased plants were rogued. There was a total virus content in the crop of 14% PVY, 1.5% PLRV, and over 80% PVS (Fig. 2). The national seed program has concluded that four generations of imported seed is the maximum number of multiplications possible at present without a serious drop in seed quality supplied to the farmer.

A set of clones previously selected at the June 1985 harvest were placed in cold storage until February 1986. They were then planted at the Saida site of the National Center for Agricultural Research (CPRA) and compared with five-month-old tubers of imported Spunta, the standard variety. The objective was to identify clones adapted to North Africa, but with good resistance to PLRV, PVY, and PVX. Clones 381453.1 and 382250.1 gave yields similar to Spunta, but were still somewhat late-maturing for Tunisian conditions. Among the 15 new tuber families introduced from CIP, Lima, and planted in March 1986, there were several clones that seemed more suitable and initial selections have been made. Among the most promising families are 384523 and 384524.

Stability of resistance to potato viruses PVX and PVY and incidence of other epidemiologically important viruses. Studies were completed in Peru on the stability of genotypes resistant to PVX and PVY and on the degree of degeneration due to other virus infections when exposed under field conditions. After four field exposures in Lima and Huancayo, clones immune to PVX and PVY were not infected by these viruses. Clones highly hypersensitive to PVY such as Serrana, CEX 69.1, and MEX 750815 showed 0%, 0%, and 6% of PVY infection, respec-

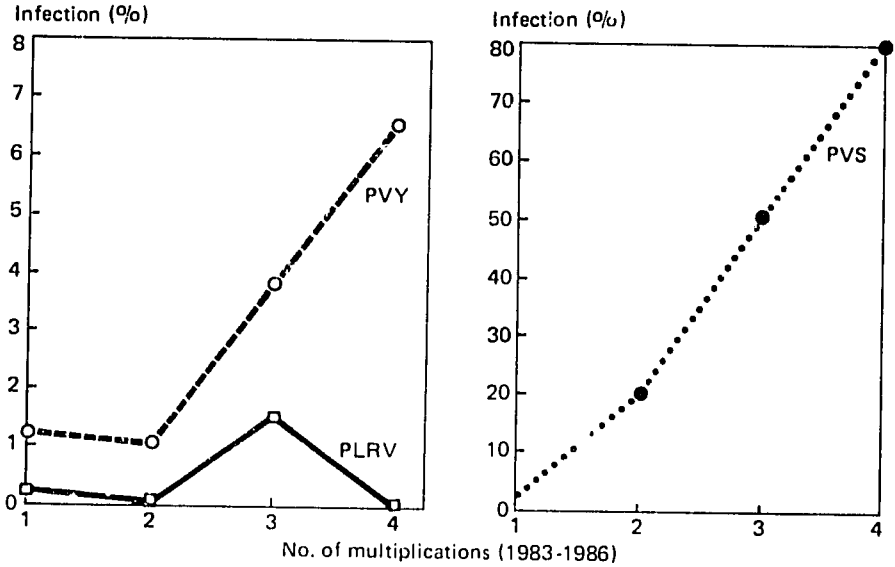


Figure 2. Percentage of virus content (PVY, PLRV, and PVS) in seed potatoes after four multiplications of imported seed, Tunisia.

tively. However, clones with low hypersensitivity to PVY such as Rosita and Tomasa Condemayta showed 30% and 70% PVY infection, respectively. Independently of the level of resistance to PVX and PVY, PVS was more prevalent in all of clones tested than PLRV, APLV, and APMV. Aphid counts in the experimental plots at both sites indicated large populations of winged *Myzus persicae* and *Macrosiphum euphorbiae*, assuring a high incidence of aphid-transmitted viruses in the experiments. The clone Serrana showed 9% PLRV infection and clone LT-4 showed 80% infection, stressing the relative resistance of Serrana to PLRV.

Degeneration in clones without immunity to PVX and PVY was shown by their high "symptom intensity indexes" (SI) and by a high yield decrease (20-63%) after four field exposures when compared with the yield of the first exposure (Table 1) (Fig. 3). Clones immune to PVX and PVY showed a low SI and low yield reduction due to other virus infections.

Table 1. The "symptom intensity index" (SI) in clones after four field exposures to virus infection and their percentage of yield reduction when the same clones with four field exposures were compared with their first exposure.

Clone	Reaction to[a] PVX	PVY	SI[b]	% Yield reduction
XY 13.15 (V2)	I[c]	I	32	20*
ARSH32	I	I	26	4
78C11.5 (V3)	I	I	20	5
Bzura	I	I	22	1
LT-4	S	I	40	11
78C8.1	S	I	26	4
Serrana	H	H	26	6
CEX-69-1	S	H	38	−6
MEX 750815	S	H	34	27*
Tomasa Condemayta	S	h	42	20*
Rosita	S	h	60	63*

[a]Under greenhouse conditions, unpublished data.
[b]SI = ranges from 20 (no symptoms) to 100 (death).
[c]I = immune; S = susceptible; H = hypersensitive, no systemic infection detected; h = low hypersensitivity, systemic infection detected.
*Significant at the 5% level.

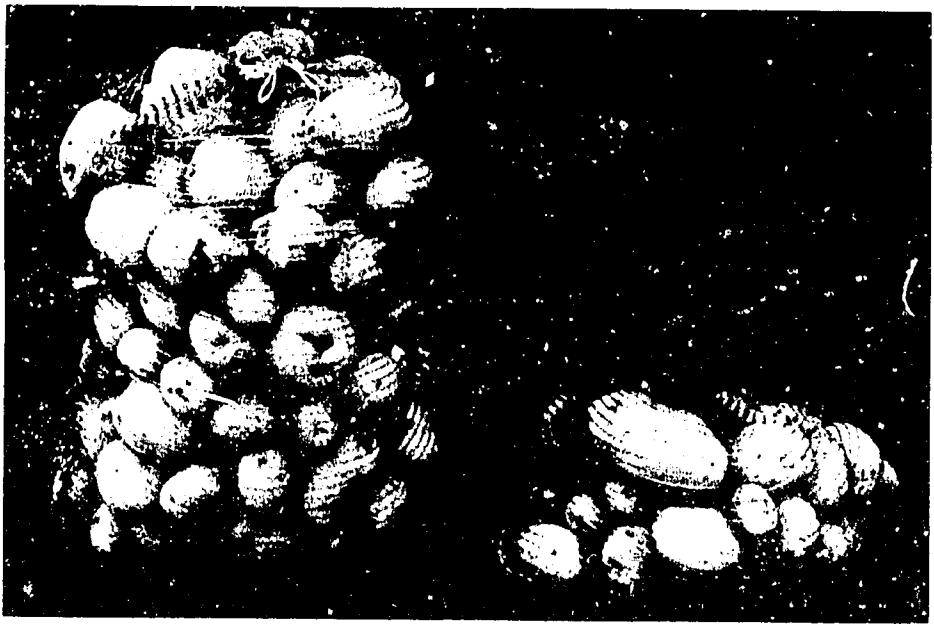


Figure 3. Yield from ten plants of the cultivar Rosita exposed to virus infections under field conditions at Lima in 1985. *Left:* yield from first exposure. *Right:* yield from fourth exposure.

Studies under natural field conditions confirmed the hypothesis that immunity in potato to PVX and PVY will give a stable resistance to these viruses and, in general, will decrease the degree of degeneration of new cultivars due to other virus infections. Similar studies are being initiated in Uruguay and Egypt with the collaboration of their national programs.

VARIABILITY OF POTATO VIRUSES AND STUDIES ON OTHER VIRUS DISEASES

Variability of PVY. In collaboration with Dr. D. C. Baulcombe at the Plant Breeding Institute in Cambridge, United Kingdom, four nucleic acid hybridization (NASH) probes for PVX have been tested against distinct PVX strains mainly from the Andean region. Also, three probes were tested against a broad spectrum of PVY isolates obtained from different geographical areas and to other potyviruses found naturally in potato or in other hosts of PVY. The four PVX probes showed the same general pattern (Fig. 4) in that strains GUA 2 and NZ hybridized much more strongly than ep and HB, except for one probe that did not hybridize with the ep strain. These results support previous findings in virology work at CIP in that Andean PVX strains belong to a different genomic group of PVX strains. The test with the PVY probes indicated that probes pPVY 6 and pPVY 19 are identical. Probes pPVY 15 and pPVY 6 overlap and are derived from the central region of the PVY genome and not the coat protein gene. Hybridizations showed a broad specificity of the probes to the broad spectrum of 27 isolates tested from the PVY^{O}, PVY^{N}, and PVY^{C} groups of strains. PVY probes did not hybridize or hybridized very weakly with PTV, PVV, TEV, WPMV, and PVA, providing conclusive evidence that these

viruses are distinct yet related potyviruses. Reports in the literature on serological relationships among potato potyviruses take into account only the part of the genome that codes for the virus coat protein, whereas the NASH test also analyzes other parts of the genome of the potyviruses.

Variability of PLRV. Many wild *Solanum* spp., which were selected in 1985 as resistant to PLRV, later proved to be resistant only to the aphids and not to the virus. Therefore, the development of a set of differential hosts to study the variability of PLRV using wild *Solanum* species was not successful. Four PLRV isolates available at CIP, code-named 01, 29, 10, and Chinese, were tested by the NASH test against a PLRV nucleic acid probe produced by Dr. Baulcombe. Results did not show any variation in the four PLRV isolates tested. The PLRV probe produced by Dr. Baulcombe mainly contains the cDNA for the coat protein of the virus. These results confirm the findings of other virologists who, using monoclonal antibodies to PLRV, did not detect a significant variation among PLRV isolates.

Identification of viruses. The SB-22 virus, which appears to be widespread among Peruvian potatoes, was shown to be transmitted mechanically and through the botanical seed of *Physalis floridana*. Infected seeds showed mild to severe necrosis (Fig. 5). Experiments to determine its transmission by TPS are in progress at Lima.

A virus-like agent was transmitted with difficulty from plants of the cultivar Serrana showing symptoms of potato deforming mosaic virus (PDMV) to *Nicotiana benthamiana*. *N. benthamiana*-infected plants showed line patterns and

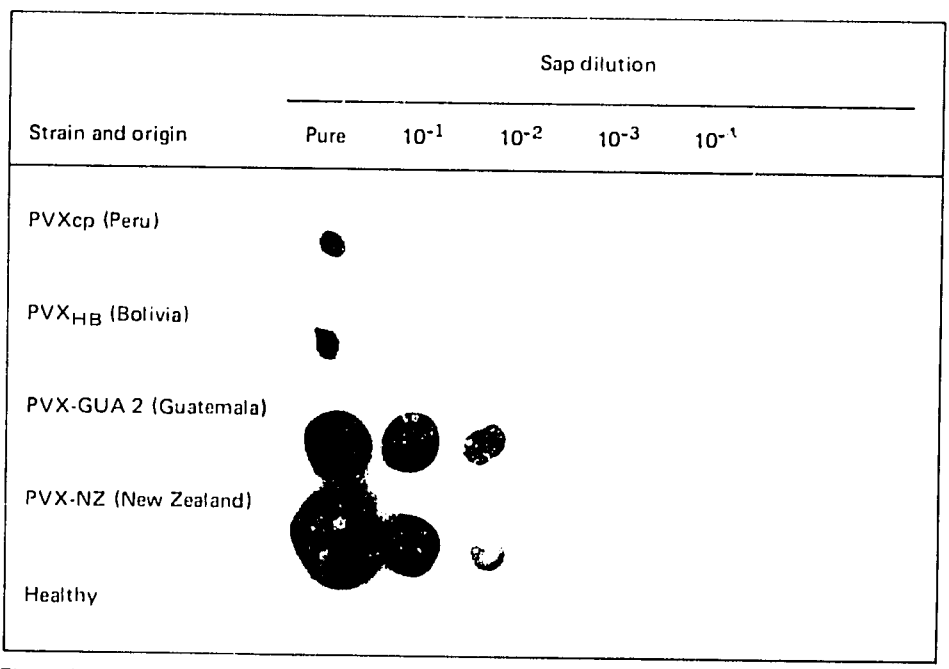


Figure 4. Detection of potato virus X (PVX) strains by the NASH test. Two μl of pure and diluted crude sap from infected and healthy plants was spotted on nitrocellulose, the virus was hybridized with (^{32}P) labeled pPVX19 cDNA, and hybrids were detected by autoradiography.

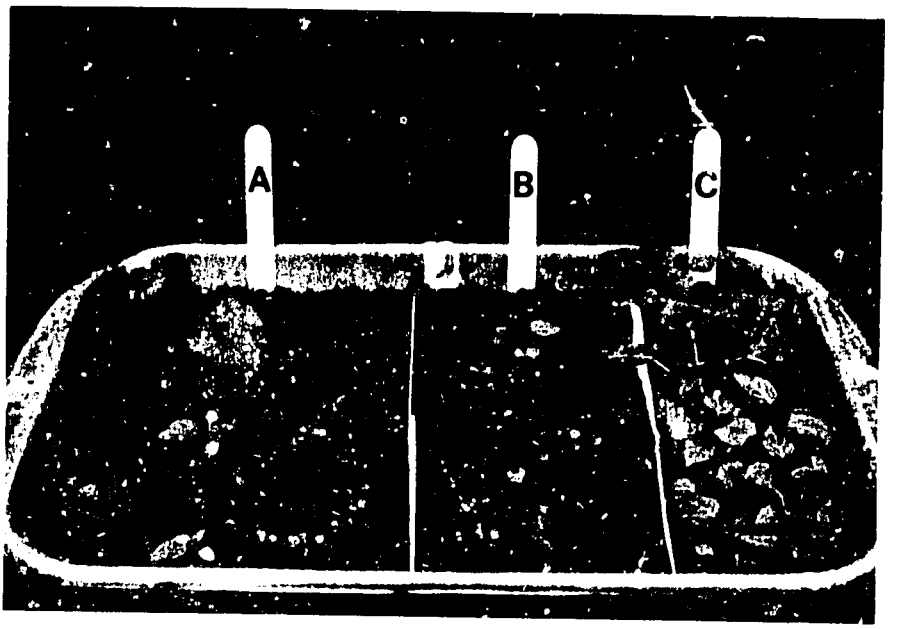


Figure 5. Effect of virus SB-22 on germination of *Physalis floridana* seeds. (A) seeds with mild necrosis; (B) seeds with severe necrosis; and (C) seeds without visible necrosis.

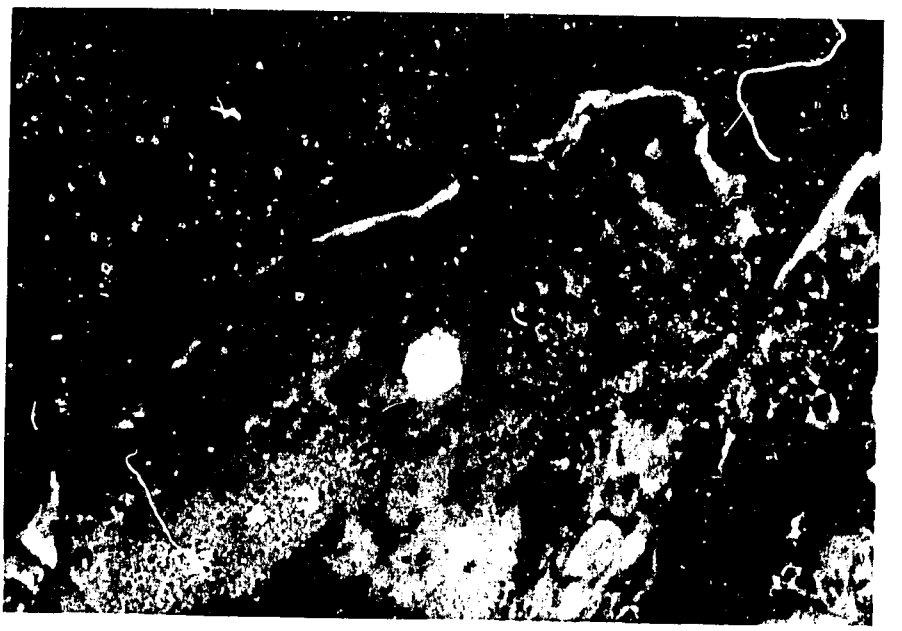


Figure 6. Longitudinal section of embrionary aphid showing a disseminated fluorescence in symbiontes of a mycetosite. Magnification X 250.

strong chlorotic mosaic. This is the first report in the literature on sap transmission of the PDMV agent from naturally infected plants.

A potyvirus (SB-20) was isolated at CIP from plants of *Solanum commerssonii*, a wild species collected in Uruguay. Serological tests (latex and ELISA) and the symptoms induced in *Solanum demissum* "A" indicated that SB-20 is an isolate of PTV.

Intracellular location of PLRV in the aphid Myzus persicae Sulz. Sections (ca. 2 μm thick) of PLRV-infected and healthy aphids embedded in paraffin were washed in xylol and staining buffer (pH 7.2) and stained with fluorescein isothiocyanate (FITC)-labeled PLRV IgG. Under a fluorescence transmission microscope, strong fluorescent microcrystals were found in cells of aphid hindgut and other organs. The presence of microcrystals was confirmed by electron microscopy in ultrathin tissue sections of the stomach, the first part of the intestine, and the thoracic ganglion. Also, a disseminated fluorescence was observed in the nucleus and cells from the mycetome and in the cytoplasm of trachea cells of embrionary aphids located in the abdomen of viruliferous aphids (Fig. 6). No fluorescence was observed in sections of non-viruliferous aphids. At present we do not know the significance of these findings on the virus ecology, and experiments are being devised to determine the role of aphids on virus survival in the tropics.

Studies on PSTV replication and plant resistance. This study was conducted at the U.S. Department of Agriculture (USDA) in Beltsville, Maryland, with the collaboration of Drs. R. A. Owens and R. Hammond. The mechanism of infection and replication of potato spindle tuber viroid (PSTV) was studied by inoculation of *Lycopersicon esculentum* (tomato), *Helianthus annuus* (sunflower), *Brassica napus* (turnip), and *Solanum acaule* (OCH 11603) with PSTVcDNA by means of *Agrobacterium tumefaciens* as a vector. Sap inoculation and grafting were also used for comparison of transmission.

Analysis of single- and double-stranded PSTV-related RNA sequences from the inoculated plants suggested the presence of different resistance mechanisms in different plants. As was expected, susceptibility was found in tomato by all methods of inoculation, indicating that the initial process of infection (the attachment of viroid molecules to cells), as well as replication and translocation, proceed in this host without restriction. Turnip was not infected by PSTV, which was found only in the galls after inoculation with *A. tumefaciens*. This occurrence was probably due to local RNA transcription from plasmid PSTVcDNA acting as a template. Therefore, turnip can be considered as an immune host in which replication and translocation of PSTV is completely inhibited. Sunflower was not infected by sap inoculation, and very small amounts of PSTV were found in the roots of the approach-grafted plants. However, when sunflower was inoculated with *A. tumefaciens*, PSTV-related-RNA was found in the galls and roots.

A mechanism can be envisaged in sunflower in which the initial stages of infection and replication of the viroid can be prevented. If the viroid, however, is placed directly into the vascular system it could be translocated and accumulated in the roots.

TECHNIQUES FOR DIAGNOSING VIROID AND VIRUS INFECTIONS

Detection of PVA. Potato virus A (PVA) was purified from leaves infected with *Nicotiana occidentalis* and an antiserum

was produced in rabbits by multiple intradermal injections using a total amount of 200 μg of purified virus. With the latex test it was possible to detect the homologous and heterologous isolates of the virus in infected potato plants without differences in reaction intensities. In no cases were nonspecific reactions observed. With ELISA high absorbance values were obtained from potato and from *N. occidentalis* infected with the homologous isolate, but low values were obtained with the heterologous isolate. Further studies are in progress to determine the sensitivity and specificity of both methods for detecting PVA in potato plants.

Simplification of the latex test. An inexpensive latex source (latex used in the shoe industry) was studied to determine the feasibility of replacing the expensive reagent grade latex used in the test for virus detection. Latex spheres, washed and purified from commercial latex (Tektiron 116-E Polystyrene, from Tecnoquímica, Peru) were sensitized with IgG for PVX, PVY, and APLV and used to detect those viruses in sap from infected indicator plants and field-grown potatoes. The results showed that Tektiron 116-E was as sensitive as the reagent grade (Sigma) latex. This latex source, being forty times less expensive than reagent grade latex, is a cheap source available in most developing countries.

Other alternative antibody carriers were compared against latex for their efficiency in detecting viruses. Bacterial cells seemed a good possibility. Heat-treated *Staphylococcus aureus* Ros. (strain Corwan 1) was also sensitized with IgG for PVX, PVY, and APLV. The Fc portion of the IgG attaches to naturally occurring Protein A on the bacteria cell wall, leaving free the $F(ab)_2$ combining sites. These IgG-sensitized bacteria cells were almost equally sensitive to the IgG-sensitized latex. In virus detection in field samples, IgG-sensitized bacteria reacted more rapidly than latex. The use of bacteria might be a good alternative in situations where latex is not available.

Antisera production. CIP continues to support the National Center of Horticultural Research (CNPH) in Brazil in producing its own antisera for virus testing. In 1986 a CIP technician visited CNPH to give further training in the production of antiserum and to refine the existing methods.

Use of other ELISA procedures. A NC-ELISA (nitrocellulose-ELISA) technique, also known as DIBA (dot immunobinding assay), has been adapted at CIP for PVY detection. Present results show that NC-ELISA has a similar sensitivity to the double-antibody (sandwich or direct) ELISA used at CIP; however, the advantage of NC-ELISA is that it needs only common laboratory facilities and is a simple and quick test to perform. After preparation and application of plant extracts onto nitrocellulose membranes, the entire test can be carried out in half a day.

Nucleic acid spot hybridization. Dr. Baulcombe and collaborators from the Plant Breeding Institute prepared complementary DNA (cDNA) to PVX and PVY and cloned cDNA into *Escheridia coli* plasmid pBR 322. In collaboration with Dr. Baulcombe, these cDNAs were used as probes in a nucleic acid spot hybridization method (NASH) for the detection of PVX and PVY in crude sap samples. The method is highly sensitive and facilitates analyses of larger numbers of samples with less labor than ELISA. Thus it is likely that this method will be applied to PVX and PVY detection in quarantine, seed certification, and breeding programs for virus resistance.

Plasmids pPVX19 and pPVY15 have been selected as detection probes for PVX

and PVY, respectively. They have been kindly donated to CIP by Dr. Baulcombe and are now being multiplied and transformed into new plasmid vectors.

Improvement of PSTV hybridization probes. A PSTV insert which had been cloned by Dr. R. A. Owens (USDA) in the DNA of bacteriophage M13 was adapted for use in routine PSTV detection at CIP. The method is based on the elongation of a primer annealed to the vector DNA to copy the PSTV insert and then excising and purifying the probe by gel electrophoresis. This process yields a highly specific probe, but the process is too long and laborious for routine use. A second alternative was studied in collaboration with Dr. Owens in which the PSTV

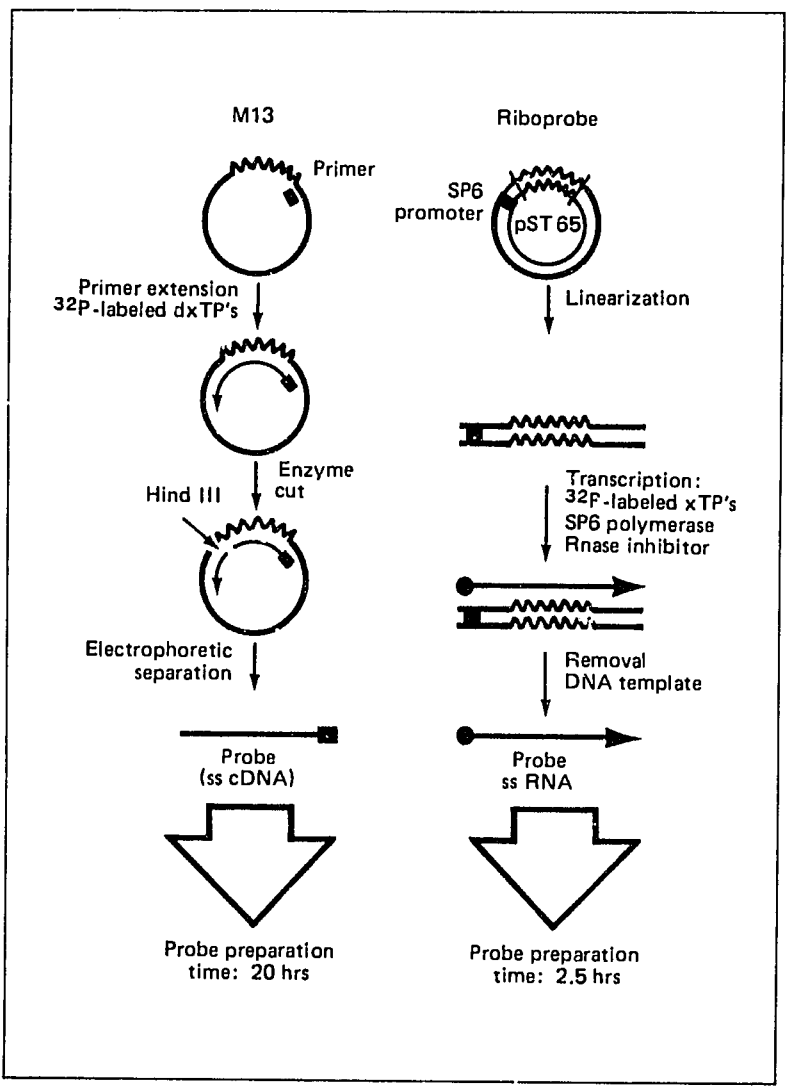


Figure 7. Two methods to prepare highly radioactive and specific probes for detection of potato spindle tuber viroid (PSTV) by NASH.

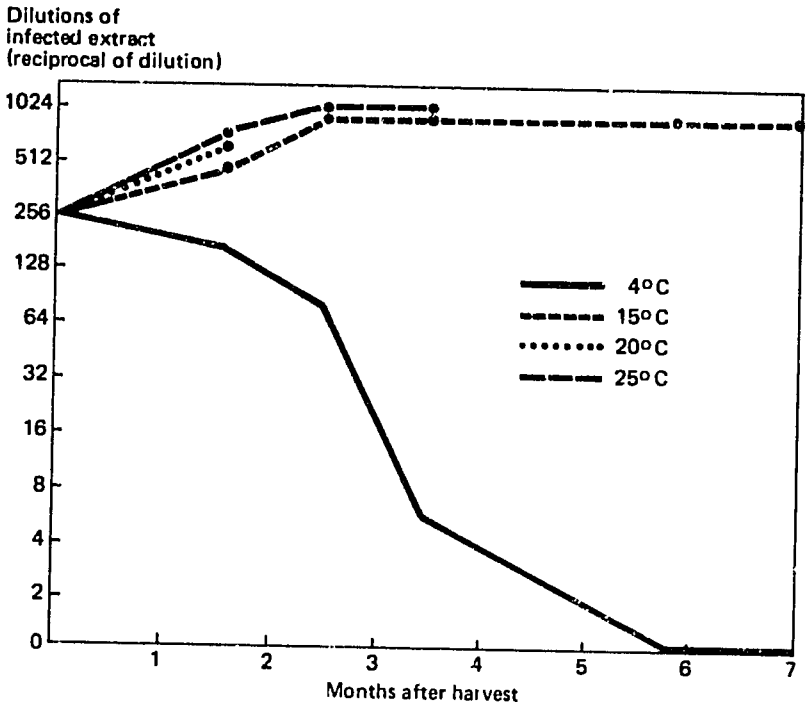


Figure 8. Effect of tuber storage temperatures on detection of potato spindle tuber viroid (PSTV) by NASH.

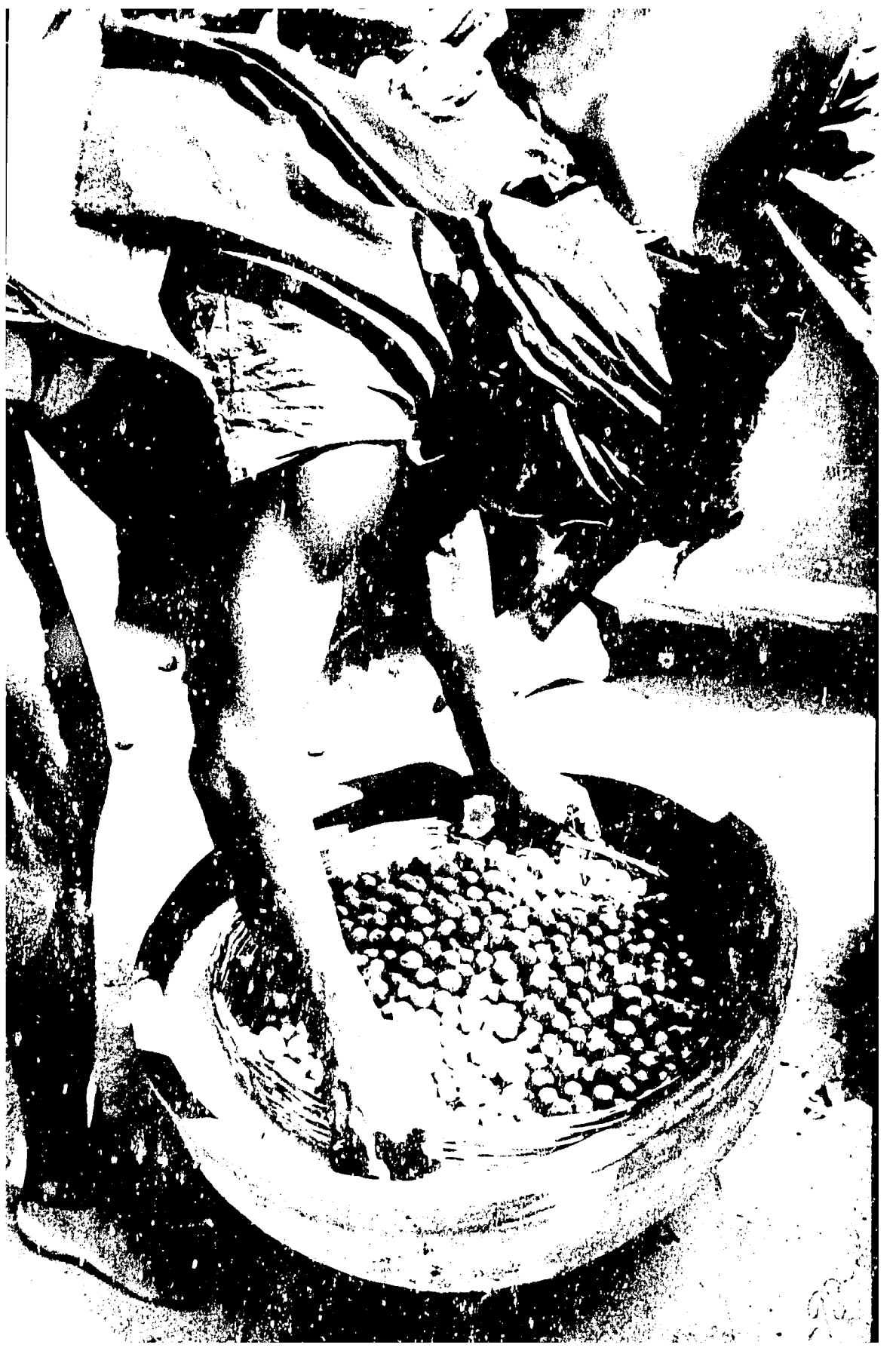
insert was cloned in vector pSP65, which contains a polymerase SP6 promoter. By the use of this vector, RNA probes—instead of DNA as in previous methods—can be transcribed using a linearized pSP65 template. RNA probes are about 100 times more sensitive than nick-translated or M13 probes, nonspecific reactions can be eliminated, and the process takes only a few minutes. These probes are in use now at CIP (*see* Fig. 7 for probe preparation). Experiments are underway to replace ^{32}P with ^{35}S and a non-radioactive label, both of which have a longer shelf life than ^{32}P.

Factors affecting detection of PSTV by NASH. Storage of PSTV-infected tubers at 4° C was shown to drastically reduce viroid detection, as PSTV becomes undetectable in four to five months (Fig. 8). Storing tubers between 15° to 25° C did not affect PSTV detection. In sprouts detached from infected tubers and store at −15° C, PSTV detection was drast cally reduced in four to five days an became undetectable in about 15 days. Th effect of storage on infected leaves was not as drastic, although some reduction of PSTV detection was observed. The reason for this effect is unknown, and further experiments are needed to determine the cause. No reduction of PSTV was observed in TPS stored at 4° C for more than one year.

TRAINING

Seven visiting scientists from Europe, Africa, Asia, and South America received a total of 38 weeks of training on laboratory and glasshouse techniques for the detection of viruses and PSTV. A field-level virology course was given in Nepal

to support the national seed production program, and an in-country course was given in Turkey on serological detection of viruses. This course was designed for seed production specialists and national potato program staff working in the breeding program on selecting clones for virus resistance.



THRUST V

Integrated Pest Management

Major emphasis was placed on screening potato genotypes for resistance to nematode and insect pests and on noncheinical control methods. Eight percent of 150 potato clones and 4% of a segregating population of 3000 genotypes showed resistance to root-knot nematode, *Meloidogyne incognita*. Thirty-one clones from pathogen-tested and advanced selections were found susceptible. A combination of the nematode parasitic fungus *Paecilomyces lilacinus* and aldicarb looked promising in controlling *M. incognita*. A series of screening trials for resistance to potato cyst nematode showed resistant clones in early and advanced materials. Forty-three selected resistant clones were passed to the national potato program of INIPA, Peru, for adaptation tests; one clone (G3) is being released as a new variety in Peru and four are still in advanced regional trials.

Four of 60 species of potatoes showed a certain degree of resistance to potato tuber moth (PTM) (*Phthorimaea operculella*) damage in the foliage, which was partially associated with the presence of glandular trichomes. Progenies from different crosses of selected materials are being evaluated for the presence of glandular trichomes and for yield. Resistance to tuber moth damage in tubers has been found in increasing amounts, e.g., from 1% in 1983 to 11% in 1986 and new sources of resistance were identified in clones derived from wild diploid material. For leafminer fly (*Liriomyza huidobrensis*), 194 clones were field-evaluated and 19 were selected for resistance. Biological control of tuber moth was attempted in field and stores by using a granulosis virus identified from tuber moth larvae reared in Lima. This virus proved effective under both field and storage conditions. For Andean weevil (*Premnotrypes suturicallus*), the fungus *Beauveria bassiana*, was moderately effective in the field.

In Tunisia, relationships among potato plant development, tuber maturity, harvest date, tuber yield, and seasonal potato tuber moth occurrence and damage were investigated. As a result optimal harvest dates were determined. In Egypt, the combined use of light and sex pheromone traps, and the use of phosphine as a fumigant were both effective in controlling PTM in stores. Aphid populations were monitored in three areas in Colombia; *Myzus persicae* was the most predominant of the 13 species recorded.

Farmer in Bangladesh being trained to treat potato tubers with a granulosis virus for biological control of potato tuber moth.

ROOT-KNOT NEMATODE

Screening for resistance. Thirty-one clones from a combination of CIP's pathogen-tested and advanced selections from tuber families were tested for their reaction to root-knot nematode (RKN), *Meloidogyne incognita*. All were found susceptible. Depending on the origin of nematode inoculum, 8-13% of 159 clones subjected to three different nematode populations were found resistant. In another test, 4% of the segregating population of 19 tetraploid families comprising approximately 3000 genotypes were found to be resistant. The selected materials will be retested for resistance to three distinct nematode populations and the confirmed resistant material will then be cleaned for regional trials.

Biological control. Different combinations of the parasitic fungus *Paecilomyces lilacinus* and dosages of aldicarb, down to one fourth of the recommended rate, were effective in controlling over 90% of the root-knot nematodes under greenhouse conditions. Data indicate that one fourth of the recommended dose of aldicarb in combination with *P. lilacinus* was as effective as the application of the full recommended dosage of the same nematicide in controlling nematodes. Tests are being conducted to verify these results under field conditions.

Cleaning, identification, and confirmation of the nematode biological control activities of several fungal isolates collected during the past several years continued. Confirmation of field biocontrol activity is underway.

POTATO CYST NEMATODE

Screening for resistance. The progeny of 200 families crossed in 1985 (G-85) using 60 females (including late blight- and frost- resistant females) and four males resistant to potato cyst nematode (*Globodera pallida*) were evaluated in Huancayo for agronomic traits and combining ability for resistance to P4A and P5A races of *G. pallida*. In the field, 7.8% (1200 clones) were selected; of these, 45% were rated as resistant. However, results still showed a negative correlation between resistance and yield, and resistance and tuber quality.

After resistance to P4A and P5A races of *G. pallida* in G-84 crosses was confirmed in 560 clones, 145 were further selected for their agronomic performance. Part of this work is being carried out by the Peruvian national potato program of INIPA.

Forty-three out of 100 selected clones (G-83) were passed on to the national potato program to be tested for resistance to cyst nematode and adaptation in the north and central highlands of Peru. The ten best selections from this trial are shown in Table 1. A summary of all the genetic

Table 1. Yields and resistance to different races of *G. pallida* in the ten best clones tested out of 100 crosses made in 1983. Huancayo, Peru, 1985-86.

Clone	Yield/plant (kg)	Resistance[a] and race	
		P4A	P5A
279142.12 (G_3)	2.6*	MR	R
G83233.12	2.5	S	R
CFK-69.1 (control)	2.4	S	S
G83009.23	2.4	MR	S
G83193.3	2.4	S	MR
G83251.23	2.3	S	MR
Revolución (control)	2.2	S	S
G83117.4	2.2	R	R
G83009.5	2.1	S	R
G83141.12	2.1	R	R

CV 23.96%; * nsd among clones

[a] R = resistant; MR = moderately resistant; S = susceptible.

Field evaluation of a clone with potato cyst nematode resistance, undertaken by the national potato program of Peru.

material tested in 1986 for resistance to *G. pallida* P4A and P5A is presented in Table 2. This includes material developed at CIP by several breeders as well as material coming from other institutions.

The Peruvian national program, after five years of cooperative trials, has decided to release CIP selection 279142.12 (G-3), which has an outstanding performance in the northern and central highlands of Peru. This clone shows high levels of resistance to *G. pallida* P5A and moderate resistance to P4A. Throughout four years of trials it has shown tolerance to late blight and outyielded local varieties. Table 3 presents this clone as well as other promising selections.

In Ecuador, resistance screening to cyst nematode has been carried out by the national potato program of INIAP for the past six years. In regional trials, two rotation studies were carried out to determine the nematode population under an integrated management system.

Five resistant clones selected from regional trials in Ecuador are currently undergoing virus elimination at CIP headquarters. Of 86 new clones sent in 1985 to Ecuador, 40 were found resistant and will be evaluated under field conditions.

Table 2. Material tested for resistance to two races (P4A and P5A) of *Globodera pallida* during a one-year period (1986).

Genetic material	No. clones/families	% Resistance
Root-ball method		
Scurrah material G84	921	60
Confirmation test G84	200	95
Vernei hybrids (CIP)	50	32
Wageningen	93	38
Iwanaga (2x-4x material)	136	15
Cornell (clones)	390	40
Set No. 7 Export	180	40
Bryan pathogen-tested material	34	2
Petri dish method		
Clones G83	122	35
Mass seedling screening	193 (families)	0

Table 3. Yield and resistance to potato cyst nematode *(G. pallida)* of selected clones tested in the highlands of Peru by the national potato program, 1985-86.

Clone	Yield (t/ha)	Field resistance[a]	Multiplication rate (Pf/Pi)[b]
280179.7	42.9	MR	1.5
279142.12 = G3	32.7	MR	1.8
AG279098.5	27.7	MR	1.6
280363.1	26.8	MR	3.1
AG279212.1	26.6	MR	1.9
Yungay (control)	18.5	S	5.3

[a] MR = moderately resistant, equivalent to 1 in 0-3 scale; S = susceptible.
[b] Pf/Pi = final nematode density/initial nematode density.

Studies on spatial distribution of nematodes at different population densities were carried out to improve sampling procedures. Results confirmed that the highest densities were around the root zone, and at higher population densities smaller samples are required.

At the testing site of the national potato program of Venezuela (Merida), 21 clones with apparent resistance to cyst nematode (*G. rostochiensis*) were evaluated. Of these, 15 clones were selected based on their agronomic characteristics.

ROOT-LESION NEMATODE

Nine Peruvian potato cultivars were tested for their reaction to root-lesion nematode (*Pratylenchus flakkensis*) under greenhouse conditions. Higher reductions in tuber weight were recorded for Cuzco and Revolución, but the higher reduction of total biomass occurred in Tomasa Condemayta, Amarilla, and Renacimiento. The most tolerant hosts were Mi Peru, Rosita, and Huayro.

In a study on the simultaneous attack of the fungus *Verticillium dahliae* and root-

lesion nematode on the cultivar Revolución in pots, wilting symptoms appeared 12 days earlier than with the fungus alone. The percentage of wilted plants was 28% higher in the simultaneous attack.

POTATO TUBER MOTH

Screening for resistance. Sixty wild potato species were evaluated in the greenhouse at Lima for foliar resistance to larval mining by potato tuber moth (PTM) *Phthorimaea operculella*. Five species, *Solanum berthaultii*, *S. demissum*, *S. fendleri*, *S. pinnatisectum*, and *S. polyadenium*, showed less than 17% foliar damage as compared to that of the susceptible check (DTO-33) with 75%. Pupation in the five species varied from 17% to 37%, while in the check it was 75%. *S. berthaultii* has high densities of trichomes of type A and B. Most of the materials provided by Cornell University through a research contract (*S. berthaultii* x *S. tuberosum*) were susceptible to PTM foliar damage, although clones TV22 and TV21 had less than 25% pupation.

In breeding clones for glandular trichomes, 39 out of 326 clones were selected from intercrosses of selected material, on the basis of the presence of glandular trichomes and yield. These selections will be field-evaluated for PTM resistance at Lima during summer 1987. A total of 200 families, including 14 new families from Cornell, and intercrosses of selected materials have been planted in San Ramon and Huancayo to form the basis of lowland and highland populations.

A total of 369 clones were screened in tests conducted in San Ramon for PTM resistance in tubers. Sixteen clones from cycle P85 were selected and are being multiplied for confirmation of resistance. The percentage of clones rated resistant in storage trials has risen from 1% in 1983 to 11% in 1986. In Colombia, CIP's regional program selected two clones (Parda Pastusa and 82.3.5) as resistant; however, they were found susceptible to PTM populations from Lima and San Ramon. These results indicate that the Colombian and the Peruvian PTM genotypes may be different in their aggressiveness. This population behavior is being investigated further.

Material originally selected for resistance to PTM populations in Peru was tested in Australia against a Victorian population of PTM. Selected resistant clones are in different stages of multiplication and screening against Peruvian PTM populations.

At CIP, Lima, of 252 clones derived from wild diploid material, 38 were selected as new sources of resistance to tuber damage by PTM. Five clones derived from OCH6579 OP were rated as resistant and will be retested in 1987.

Biological control. A granulosis virus (Fig. 1) infecting PTM larvae was identified at CIP from colonies reared in stores in Lima. The infected larvae turn white and fail to pupate. The Peruvian isolate was tested in rustic stores at San Ramon, where high percentages of larvae became infected (75% to 98%), and the intensity of tuber damage was low (Fig. 2). Trials in the field to control foliar infestations of PTM showed that more than 90% of the larvae became infested and foliar damage was also reduced significantly. The Peruvian isolate of the granulosis virus is now being tested with other strains collected from Australia, India, and Tunisia.

Control by trapping. In a field study on pheromone longevity, vials and white rubber dispensors impregnated with impure and pure PTM pheromone were tested in funnel traps for PTM capture for a period of 12 months in San Ramon. No significant differences in trap capture were

Figure 1. A granulosis virus isolated from potato tuber moth in Peru.

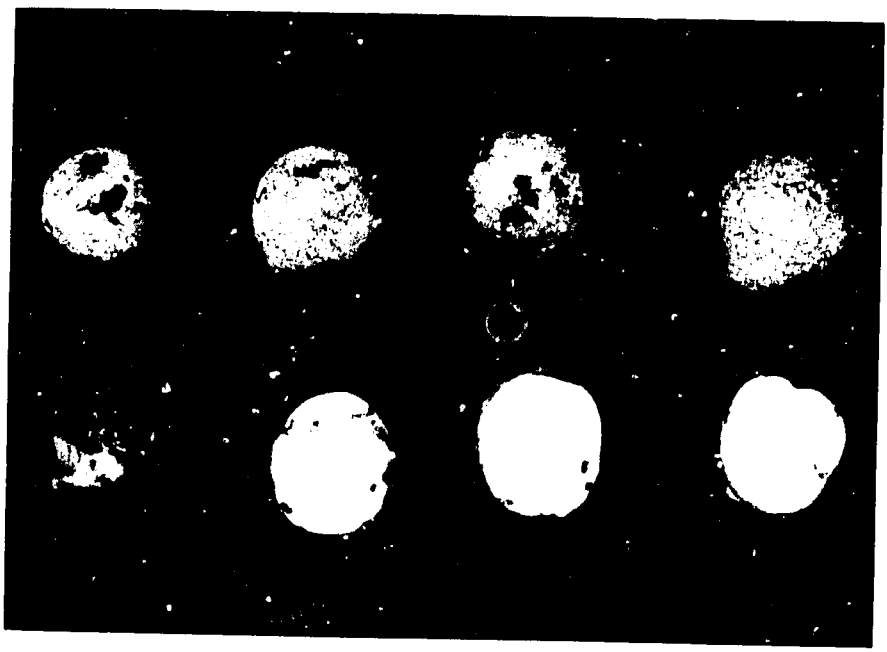


Figure 2. Potato tuber moth damage in tubers treated and untreated with granulosis virus. *Left* to *right:* untreated control, low, medium, and high dose of virus.

observed. Trap capture in all the formulations dropped after four months of field use. Light bulbs (yellow, blue, red, and UV black light) were also evaluated in funnel traps. Highest captures were found with UV black light. Results of another trial showed that trap captures could be increased significantly by using light traps (UV and yellow) along with the pure sex pheromone.

Control in stores. In seed stores in Egypt, CIP and the national program found that traps with halogen light bulbs were more efficient than pheromone traps for catching PTM. A combination of both types of trap (light plus pheromone) in the stores reduced PTM infestation and losses by 50%; but, it is recommended that tubers are examined for PTM damage before entering the store and that all windows or ventilation openings are covered with metal screening to exclude PTM. Tests were also carried out in stores with phosphine gas to kill PTM larvae in tuber tunnels. Eight hours exposure in a sealed container killed the larvae, but as phosphine may also stimulate sprouting, this can be a drawback when storing seed for several months. The effect of phosphine on PTM and tuber sprouting still requires further study.

Population dynamics. Population monitoring of PTM was continued by CIP and the national program for a third year in Tunisia in five localities by using the water trap method. Adult male PTM were trapped throughout the year and the number of moths increased from 1-10 per week per trap in February to about 500-1000 moths in July. It was shown that PTM counts dramatically diminished in areas where potatoes were not stored by farmers during the warm season (July-August). Levels remained high where farmers store the tubers (seed and consumer) under ambient conditions. The main damage caused by PTM in stores occurs in July and August, rendering the tubers unmarketable. However, if not rotten, the 100%-attacked seed tubers with a low intensity of PTM damage (at least one hole) did not lead to lower yields in the fall season. This is important information for the Tunisian seed multiplication scheme and indicates that low to moderate PTM damage does not necessarily diminish the seed quality.

Chemical control usually has an adverse effect on natural enemies of PTM. In Tunisia, PTM foliar damage was higher in a once-sprayed crop than in a crop which had not received insecticide. This was due to the killing of PTM predators. An average of 36.6% of eggs were consumed within 24 hours in a trial conducted in Tunisia when eggs were exposed to predation on four different dates.

At the Saida research station (Tunisia), relationships between plant development, maturity, harvest date, tuber yield, and PTM damage were investigated. Tuber weight losses were lowest for the second harvest (May) and highest for the last harvest date (June). Three different methods (spraying, dipping, and dusting) of applying the biological control *Bacillus thuringiensis* for protecting tubers from PTM damage during storage were compared. Dusting gave the best performance with only 6% damage, while spraying was ineffective with 27% damage.

Chemical control. Thiodicarb (Larvin), methomyl (Lannate), diflubenzuron (Dimilin), and phenthoate (Cidial) were evaluated in rustic diffused-light stores located at San Ramon. Phenthoate dust at 2 kg/t was the most effective in reducing PTM damage. The fumigant phostoxin at 1 tablet/100 kg potatoes controlled all the PTM mining larvae inside the tubers of the cultivar Revolución. Sprouting on treated tubers was not affected by the phostoxin treatment.

GREEN PEACH APHID

Control of green peach aphid, *Myzus persicae*, in nursery beds located at Lima was studied in DTO-33 seedlings. Treatments were aluminum foil (as a repellent), yellow sticky traps, and aldicarb applied to soil as a granular formulation, plus weekly applications of methamidophos applied as spray to foliage. None of these treatments was effective in reducing the aphid population, and the incidence of potato leafroll virus (PLRV) and potato virus Y (PVY) was high in all treatments (PLRV varied between 17-45% and PVY between 0-45%).

In collaboration with the Colombian national program of ICA, a study of all aphid populations in three main potato-growing areas of Colombia was made. At the La Selva experimental station, Medellin (2100 m), the mean yield per yellow water trap was 638 adults/week during five months. *Myzus persicae* was the most prominent species and always present, but 12 other aphid species were recorded. At the Tibaitata site (2650 m), only 610 adults were captured during 11 months with mean weekly fluctuations from 0 to 60 adults/trap. At the San Jorge site (3150 m), only 210 aphids were trapped in eight months and the mean weekly range was 0 to 27 winged aphids/trap.

LEAFMINER FLY

A total of 144 clones from the CIP germplasm were field-evaluated at Lima for damage by leafminer fly, *Liriomyza huidobrensis*, and 19 clones were selected as resistant. This material will be retested in the winter of 1987.

ANDEAN POTATO WEEVIL

Biological and cultural control. Preliminary trials were carried out in Huancayo (Peru) and in Colombia to study the possible existence of an aggregation pheromone for *Premnotrypes suturicallus* and *P. vorax*, respectively. Initial results were encouraging and more field tests are underway. The fungus *Beauveria bassiana* was tested on *P. suturicallus* in the field at Huancayo. The highest infection (29%) of adult weevils was obtained by applying the fungus at the time of hilling-up. In a separate study of cultural practices, the lowest tuber damage by potato weevil was observed at deeper planting and a high hilling-up combined with the use of pesticides.

SOCIOECONOMIC STUDIES OF INSECT PESTS

The characteristics, costs, and variability of potato farmers' current practices for the control of key insect pests were studied by CIP in collaboration with national programs in selected regions of Peru and Tunisia.

Leafminer fly has been a key pest in the past 30 years in the Cañete Valley of Peru (coastal area). Populations build up during the potato growing season, reach their peaks in August- September, and then fall off again as temperatures rise. National programs have proposed that farmers plant early enough to avoid the peak, but prices in the Lima market tend to rise steadily after a seasonal low in June or July. The farmers' average expenditure on insecticide for leafminer control was higher than for any other input, including seed.

The Andean weevil, *Premnotrypes* spp., is the major potato pest in the Mantaro Valley in the central highlands of Peru. To measure the effects of standard practices such as deep planting, high hilling, timely pesticide application, and timely harvest on Andean weevil control, experimental plots were laid out in the Mantaro

Valley (3280 m). This research was conducted in coordination with the Peruvian national potato program and 70 farmers from the Mantaro Valley area. Climatic conditions did not favor weevil damage, which averaged 18% in sample fields. Expenditures on insecticides by the farmers surveyed ranged from zero to more than US$350/ha. The pest attack was variable over short distances, but tended to be a problem at intermediate elevations on farms with intensive management. Similar socioeconomic experiments are underway in Tunisia where PTM is the key pest in stores. A cooperative research project between CIP and the Tunisia National Research Program (INRAT) has developed recommendations for timely harvest and the proper management of pest control in stores. The variability of key management practices was the subject of a survey carried out in two major potato-producing regions in September.

TRAINING

During the year more than 100 scientists attended courses and workshops, or received individual training, on nematology and integrated pest management throughout the CIP regions. A major effort was made in Latin America with an in-country nematology course in Bolivia and a regional workshop in Panama to assess the progress made in nematology research during the previous two years. The first integrated pest management course, held in Colombia, was attended by scientists from nine South and Central American countries.

The success of a 1982 nematology workshop in Peru and a 1984 follow-up workshop in Panama, in organizing work plans for nematology research in Latin America, promoted the initiation of a similar exercise in Asia. A workshop to develop a strategy for nematology research in Asia was held in the Philippines in 1986 and attended by representatives from seven countries. This event was followed by the Second International Workshop on Biological Control sponsored by CIP and the Philippine Council for Agriculture and Resources Research and Development (PCARRD).

THRUST VI

Warm Climate Potato and Sweet Potato Production

Further studies on nitrogen fertilization strategies at San Ramon, Peru, have confirmed the lack of response of tuber yield to split nitrogen (N) applications at all rates tested (0-160 kg/ha) during the dry season. During the rainy season, however, splitting the N application significantly increased final tuber yield by 50 g/plant relative to a single application. Intercropping experiments in Peru are now designed to identify potato clones tolerant to shade. A number of clones are proving tolerant to reductions of 25% incoming solar energy. Intercropping experiments in the Philippines with potato:maize in the proportion of 8:1 have been very successful, as has relay cropping in Egypt. In Bangladesh, potato has been grown successfully with sugarcane and has led to a gross income double that of other sugarcane intercrops.

Our experiments have highlighted the poor yield potential of replanted warm-produced tubers, especially those stored in diffused-light stores in warm climates. Yield decline of replanted tubers over seasons and years was site- and clone-dependent and could only be offset to a small extent by cold storage. Alternatives to warm climate, field-produced seed tubers were studied. Rooted stem cuttings of some clones gave yields similar to those of their cool-produced seed tubers. TPS transplants also gave comparable yields but these were characterized by large numbers of small tubers.

A study of practices useful in the screening of heat-tolerant clones has illustrated that heat tolerance is probably not related to one specific character, and that various tests may be necessary to quantify heat tolerance. In contrast, clonal response for salt tolerance may be simply quantified using in vitro techniques. Field screening for heat tolerance continues to identify clones with heat tolerance and certain clones are known to be good parents. Screening of the pathogen-tested list of clones at San Ramon has also identified new sources of heat tolerance that outyielded the early maturing LT and DTO clones, but which matured two weeks later. Several genotypes appeared more suitable to hot conditions, when evaluated in the coastal area of Kenya. Similarly, some of the introduced clones in Senegal showed heat tolerance even though storage conditions prior to planting affected tuber yield.

Relay cropping of potato with maize in China. Note leaf removal from maize on right to manipulate shade level for the potato crop.

OBJECTIVES

We continue to search for production strategies and genotypes that will permit the farmer in the warm tropics to make efficient use of the limited resources available to him. In this context much effort has been placed on reducing the cost economies of seed tubers acquired from cooler regions—a major economic factor at present. Screening and selection of cultivars well adapted to warm climates often requires identification of tolerance to other stresses in addition to heat. Studies are now in progress to identify such sources.

AGRONOMIC STUDIES

Nitrogen (N). The role of nitrogen (N) fertilization in the adaptation of potatoes to the warm tropics has received little attention in general. It has been shown that an increase in plant N delays leaf senescence in potato and other crops. Little work has been done that describes the effects of plant N levels on N partitioning, canopy senescence, and tuber yield for potatoes grown in the warm tropics. Differences in N metabolism may partly explain differences in canopy senescence and tuber yield observed between cultivars when grown in the tropics. Understanding relationships between plant N and tuber yield may provide an important tool for breeders in selecting for heat tolerance in potatoes.

Previous studies during the dry season at San Ramon have demonstrated little benefit in splitting N applications (160 kg/ha[1]). Results are now available on the influence of splitting N into two equal applications, at four N rates (60, 120, 180, and 240 kg/ha) as urea, during wet and dry season crops planted with the cultivar Desirée. During the wet season at San Ramon there was a significant response in tuber yield with increasing N fertilizer at

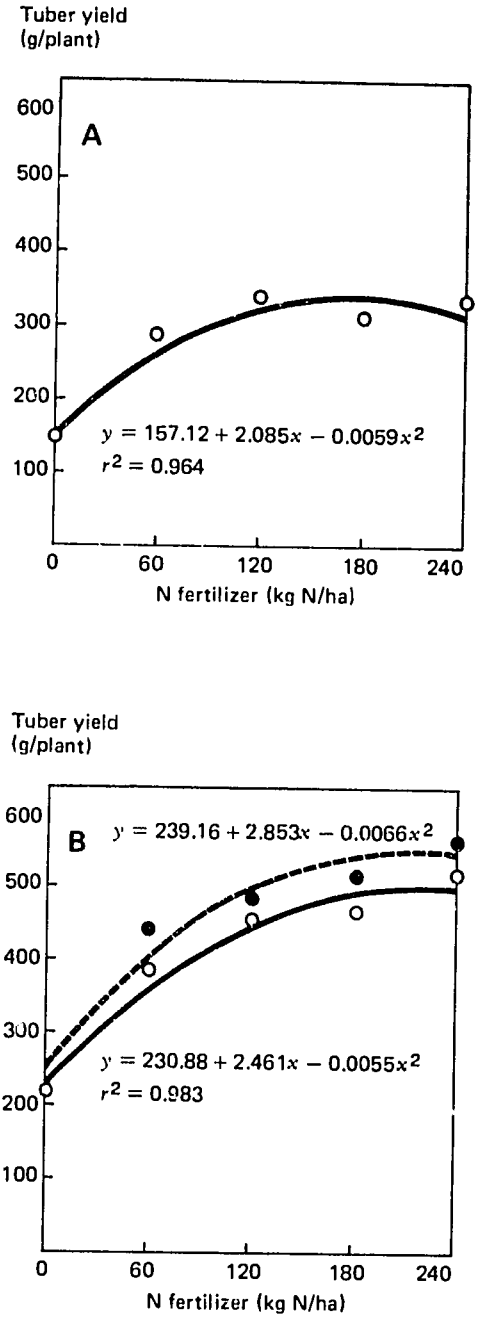


Figure 1. Tuber yield as a function of nitrogen (N) fertilizer rate for (A) early harvest, and (B) the influence of split N applications (-•-) compared to single applications (-∘-) on late harvest at San Ramon (wet season).

early and final harvests (Fig. 1). No differences in yield were observed between single and split applications for the early harvest. Splitting the N application, however, significantly increased final tuber yield over single applications.

In the dry season crop, there was again a response to increasing levels of N fertilizer (Fig. 2); however, there was no yield response to the split N application. Because of the lack of heavy rainfall during the dry season, it is likely that little leaching of N occurred. This may explain why the plants did not respond to the split N application.

Results from the dry season also suggested that tuber yields at the higher N fertilizer rates tended to be lower early in the season when compared to the lower N fertilizer rates. When 60 kg N/ha was applied in either the split or single application, maximum tuber yield occurred about 73 days after planting and yield subsequently decreased to final harvest, 82 days after planting. The yields of all other treatments that received N increased to the final harvest. The results suggested that plants matured earlier at the lower N rates and that optimal harvest dates may be earlier for low N treatments. The N content and dry weights of tubers, roots, stems and leaf canopy levels (high, middle and low) are being analyzed to determine whether differences existed in N and dry matter partitioning patterns in Desirée when grown at increasing levels of N fertilizer.

Water. In warm tropical areas the potato is often grown during the winter when rainfall is scarce and solar energy is high. These conditions induce water stress response in the potato plant. Previous results (*Ann. Rep. 1985*) have demonstrated the usefulness of the line-source irrigation system in identifying clonal response to varying levels of applied water,

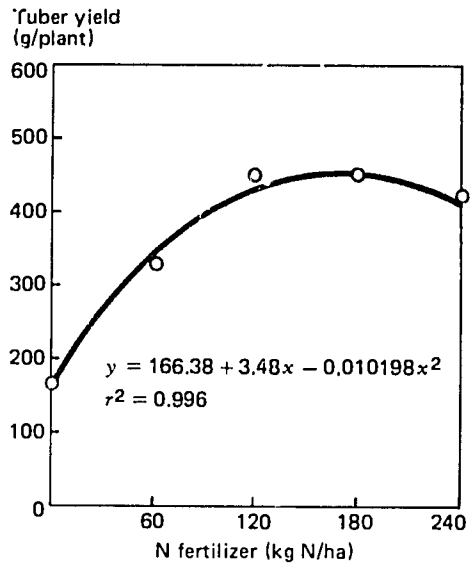


Figure 2. Tuber yield at final harvest as a function of nitrogen (N) fertilizer rate, San Ramon (dry season).

in which drought stress is enhanced as the season progresses. This system is presently being used to quantify clonal response of a range of clones to drought, and to determine whether physiological indices might assist in circumventing the large amount of time and space necessary for such field experiments.

Intercropping. Work on the intercropping of maize and potato in Peru has been restricted to two topics: 1) to refine some technical points of a potato:maize relay cropping system in which maize is planted into the potato crop to effect cooling through shading later in the potato season; and 2) to screen genotypes for their ability to yield well when planted simultaneously with maize at a proportion of 9:1 (see *Ann. Rep. 1985*, pg. 87). The latter was done in separate experiments at San Ramon (dry season) and Lima (summer). At San Ramon, of the 45 clones tested, seven (including DTO-33 and Katahdin) yielded

more than 1000 g/m^2 when mix-cropped with maize, although tuber yields were often less in the mixed crop. Yield of maize in the mixed crop was 30% of the sole crop (186 vs. 623 g/m^2 ± 23 g), and only for three clones did the land equivalent ratio (LER) of their mixtures with maize exceed unity. At Lima, of 20 clones and first generation true potato seed (TPS) tuber populations, the LERs exceeded unity in seven. Potato yields in sole plots ranged from 479 to 2226 g/m^2, while in mixed plots, yields ranged from 226 to 1329 g/m^2. Maize in mixtures yielded 29% to 49% of the control yield of 335 g/m^2. The reduction of potato yield at both sites when mixed with maize was due to the use of a more vigorous and longer season maize population than was used in previous experiments. Light interception of the maize in Lima by 60 days after planting had already exceeded 30% and continued to increase to well above the 20% reduction recommended previously (*Ann. Rep. 1980, 1985*). Intercropping did not improve the performance of clones poorly adapted to warm conditions, but certain clones (e.g., LT-2, LT-5, and LT-7) showed less yield reduction than the mean for all clones and these deserve further attention in intercropping studies.

In the Philippines potato is being intercropped with sweet corn as a means of improving potato growth in hot conditions. The canopy size of potato was reduced when 30,000 to 40,000 plants/ha of sweet corn were interplanted with 50,000 plants/ha of potato. An optimum ratio for economic returns was achieved with potatoes and sweet corn in a ratio of 8:1, respectively. The same conclusions came from experiments in San Ramon. When 55,000 potatoes and 7000 sweet corn/ha were planted simultaneously in tropical climates, both crops were harvested in 70 to 80 days. More work will be carried out on clonal response to this intercropping practice.

The technical and economic feasibility of planting potato and sugarcane simultaneously is being studied in Bangladesh in a research contract involving collaboration between CIP, the Bangladesh Agricultural Research Institute, and the Sugar Cane Training and Research Institute at Ishurdi. In comparisons between potato and other potential intercrops (e.g., wheat, mustard, or lentils), the potato:sugarcane combination gave almost double the gross income of the other combinations with sugarcane (Table 1). With the other crops, sugarcane yield was reduced by interspecific competition. The practice of fertilizing potato and sugarcane separately enhanced the yields of both crops and has been verified in on-farm trials. Since both crops are generally planted under rainfall conditions, the planting of well-sprouted tubers at a depth of 10-12 cm, plus covering the soil with mulch, are practices that reduce the variability of yields due to

Table 1. Economics of intercropping with sugarcane in different crop combinations under farmer conditions in Bangladesh (1983-84).

Treatment	Yield of intercrop (t/ha)	Yield of cane (t/ha)	Total sale proceed US$/ha[a,b]
Sugarcane + potato	5.99	36.02	1541
Sugarcane + lentil	0.60	30.82	925
Sugarcane + mustard	0.64	28.10	977
Sugarcane + wheat	1.13	27.73	911
Sugarcane alone (pure stand)	–	35.59	890

[a] Price of intercrop (US$/t): potato 107/t; lentil 257/t; mustard 429/t; wheat 193/t; cane 25/t.
[b] Calculated at exchange rate of US$1.00 = 25 taka (Bangladesh).

Chinese scientists inspect potato planted late in the hot summer under the shade of maize, the stalks were subsequently removed when the potato was established. This practice is being introduced for the summer planting in Egypt.

infrequent or no rain during the growing season.

In Egypt, potatoes are usually planted after mid-September when summer temperatures are decreasing. There is interest in earlier planting since early potatoes bring higher prices. At Kafr El Zayat, five cultivars were planted on two dates, August 20 and September 19, to test the feasibility of earlier planting. Plant establishment and stem number were reduced for the early planting with the exception of the variety Claudia. Yields obtained from the August planting ranged from 14 to 22

t/ha, compared with yields from the September planting of 19 to 34 t/ha. To reduce soil temperature at early planting of potato, a shade experiment was run in which maize was planted five weeks before potato, on the south exposed side of each ridge. Soil temperature at tuber planting depth was 10° C lower when shaded by maize than if planted without shade. Potato was planted on the north side of each ridge at the end of July and the end of August. In the July planting, tuber yields when potato was mixed with maize were significantly greater than sole potato yields (20.2 vs. 13.4 t/ha); in addition, maize yielded 5.2 t/ha. For the August planting, tuber yields were similar with or without maize (23 vs. 24 t/ha) and maize yielded 4.6 t/ha of grain. Even with the lower yields of the earlier planting, there is still considerable interest by farmers due to the higher price paid for tubers from the earlier harvests.

Two experiments were carried out in Brazil in collaboration with the National Center of Horticultural Research (CNPH-EMBRAPA) to test the feasibility of intercropping sugarcane with potato during the first three months after planting both crops simultaneously. In Experiment 1, five potato cultivars were planted on beds, 40 cm high and 1 m wide, between furrows planted with sugarcane (1.5 m wide). Yields ranged from 10.1 t/ha for the variety Achat to 22.6 t/ha for the variety Baronesa, both locally bred varieties. Bintje, the commonly grown commercial variety, yielded 19.7 t/ha. In Experiment 2, the variety Achat was planted in single (2.22 plants/m^2) and double (4.44 plants/m^2) rows between furrows of the sugarcane crop. Yields of 12.2 and 22.1 t/ha for the single- and double-row arrangements reflected the differences in plant population. The double-row arrangement reduced the percentage of marketable tubers, but total marketable yield for this arrangement was still considerably greater (19.2 t/ha) than for the single-row arrangement (11.3 t/ha).

SOIL MANAGEMENT

In collaboration with the Soils Department of the National Agrarian University in Lima, work, in relation to potato production, continues on problematical soils, particularly those with acid or saline features. In a pot experiment (Table 2) planted with tubers of the cultivar I-931, in which rates of lime and inorganic fertilizers were varied, lime improved tuber yield but with decreasing returns at the higher fertilizer rates. Two meq of lime per 100 g soil was the optimum liming rate with Al^{+++} saturation of the CEC equal to 41.4%. The use of Peruvian rock phosphate for potato production on alkaline as well as acid soils is a feasible practice. Various particle sizes of rock phosphate were compared to the use of simple superphosphate on an acid soil. Tuber yield with rock phosphate particle size less than 0.1 mm was close to that of simple superphosphate. Rock phosphate (1 t/ha) has also been used effectively in the highlands of Peru in combination with 0.25 t/ha of KCl as a basal fertilizer on a cal-

Table 2. Tuber fresh weight per pot as influenced by the liming and the application of fertilizer to an acid soil[a] from the jungle (Pucallpa, Peru).

	Lime (meq/100 g soil)		
N-P_2O_5-K_2O (ppm)	0	2	4
0-0-0	26	72	84
80-80-80	47	81	116
160-160-160	73	134	139
240-240-240	125	182	175

[a]Soil pH = 4.3; 2.9 ppm P; 100 ppm K; CEC = 5.42 meq/100 g soil.

careous soil with pH 7.4. The yield with the basal fertilizer, averaged over four N-P-K rates, was 17.9 t/ha and 11.8 t/ha without it.

In the coastal and desert areas of Peru and in other countries where potato is an irrigated crop, saline irrigation sources and soils often exist. In a pot test for salt tolerance, the cultivar Revolución was more tolerant to high salinity (6.16 mmhos/cm) than two other varieties, Ticahuasi and Mariva. In vitro screening of potato clones for salt tolerance is in progress and may replace the pot studies, since economies in time and space can be made with the in vitro procedure.

PRODUCTION STRATEGIES

Sequential potato production. At San Ramon, on-farm research permits the identification of constraints associated with a year-round supply of consumable tubers for a family of six. The system is designed to have no reliance on seed tubers. Of the tubers harvested from beds of Atzimba x R128.6 TPS seedlings by five farmers (*Ann. Rep. 1985*), tubers smaller than 28 mm were stored and served as planting material for plots ranging from 13 to 150 m^2. Although marketable yield as a proportion of total yield was low (also found when first generation seedling tubers were planted to nursery beds), high total yields offset this and resulted in yields similar to those of control plots, which contained regular seed-sized tubers of the cultivar Desirée, recently introduced from Huancayo. In this manner, not only is the farmer self-sufficient in potato production, but he can also produce a small quantity for the local market. A full-scale sequential system for family consumption and marketing is now underway based on either TPS of Atzimba x R128.6 or cuttings of the cultivar Atzimba.

Sources of seed tubers. The replanting of tubers produced and stored in warm climates has been continued for four generations at San Ramon and Lima to determine the physiological decline in yield potential. The experiment involved two sites (Lima and San Ramon), six clones, and three production cycles: 1) continuous plant/store/plant cycle with three months of DLS storage; 2) annual production cycle with nine months of DLS storage; 3) annual production cycle with nine months of cold storage. Yield decline was site- and clone-dependent and was greater at San Ramon, most notably for the clones B-71-240.2 and 278072.10 in continuous production cycles. The tuber yield from cold-stored (4°-6° C) tubers produced in the summer at Lima was superior (45-65%) to that from diffused-light storage (DLS); whereas with tubers produced in the winter at Lima, the difference in productivity of cold- and DLS-stored tubers (up to 25%) was much less. At San Ramon the relative benefit of cold versus DLS storage depended on the season in which tubers were stored. Yields from tubers harvested during the dry season were greater when tubers were cold-stored; whereas yields from tubers harvested during the rainy season were clone-dependent; yields were greater from tubers stored in DLS for Desirée and LT-1, and greater for tubers cold-stored for DTO-33 and B-71-240.2.

The experiment was also designed to provide comparative information on the selection of clones for productivity when selection was based on newly introduced, good quality seed tubers, compared to selection based on performance of clones that had been grown previously in warm climates. Selection for the highest yielding clone, based on newly introduced, good quality seed tubers for each season at San Ramon, would have identified B-71-240.2.

Based on material continuously replanted, DTO-33, by the third and fourth seasons, was the highest yielding clone and B-71-240.2 the lowest. The same ranking of these two clones was evident in the harvest of replanted tubers produced in the rainy season and stored in DLS for eight months. At Lima, based on the planting of good quality seed tubers, Desirée, CGN-69.1 and B-71-240.2 would have been selected as the highest yielding clones in the four seasons. By the third and fourth continuous seasons in Lima, B-71-240.2 was close to the poorest yielding clone. Under the annual production cycle, in all season-by-storage combinations at Lima, B-71-240.2 was the highest yielding clone.

The results therefore indicate the following: 1) that the yield of warm-produced and warm-stored tubers was much less than that of highland, cool-produced, good quality tubers, 2) the yield decline was clone- and site-dependent; 3) cold storage could, to some extent, reduce the yield decline, and 4) the relative yield performance of clones based on newly introduced seed tubers from a cool climate may not bear a close relationship to yield performance following continuous production, or annual production spanned by a long DLS period. Data from one more season must be obtained before a full discussion of the physiological response of the clones to continuous or annual replanting is possible.

Comparisons between alternatives to the use of good quality seed tubers. In response to the poor yield potential of locally produced seed tubers in warm climates, and given the unavailability or high cost of good quality seed tubers, the following three types of planting materials, which could be produced locally, were compared in a series of experiments in Lima and San Ramon: 1) field-multiplied seed tubers, 2) seed tubers produced in beds either from TPS or from cuttings, and 3) TPS transplants or rooted cuttings for direct production of consumer potatoes.

In Lima during the summer the following types of planting materials were compared: rooted stem cuttings and cool-produced seed tubers of LT-5 and Rosita, and TPS transplants of both Atzimba x R128.6 and Atzimba x DTO-28. Spacing was 30 x 70 cm for seed tubers and 20 x 70 cm for transplants and cuttings, with one cutting or two TPS transplants per hill. Plant stand was best for seed tubers, intermediate for cuttings, and lowest for TPS transplants, indicating a better survival rate for cuttings than for TPS transplants, even though only one cutting versus two seedlings were transplanted per hill (Table 3). Early canopy development was fastest for seed tubers, intermediate for cuttings, and slowest for seedlings. The same ranking was observed when the efficiency of crop cover was measured over 0-65 days.

Cuttings had significantly fewer stolons and tubers throughout the growing season than seed tubers or TPS transplants. Rooted cuttings of Rosita gave a tuber yield equal to that of the cool-produced seed tuber treatment (Table 3); whereas the yield of rooted cuttings of LT-5 was 27% less than yield of LT-5 cool-produced seed. Cuttings produced few tubers per m^2 but subsequently had a high portion of large-sized tubers. The TPS progeny Atzimba x DTO-28 produced 20 t/ha, but tuber size distribution of a crop from TPS transplants would be unfavorable for consumer potato production.

In a field trial during the San Ramon dry season, the following planting materials were compared: seed tubers, tubers from cuttings of three clones, seedling tubers, and TPS transplants of two progenies. All tuber planting material was

Table 3. Field performance of three types of planting materials grown under Lima summer conditions.

Treatment	Plant stand[a] (%)	Yield (t/ha)	Tuber number (no./m^2)	Proportion of large tubers (<3.5 cm) %
Cool-produced seed tubers				
Rosita	96.7	19.7 b*	63 b	69
LT-5	99.5	24.6 a	65 b	81
TPS transplants				
Atzimba x R128.6	70.5	14.0 c	75 b	50
Atzimba x DTO-28	89.6	20.0 b	139 a	36
Rooted cuttings				
Rosita	89.3	19.5 b	38 c	81
LT-5	93.1	17.9 b	35 c	89

[a] Observed at 18 days after planting or transplanting.
*Numbers in each column followed by different letters are significantly different at the 5% level.

Table 4. Effect of type and origin of planting materials on yield[a] under dry season conditions at San Ramon.

Type of planting material	Origin	Tuber no./ hill	Yield (g/hill)	$\frac{\text{Warm yield}}{\text{cool yield}} \times 100\%$
Seed tubers	Cool	7.1**	512***	
	Warm	5.4	287	56
Tubers from cuttings	Cool	6.7***	424***	
	Warm	4.5	300	71
Seedling tubers	Cool	8.6***	501***	
	Warm	5.9	354	71
TPS transplants	Warm	15.5	419	

[a] Data for seed tubers and tubers from cuttings are the means of three clones, and for seedling tubers and TPS transplants are the means of two progenies.
, * Significance between origins 1% and 0.1%, respectively.

derived from both a cool (Huancayo) and warm (Lima, summer) harvest. Regardless of the propagation system, tubers produced in a cool environment exhibited greater yields and tuber numbers than tubers from a warm environment (Table 4). The differences in yields from warm-origin seed tubers, tubers from cuttings, and seedling tubers were small despite differences in seed size between these three types of tuber materials (seed tubers 60 g; tubers from cuttings and seedling tubers 20-40 g). The origin effect on tuber yield was less drastic for tubers from cuttings or for

seedling tubers than for field-grown seed tubers. TPS transplants yielded well and proved to be an important alternative to overcome the negative effects of seed origin.

Seedling tubers and tubers from cuttings were produced in cool (Huancayo) and warm (Lima. summer, and San Ramon) environments. In terms of yield and multiplication rates, the following were found: 1) Yields of seedling tubers and tubers from cuttings (mean of 2 progenies or 3 clones, respectively) were similar within each production site, but were three times higher in Huancayo than under the warm conditions of Lima or San Ramon. 2) Tuber numbers from TPS were twice as high in the cool environment compared to the warm environment (about 720/m^2 vs. 400/m^2). Regardless of production site, tuber numbers from cuttings were generally low (150-250 tubers/m^2). Subsequently, the proportion of medium- and large-sized tubers was greater from cuttings than from TPS.

Unless tuber numbers can be increased, production from cuttings would be less appropriate for seed production and perhaps more useful for direct consumer production because of the greater proportion of large-sized tubers. In contrast, the large number of small-sized tubers produced by TPS would make production more useful for seed than for direct consumption.

In Vietnam, in the area near Ho Chi Minh City, research by the national program has shifted from seed tubers to the use of cuttings and in vitro plantlets for the production of small tubers for field planting. These are being grown from November to May in sequential plantings, and the harvested tubers are stored for the commercial crop planted in November. The cultivar B-71-240.2 appears to be particularly well-adapted as it tuberized even with high temperatures in May (day temperatures 30°-32° C; daylength 12.5 h).

In response to the high proportion of production costs for the potato in warm climates being attributed to high seed costs, CIP carried out a series of experiments to reduce seed costs. These experiments were run from November 1985 to March 1986 in the lowland tropics at Canlubang, Philippines (14°N, 150 m). Increasing the seed rate from 1 to 3 t/ha influenced growth due to increase in stem number and faster canopy cover. However, the rate of return (harvest weight per seed weight) was reduced from 16.2 to 7.5 as the seed rate increased. At seed rates of 1.5 to 2.5 t/ha, there was no significant difference in yield. The rate of return on small-sized tubers (13 g) was much greater (24 t/t of seed) than when larger-sized tubers were planted. This indicates the possibility of using very small seed such as TPS tubers or perhaps cut tubers. On this basis, experiments were made to test the effect of cutting seed as a means of increasing the multiplication rate. The treatments consisted of physiologically young tubers cut in halves or quarters and cured for five days with or without disinfectant and fungicide. Yields of cut seed were similar to those of whole seed (20-22 t/ha) at equal plant populations. Cutting and dipping tubers in chlor[illegible] prior to planting was detrimental to plant survival and therefore yields were reduced to 1[illegible] t/ha.

These results indicate that farmers who are prepared to give the care that cutting requires could reduce their seed rate to 600 to 700 kg/ha and halve their seed costs. The use of small tubers and cuttings as means of reducing costs associated with planting materials is another alternative currently being studied in lowland environments.

The use of cuttings in Southeast Asia is well established in rapid multiplication programs at research stations or in seed

programs. The development of cuttings as a technique to be used by farmers is receiving increasing interest and efforts.

In field trials carried out by CIP under lowland conditions in the Philippines, cuttings appeared to be a very promising planting material. Field performance of transplanted cuttings was superior to field-grown seed tubers produced under lowland conditions. The yields of TPS transplants for some of the 42 progenies tested at the Canlubang lowland-station (Philippines) were also quite promising; however, yields consisted mainly of small tubers. Suitable progenies for withstanding transplanting shock still need to be identified.

Successful techniques for Southeast Asian farmers to produce and use cuttings as planting material would be strongly dependent on location and circumstances. The lack of rustic, well-adapted genotypes appears to be a major limitation to production. Research carried out under tropical mid-elevation conditions at CIP's Sta. Lucia station (800 m) in the Philippines showed that yields from cuttings of 30 clones transplanted to the field at four different dates were variable, depending on temperature and daylength conditions. Cuttings transplanted in November-December yielded poorly due to early tuberization; whereas later transplantings gave better yields with an average of 12 t/ha (range 2.1-26 t/ha). Genotype by transplanting date interactions were apparent. Germplasm was also evaluated for seedling tuber production from cuttings in nursery beds. Apical shoot cuttings were used from mother plants established from in vitro plants in high density beds (400 plants/m^2). Out of 40 clones, 15 were found to be adapted for seedling tuber production, giving yields of up to 3.8 kg/m^2 and 165 tubers/m^2 (at 30-40 plants/m^2).

Results showed that the selection of suitable genotypes for the production of cuttings for field transplanting needs major emphasis. This is actually being done in many germplasm evaluation schemes in Southeast Asian countries.

On-farm CIP-SAPPRAD trials in the Philippines on the production of cuttings and subsequent transplanting indicated that improper mother plant management can be a constraint to farmer adoption of this technology. At the research station level, however, the problem of rapidly aging mother plants has been solved. Mother plants were maintained in a physiologically young vegetative stage for periods of six to nine months when photoperiods were artificially extended to 16-17 hours.

SCREENING AND SELECTION FOR HEAT AND OTHER TOLERANCES

The correct choice of a potato variety for use within cropping systems in the warm tropics is an important consideration and mention has already been made of the difficulties involved when tubers have to be stored and reused.

Our work in Peru has taken three different approaches: 1) laboratory screening for components of heat and other tolerances, 2) the population breeding approach in selection for heat tolerances, and 3) the screening of various sources of germplasm under field conditions.

Laboratory screening. This approach has been initiated to identify simple characters that are related to heat tolerance. Simple vegetative characters such as height, number, and length of internodes and leaf number were not useful in discriminating between heat-tolerant and non-heat-tolerant clones under high temperature conditions in growth chambers. Under cooler conditions, however, all the heat-tolerant clones were distinct in having

fewer internodes and bigger leaves. They were also shorter than the non-heat-tolerant clones. These features alone were not satisfactory for the identification of heat-tolerant clones. Cell membrane integrity, as measured by conductivity tests following diurnal periods of leaf exposure to 35°/22° C day/night regime, was not well related to known heat tolerances (the latter being based on tuber yield in the field). This result was in contrast to results from a different set of clones from the previous year. This may not be surprising as the term "heat tolerant" represents a combination of favorable characters, all (except for tuberization response) at a low level of expression and therefore not necessarily closely related to a specific characteristic. Another type of test involving seedling survival at high (50° C) temperatures for five or ten minutes has provided some promising results when the surviving seedlings were transplanted to the field in San Ramon. Yields of survivors were much greater than those of the nontreated plants. However, the definitive test with a planting of the resulting tubers still remains to be done.

In vitro tuberization should be more closely related to known heat tolerances but results have been inconclusive. Of the five clones tested under high-temperature dark conditions, three (DTO-33, Atzimba, and BR63.65), including one heat-tolerant clone, were not induced to tuberize; one (Des'.ée) was delayed and yielded much fewer tubers; and one (LT-2) exhibited lower tuber yield under high temperature, although the rate of tuber initiation was not affected. Another experiment was set up to explore the possibility of identifying heat-tolerant clones on the basis of fast rates of callus growth of undifferentiated cells on culture medium. Clone LT-7 was outstanding in this character (Table 5), and work continues on evaluating the methodology.

Tolerance to salt, whether in irrigation water or the soil, is of increasing importance in certain warm potato-growing areas, particularly in desert climates. Initially, studies have focused on assessment of TPS and seedling responses to increasing NaCl levels, and on in vitro methods for evaluating clonal response. The following are the salient results: 1) 6000 ppm of NaCl was the optimal concentration to effect notable reductions in percent germination and root length (7 days after planting), 2) the progenies India 931 x Katahdin and Atzimba x R128.6 were most tolerant to high NaCl with respect to percent germination and root length, and 3) growth response of in vitro cultured cut-

Table 5. Effect of high temperature on relative increase in fresh weight of callus in the dark after 25 days.

Cultivar	Control[a] (% increment)	Treatment[b] (% increment)	Damage[c] coefficient
LT-7	128.1 + 8.5	147.3 + 113.8	−15
Atzimba	533.6 + 53.6	350.0 + 56.4	34
DTO-2	181.3 + 34.7	109.1 + 19.3	40
DTO-33	173.0 + 46.3	100.8 + 36.4	42

[a] Temperature = 18° C continuous.
[b] Temperature = 30°/22° C day/night.
[c] Damage coefficient = (1 - b/a) x 100.

tings under high (9000 ppm) NaCl concentrations was reduced in all clones tested. Two of the eight clones (BR69.84 and Desirée) showed a greater shoot production and less damage for other traits quantified, and DTO-33 and P-3 were intermediate in response. The trait most affected in all clones was the fresh root weight. Water content in the two most tolerant clones was greater than that of the other clones, suggesting that they might adjust their internal osmotic status in the presence of high salt concentrations.

Population breeding. Yurimaguas and San Ramon continue to be the sites in which preliminary selection for adaptation to heat and associated stresses in the field is made. During the rainy season at Yurimaguas (Dec.-Feb.), several third generation clones (C84.126, C84.129, C84.299) were selected in the presence of excess rainfall; however, during the dry season the rate of selection increased to 11% in third and fourth generation clones. The constant presence of the clones LT-7, 378015.16, and bulked pollen of the family 378015 was evident in the pedigrees of clones selected at Yurimaguas. At San Ramon, during the 1986 dry season (June-August), the same set of clones was tested as in Yurimaguas, and clones C84.617 and C84.550 were outstanding at both sites. Two clones, C84.617 and C84.652, are in the process of multiplication for larger scale testing and probable release to the CIP seed program for cleanup and distribution. A new clone, 379706.34, with heat tolerance, earliness, and immunity to potato viruses X and Y has been introduced to the seed program under the code name LT-9.

Germplasm screening under field conditions. Over the past two years, screening of clones listed on CIP's pathogen-tested list has been done during the dry seasons at San Ramon. Their yield performance has been compared against that of some standard control clones (LT-5, DTO-28, DTO-33, and Desirée). Although no clones exceeded yields (1200-1430 g/m^2) of the best control 80 days after planting, some clones harvested 12 days later exceeded the control yields (e.g., B-71-240.2, CEW-69-1, Saturna, AGG-69-1, Atlantic, and Pirola yielded 1470-2140 g/m^2). Other clones that matured beyond 100 days after planting also outyielded the control clones, but were considered too late for existing cropping systems in warm climates. There was a general trend for early maturing clones to convert intercepted radiation more efficiently to tuber dry matter than later clones. This was probably due to their more efficient partitioning of dry matter to tubers.

Evaluations of germplasm were made at three sites representing the warm coastal climate of Kenya where crops are rainfed but where rainfall can be very erratic. Clones 378017.2 (LT-7), 720109 (Santo Amor), and 800938 (AVRDC-1287.19), and cultivars Desirée and Atlantic were the most promising. For closer supervision of this work, all future screening will be carried out at the warm-climate Shimba Hills station (400 m) where there is potential for supplementary irrigation.

In Senegal, previously selected clones and newer materials from CIP were grown at the Center for Horticultural Development (CDH) for evaluation of heat tolerance. Clones grown in 1985 were stored in either DLS or cool storage and their subsequent performance was compared with that of standard cultivars such as Desirée. The planting date was early October 1985 when summer day temperatures reached 35° C. Comparisons were made on 40-hill plots with no replications. The overriding factor affecting yields was the seed tuber storage method, since the yield per plant from cold-stored seed

was nearly double the yield from seed stored in DLS. No clones exceeded Desirée in yield performance. Among the newly introduced clones from CIP (planted in mid-October), LT-7 and I-1124 gave excellent yields of over 500 g/plant, and several others also outperformed the standard varieties.

Potato planting in the Dhaka area of Bangladesh is concentrated at the beginning of the short winter season from late November to mid-December. The combination of mulch at planting to reduce high soil temperatures and the correct choice of heat-tolerant clones has permitted a six-week earlier-than-usual planting in this area. For clones planted in early October and harvested 65 days later, the maximum yields were above 18 t/ha for three clones (DTO-33, AVRDC 1282-17, and 1282-19) with mulch, but without mulch, yields did not exceed 15 t/ha. In addition to the benefit of a high price for consumer potatoes at harvest, the farmer can then plant vacated land to wheat or maize. Thus, when early plantings are possible, two crops may be grown during the winter months, when traditionally only one of the two crops could be grown. To extend the harvest beyond the traditional period of mid-February to mid-March, a late planting was made in mid-December with genotypes and mulch treatment similar to those of the experiments on early planting. Mulch did not improve yields (plots were irrigated); however, yields of various clones exceeded 25 t/ha without the cracking observed in the cultivar Cardinal in the same experiment.

TRAINING

Much of the success in the introduction of potato to warm climates has been due to the effort placed on training of competent national scientists. In March 1986, a high level training course held in the Philippines, sponsored by CIP, PCARRD and the Southeast Asian country network SAPPRAD, gave specialized training in production techniques for potato in warm climates, with emphasis on intercropping practices and sources of alternative planting materials. The coordination of the transfer of lowland tropical agronomy to farmers in Southeast Asia is through the SAPPRAD network. For example, in Indonesia, SAPPRAD is training farmers by means of on-farm trials, which include the best cultivars, use of mulch, irrigation, and fertility levels. In the Pacific Islands, a CIP regional potato production course held in New Caledonia has had encouraging results in a number of countries including Fiji and Vanuatu, where several farmers were able to store their own seed and plant it off-season to benefit from higher market prices at harvest.

THRUST VII

Cool Climate Potato and Sweet Potato Production

Further emphasis was placed on developing the breeding population with genetic tolerance to frost for the non-Andean region. In Peru, early maturing clones immune to potato viruses X and Y were crossed to selected frost-tolerant clones and provided segregating progenies that were screened initially for frost tolerance. Testing the frost-resistant population for adaptability to long days was continued in Chile in the greenhouse and field in collaboration with the National Agricultural Research Institute (INIA). Further testing of selected clones from the highland tropical population, introduced earlier to Chile, has shown higher yields than those of local cultivars. Collaborative work with the Colombian Agricultural Institute (ICA) has reported several clones in the final stages of testing for frost tolerance.

The search for clones efficient in their use of nitrogen (N) indicated a variety of responses. There was a general tendency in most of the clones that yielded well under low levels of N not to increase their yields after an additional supply of N. Pot experiments in the greenhouse to identify clones efficient in N uptake did not give results similar to those of field experiments.

Harvest of clones being tested for frost tolerance at 3800 meters (Usibamba, Peru).

BREEDING FOR FROST TOLERANCE

Seedling and clonal testing. In Peru, further emphasis was given to the development of the population for the tropical and subtropical non-Andean region. This population should combine frost tolerance with earliness and compete with *tuberosum* cultivars widely grown as local varieties throughout this area of the world. Additional traits that are also being introduced are immunity to potato viruses X and Y (PVX, PVY).

During 1986, a sample of 36,000 seedlings, grouped into 200 families from crosses between advanced sources of frost tolerance and selected early maturing clones immune to PVY and PVX, was screened in a walk-in growth chamber at −4° C for two hours with a survival rate of 30.6% (Fig. 1). One week after exposure to frost shock in the growth chamber, the surviving seedlings (11,154) were transplanted to the field in Huancayo. At harvest, single-hill selections were carried out for qualitative traits such as tuber shape, number, color, and uniformity. A total of 981 clones were selected and await further testing for frost tolerance under field conditions at Usibamba (3800 m).

Advanced clones from the Andean and non-Andean breeding populations were tested for frost tolerance and yield potential in nonreplicated and replicated trials in Usibamba and Huancayo. The incidence of frost was not severe enough to affect the clonal material; therefore agronomic selection was the primary activity. In Usibamba, 358 clones were selected from ten-hill observation plots and 470 were selected in Huancayo. In collaboration with the Peruvian national potato program of INIPA, duplicate samples were sent to INIPA's experiment station in Puno (3850 m, southern Peru) for frost testing and selection in the field; however, all samples were lost in a flood that struck

Figure 1. Seven-week-old seedlings screened for frost tolerance in a growth chamber (−4°C). *Left:* CIP hybrid progenies showing frost tolerance. *Right:* progeny of the local variety Renacimiento.

over 70% of the farmland in the province.

Two randomized complete block designs (RCB) and two lattices of 10 x 10 were used to test clones of different stages of selection in both Usibamba and Huancayo. Results from the RCBs indicated yields up to 2.2 kg/plant with a plant density of 37,037 plants/ha in Usibamba; and 1.8 kg/plant, and 44,444 plants/ha in Huancayo (Figs. 2, 3). The overall yield

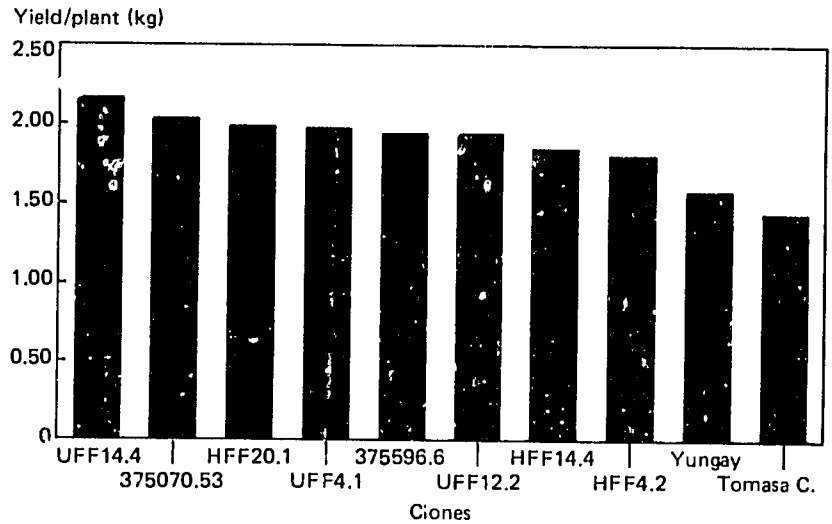


Figure 2. Tuber yield performance of the best eight clones selected for frost resistance as compared to yields of two local cultivars (Yungay and Tomasa Condemayta). Usibamba, Peru (3800 m).

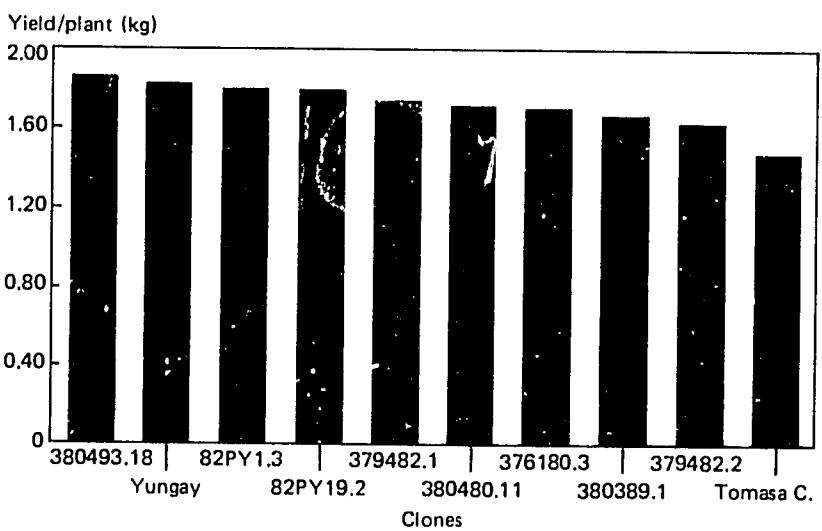


Figure 3. Tuber yield performance of the best nine clones under a nonfrost environment as compared to yields of two local cultivars (Yungay and Tomasa Condemayta). Huancayo, Peru (3200 m).

averages in both localities were 1.6 kg/plant for Usibamba and 1.4 kg/plant for Huancayo. Likewise, the overall yield performance of a new set of clones tested in a lattice 10 x 10 in Huancayo averaged more than 1.0 kg/plant, the highest yields being more than 2.0 kg/plant.

During the process of testing and selecting for frost tolerance in combination with earliness and other desirable agronomic attributes in the non-Andean population, the yield potential is being enhanced in the advanced selections. These selections will eventually be used as parental material for further intercrossing, or crossing to other advanced sources of disease resistances important in cool environments. Crosses with these selections will also provide segregating material for distribution to regional centers of germplasm redistribution and country programs. Some of these clones will also become available for use as advanced clones for variety selection in national programs.

Progenies were tested in Colombia with frost resistance derived from *Solanum acaule*, *S. ajanhuiri*, and *S. curtilobum*. As part of a collaborative effort with the national potato program of ICA, a group of 100 clones selected previously were planted at the San Jorge test site in October 1986, where frosts normally occur during December and January.

A second group of 3000 seeds of hybrids of *S. phureja*, crossed with wild species and back-crossed to commercial varieties and advanced clones, was grown in a greenhouse during 1986 and transplanted to the field in November for assessment of frost resistance. Results of this and the previous test will be reported in 1987.

Ten clones (3 CIP and 7 ICA) selected for frost resistance in previous years are now in their final stages of testing. They also have excellent yields and good cooking quality. One of these, clone 379055.1 with frost resistance derived from *S. curtilobum* and *S. ajanhuiri* and with Mexican late blight resistant clones in its genetic background, is now being tested in ICA's regional trials.

Adaptability of the frost-resistant population to a wider range of environments. In our approach to widen the adaptability of the frost-resistant population for the non-Andean region, a new sample of this population was sent to southern Chile (Osorno, lat. 40°S) to be tested for performance under natural long daylengths. This project was carried out in collaboration with the national potato program of INIA. The sample, consisting of 252 clones grouped in 16 families, was subjected to a new methodology of screening potato plants for long-day performance by using natural short days, supplemented with artificial light to simulate long days from planting to harvest. Preliminary 1986 results on tuberization response in the greenhouse will be used in an attempt to establish a correlation with field performance under natural long days. Field data will be available in 1987.

Additional information has been produced by the national program on the use of selected clones from the highland tropic population introduced earlier to test for adaptation to long days. This indicated, for the second consecutive year, the higher yield performance of selected clones over locally grown varieties. The average marketable and total tuber yields (t/ha) for the two growing seasons are consistently higher than for those of the controls (Table 1).

AGRONOMIC AND PHYSIOLOGICAL STUDIES

Screening for efficient use of nitrogen fertilizer. Further evaluation of a sample

of CIP clones and local varieties from 1985 experiments was run in the field at Huancayo to continue the search for potato varieties efficient in their use of nitrogen (N). A split plot design was used with two levels of N (90 and 180 kg/ha) to study their effect on 64 different clones. Of the clones tested, 14 were chosen from the previous season's trial as representatives of the four types of response observed: 1) high yield in low N and high response to added N; 2) high yield and low response to added N; 3) low yield and high response; and 4) low yield and low or negative response. As in the previous year, the general tendency was for high yielding clones under low N not to respond to additional N. A number of exceptions existed, however, and 10 of the 14 clones or varieties from the previous season maintained their previous classification with respect to response to additional N (Table 2). This group exhibited a close correlation in yielding ability over both years under low N ($r = 0.544^*$). The slope and y axis intercept of the inverse relationship between yield increase due to N and tuber yield under low N were both less in the 1986 than the 1985 season ($y = 25.36 - 0.0031x$ and vs. $y = 89.90 - 0.0106x$ where $y = \%$ increase due to additional N and x = fresh tuber yield in kg/m^2). The smaller intercept and slope in the 1986 season suggests a greater supply of N through mineralization in the field for that season.

The present results indicate some promise in the field plot methodology in screening for efficient use of N fertilizer, with only two levels of N. It may be necessary in the future, however, to evaluate clonal response under a range of N treatments, given that clones of a different maturity class may vary drastically in their optimum N requirement. Further studies are in progress to resolve this question.

Table 1. Yield performance of a sample of selected clones previously introduced for long-day adaptation in Osorno, Chile (lat. 40° S).[a]

	Yield (t/ha)					
	1985		1986		Average (t/ha)	
CIP no.	Marketable	Total	Marketable	Total	Marketable	Total
381079.41	77.6	78.8	71.2	74.0	74.4	76.4
381132.21	69.7	71.1	75.6	77.4	72.7	74.3
381114.202	69.4	70.7	75.2	75.5	72.3	73.1
381135.3	67.3	70.3	50.4	51.5	58.9	60.9
381132.63	64.9	70.3	61.9	65.5	63.4	67.9
381132.200	63.7	65.1	71.2	71.6	67.5	68.4
380554.125	61.3	62.2	58.9	61.9	60.1	62.1
381118.261	49.6	52.1	63.3	65.9	56.5	59.0
Controls						
Mirka	46.8	49.3	46.7	48.9	46.8	49.1
Yagana	42.7	44.4	52.2	55.3	47.5	49.9
Ultimus	41.2	44.4	59.0	64.1	50.1	54.3
Desirée	40.2	41.2	32.6	33.0	36.4	37.1
CV (%)	15.2		16.9			

[a] Data from INIA, Chile.

Table 2. Tuber yields and percent increase or decrease in yields due to additional nitrogen (N) for 14 genotypes tested during two different seasons.

	1986		1985	
Clone/variety	Yield under low N (kg/m^2)	% Increase + N	Yield under low N (kg/m^2)	% Increase + N
374080.5	5.92	28	4.52	14
377924.1	4.58	18	4.59	64
378143.5	2.41	−30	3.33	−44
379454.1	5.03	39	3.63	95
380437.3	7.61	−10	6.82	14
380473.6	4.22	0	2.37	88
UPP86-1	6.33	−27	5.59	52
UPP95-4	6.36	−16	7.59	−18
UPP100-3	5.59	12	7.02	−33
UFP47-2	5.83	35	4.48	92
Revolución	7.21	8	4.49	18
Tomasa Condemayta	5.45	18	6.78	14
Mariva	8.50	−21	5.57	18
Yungay	7.38	22	5.65	15

In another experiment carried out in the central highlands of Peru, seven native varieties and nine selected hybrids were studied with respect to their efficiencies in N fertilizer use in both pot and field experiments. In pot experiments, nutrient solutions that differed in N concentration (low = 40 mM, and high = 120 mM)

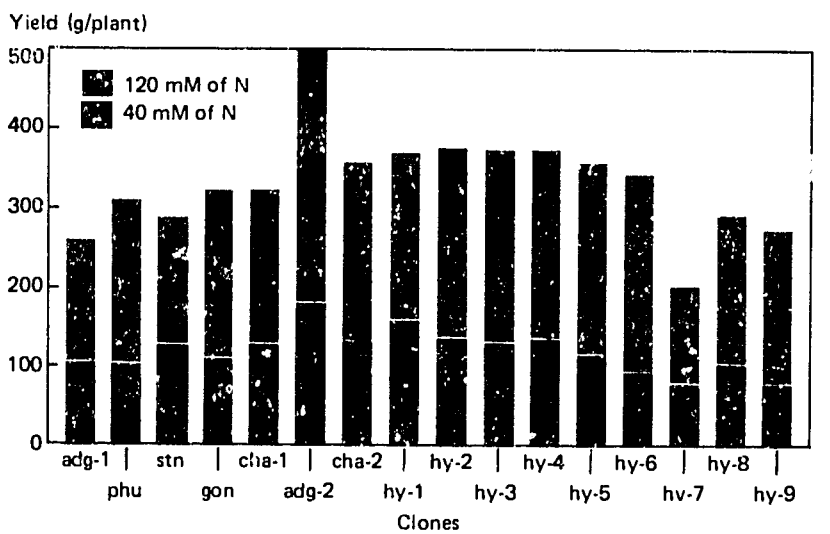


Figure 4. Tuber yield response to two levels of nitrogen supplied as nutrient solution in a pot experiment, Huancayo, Peru.

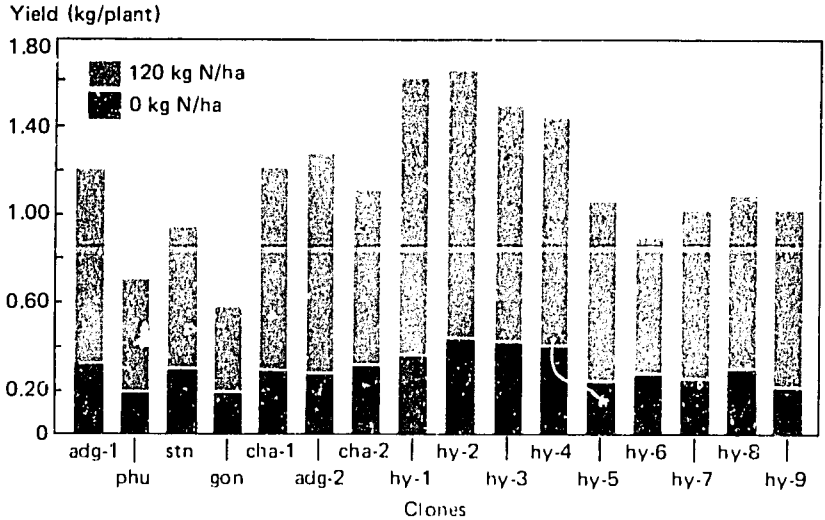


Figure 5. Tuber yield response to two levels of nitrogen in the field, Huancayo.

were supplied to potato plants during the entire growing period. In field experiments, no N and 120 kg of N/ha were used on the same genotypes in Huancayo and Tarma.

The results indicated a differential positive response to added N in both sets of experiments (Figs. 4, 5), but it seems that the pot response to added N did not follow the same trend as the field response. Therefore, the pot experiment may not be a suitable substitute for field experiments. It is noteworthy that there were dramatic responses of most genotypes to added N in Huancayo, where N content in the soil was rather poor compared to that in Tarma. The low response to the fertilizer N obtained in Tarma may have been due to a high level of soil fertility, particularly the N content. Further studies on identification of clones highly efficient in their use of N will be conducted entirely in the field.

Agronomic control of late blight. In Burundi, the national potato program of ISABU tested four possible treatments for controlling late blight: 1) unsprayed control (farmer practice); 2) Mancozeb every seven days, starting three weeks after emergence; 3) same as for (2) but followed by Ridomil when blight attack reached 10% foliar damage; and 4) Ridomil only, when 10% damage observed. The results showed that the latter treatment was considered the most feasible method for farmer adoption, and treatment (3) followed by (4) gave the best yields. There was a significant variety x treatment interaction in which the most blight-susceptible varieties derived the greatest benefit from the fungicides.

THRUST VIII

Postharvest Technology

Research has continued to focus on storage of consumer potatoes, storage of seed potatoes, and low-cost processing. Fifty clones were evaluated for storability as seed and as consumer potatoes. Different evaluation methods are being studied. Research on the storage of consumer potatoes in warm areas has given promising results. Newly constructed storage facilities in San Ramon will be used to integrate all available storage technologies including low-cost cooling systems, control of tuber moth (PTM), control of tuber soft-rots, and control of sprouting. Control of PTM by chemicals or dried insect-repellent foliage combined with the prestorage dusting of tubers with calcium sulphate significantly reduced tuber rotting.

Research on seed tubers concentrated on storage behavior and subsequent field performance of small seed tubers, derived from true potato seed (TPS) or obtained through rapid multiplication techniques, at elevated temperatures. Results showed that small seed tubers in comparison with larger tubers gave little reduction in yield potential despite proportionally high weight losses during storage in diffused light at high ambient temperatures. Also, storage management of small seed tubers related to desprouting and physiological degeneration was studied. Another study showed that the tuber-to-tuber variability in storage behavior in seedling tubers was generally not greater than that observed in similarly sized clonal tubers. This means that possible differences in variability in plant growth observed between clonal tubers and seedling tubers are not likely to result from differences in variability in storage behavior.

Low-cost processing of potatoes into dehydrated products, using solar energy, is now being evaluated in Peru, Kenya, India, and Bangladesh. A cheap, simple method to produce dehydrated French fries has been developed in Peru and the product is being consumer-tested. An anthropological study of household potato processing technologies has been carried out in the Andean Region.

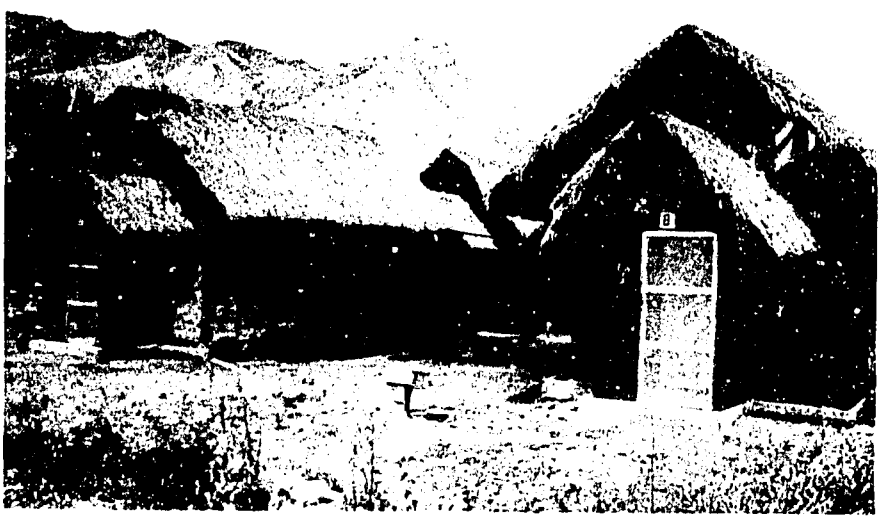
Drying mashed potatoes at the household level to prepare potato-based food mixes.

STORAGE OF CONSUMER POTATOES

Peru. Research has continued to focus on methods to reduce storage losses of consumer potatoes in warm areas. At the experimental station in San Ramon, the construction of four experimental units for storage of consumer potatoes was completed. The walls of these structures consist of either white stones or charcoal, kept in place by chicken wire. A pipe with holes at every 2-3 cm allows water to trickle on the wall, resulting in a large moist surface for evaporative cooling. At an average ambient relative humidity of 78%, the humidified walls reduced the mean daily maximum temperature in the store through evaporative cooling from 26° to 23° C. Total tuber weight loss during a four-month storage period was reduced from 13% to 10%.

Each of the four experimental stores is subdivided into ten units with a storage capacity of 500 kg each. These stores will be used to test all available storage technologies. Methods to control potato tuber moth (PTM), soft-rots, and sprouting will be integrated with technologies on store design and low-cost cooling systems.

East Africa. Storage trials were conducted in collaboration with national scientists on the coast of Kenya to test the feasibility of storing consumer potatoes in a warm climate. The main treatments consisted of bulk potatoes ventilated at different times; one store was ventilated only during the night. In another treatment, potatoes were treated with IPC sprout suppressant in a ventilated basket similar to the ones farmers use for storage. All types of stores were loaded in September 1985 and monitored for 98 days. The treatment with the least total weight loss in tubers (16%) was recorded for the night-time ventilated store. Other treatments had losses ranging from 23% and 27%, the greater part of which was due to moisture loss from tubers. Storage temperature means were 25.6° to 26.7° C



CIP low-cost experimental stores for consumer potatoes in San Ramon, Peru. Evaporative cooling of the walls (white stones or charcoal) is carried out by means of a simple water-trickle system.

with a mean ambient temperature of 27.7° C. In the next trial, a passive evaporative-type cooler will be fitted to a night-time ventilated store to see if the apparent benefit of controlled ventilation can be increased. For a length of time shorter than 98 days, storage losses of less than 10% seem possible. Although sprout suppression was not apparently effective in these storage trials, other evidence suggests that IPC can be helpful and future trials will continue to include one treatment with this chemical.

North Africa. In North Africa, storage of consumer potatoes without using expensive cold storage facilities during the four months of the hot and dry summer period would be economical, provided that excessive sprouting and attack by PTM could be efficiently controlled in traditional stores. To achieve this, experiments jointly supervised by CIP and national scientists were carried out in Tunisia. In an integrated approach, the following components and combinations of components were tested: sprout-inhibitors such as IPC or IPC+CIPC (commercial name "Germex"), covering the potato pile to reduce evaporation of the active chemicals of the sprout inhibitors, insecticides for PTM control, and height of the potato pile.

In all experiments the farmers' traditional storage technique was used, which consisted of storing potatoes under a shelter in piles (1-1.2 m high) covered with a layer of straw. Experiments were set up in early July (after a prestorage period for tuber curing) and were terminated at the end of October when the first freshly harvested potatoes from the late season crop reach the market.

The percentage of sprouted tubers at the end of the storage period was significantly less when potatoes were dusted with sprout inhibitors and covered with paper in addition to the usual straw cover (48% vs. 83% for the control). Total storage losses (in weight) with sprout inhibitors plus paper cover were 9.2% versus 14.5% for the control treatment. Sprout inhibitors alone did not reduce sprouting and resulted in a similar total weight loss in tubers as in the untreated control. When potatoes dusted with sprout inhibitors were covered with plastic sheeting (impermeable to moisture), losses caused by tuber rot were severe.

Sprout inhibitors significantly reduced the percentage of PTM-attacked tubers and the percentage of rotten tubers compared to that of the untreated control (PTM 42% vs. 94.7%; rotten tubers 3.3% vs. 17.3%). Application of K-Othrine (pyrethroid in powder form) brought the percentage of PTM-damaged tubers and the percentage of rotten tubers down further to acceptable levels of 12.7-15.7% and 0-1.7%, respectively. At the end of a four-month storage period, approximately 88 kg out of 100 kg of potatoes initially put into storage were marketable.

It can be concluded that consumer potatoes can be stored in traditional dark stores if the following factors are integrated; application of sprout inhibitors, covering potatoes with a material sufficiently permeable to moisture, application of insecticides for PTM control, and storing potatoes in piles not higher than one meter.

South Asia. Storage of consumer potatoes without refrigeration in hot tropical climates has always been a serious problem. In Bangladesh, a two to three-month storage period is all that is required to give a longer period for marketing the crop. Based on previous research by the Bangladesh Agricultural Research Institute (BARI), three locations were chosen to demonstrate to farmers a simple technique for storing small quantities (200 kg)

of consumer potatoes. Simple stores of bamboo were constructed with inside walls plastered and ventilation through the bottom from access holes on two sides. Hollow bamboo tubes (12 cm diameter) perforated with holes to serve as chimneys were installed in the stores to remove heat generated by the potatoes. Storage up to 90 days is feasible in this type of store and losses due to tuber rot and weight loss were negligible for both Cardinal and Patrones. The storage period, when combined with the use of CIPC sprout suppressant, could easily be extended to 120 days. For periods longer than 120 days, weight losses increase considerably and the method of storage is no longer economical.

In Calcutta, an underground store covered with a thatched roof was constructed by a farmers' group at Mandra in which consumer potatoes, harvested in March 1986, were stored in bulk. Weight losses were recorded after 60 days and varied according to the variety between 6% and 12%. However, during the time when the tubers were placed in storage in March and removed two months later, consumer potato prices increased by 50%. At Bareilly, a rustic store of ten-ton capacity was designed with the Society for Development of Appropriate Technology to store potatoes for the village-level potato processing unit. This store has passive-type evaporative cooling and will be used to record detailed temperature and humidity data.

STORAGE OF SEED TUBERS

Latin America. Research in Peru has continued to concentrate on the storage behavior and subsequent field performance of small seed tubers, such as first generation tubers from true potato seed (TPS) and clonal tubers obtained by rapid multiplication techniques. The performance of small seed tubers was compared with that of larger seed tubers in a study involving six grades of tuber size, ranging from 2.5-g to 80-g. Tubers were stored for 5.5 months in a cold store at 4° C and also at ambient temperatures (17° - 29° C) in a natural diffused-light store (DLS). The tubers for all treatments were subsequently planted in Lima and San Ramon.

Results showed that the tuber dormant period varied with cultivars and storage environments and was always longer in small tubers than in 80-g tubers. The effect of storage conditions on sprout length, number of sprouts per tuber, plant emergence, number of stems, and ground cover by foliage was similar in small tubers to that observed in 80-g tubers. Weight loss in the 2.5-g tubers was more than twice that of the 80-g tubers in both storage environments (Table 1). There was a significant interaction between seed tuber size and storage environment for tuber yield (Table 2). Large tubers stored at high temperature in DLS yielded less than those stored at 4° C. The small 2.5-g and 5-g

Table 1. Effect of seed tuber weight on tuber weight loss (%) in two storage environments (mean of two cultivars), Peru.

Tuber weight (g)	Storage environment	
	4°C	Diffused-light
80	8	15
40	8	15
20	9	18
10	12	22
5	13	25
2.5	17	33
Mean	11	21

LSD 0.05 Tuber weight = 1.6.
LSD 0.05 Storage environment = 3.4.

Table 2. Effect of seed tuber weight on tuber yield (g/plant) at mature harvest after storage in two different environments (mean of two cultivars and two planting locations), Peru.

Tuber weight (g)	Storage environment	
	4°C	Diffused-light
80	1128	1072
40	1094	911
20	959	825
10	902	686
5	711	729
2.5	609	632
Mean	901	809

LSD 0.05 Tuber weight x storage environment = 64.

tubers, on the other hand, yielded more when stored in diffused light. This favorable yield response of small tubers to high storage temperature was due to adequate ground cover by foliage, which in turn resulted from optimum sprout development at planting. A pre-sprouting period of two weeks after storage at 4° C appears to be too short to permit adequate sprout development in small seed tubers during storage at elevated temperatures, these tubers can be stored successfully in DLS at high ambient temperatures.

Experiments on desprouting of tubers stored in DLS were carried out to study whether or not the performance of clones with a tendency to apical dominance could be improved. Six grades of tuber size, ranging from 2.5-g to 80-g, were stored during the hot summer in Lima, and in those that were not desprouted, sprout number increased little with increasing storage period. Desprouting considerably increased sprout number in all tuber sizes and at all storage intervals (Table 3). The effect of desprouting on sprout number was greater in larger tubers due to the greater number of eyes per tuber. Observations also showed that desprouting should be done before sprouts become too old, in order to avoid tuber wounding and subsequent dehydration.

The pattern of physiological degeneration of small seed tubers was studied during prolonged storage in DLS at ambient temperatures, during the summer in Lima. Tubers were subjected to a standard sprouting test at regular intervals to measure decline in seed tuber vigor. The decline in sprouting capacity, expressed as a percentage of the maximum sprouting capacity observed during the entire storage period, was similar in all tuber sizes. It is concluded that in spite of considerable weight loss in small tubers, they maintain acceptable vigor during storage in DLS at elevated temperatures.

The tuber-to-tuber variability in storage behavior of seedling tubers was compared with that occurring in clonal seed tubers, after storage in the dark, in DLS, or in DLS with one desprouting two months before planting. The variability was estimated by calculating standard deviations of length, number and weight of sprouts, and tuber weight loss. After dark storage,

Table 3. Increase (%) in sprout number per tuber as a result of desprouting, at different intervals during storage in diffused light at ambient temperature (mean of two cultivars), Peru.

Tuber weight (g)	Time from beginning of sprout growth			
	4 wk	8 wk	12 wk	16 wk
2.5	27	27	36	54
5	54	54	90	81
10	100	100	145	136
20	191	130	175	153
40	214	180	193	141
80	210	205	232	100

the variability of these storage variables was greater in seedling tubers than in clonal seed tubers (Fig. 1). After storage in DLS with one desprouting, the variability of number, length, and weight of sprouts observed in seedling tubers was not statistically different from that observed in clonal seed tubers. All storage treatments showed a greater variability of tuber weight loss in seedling tubers than in clonal

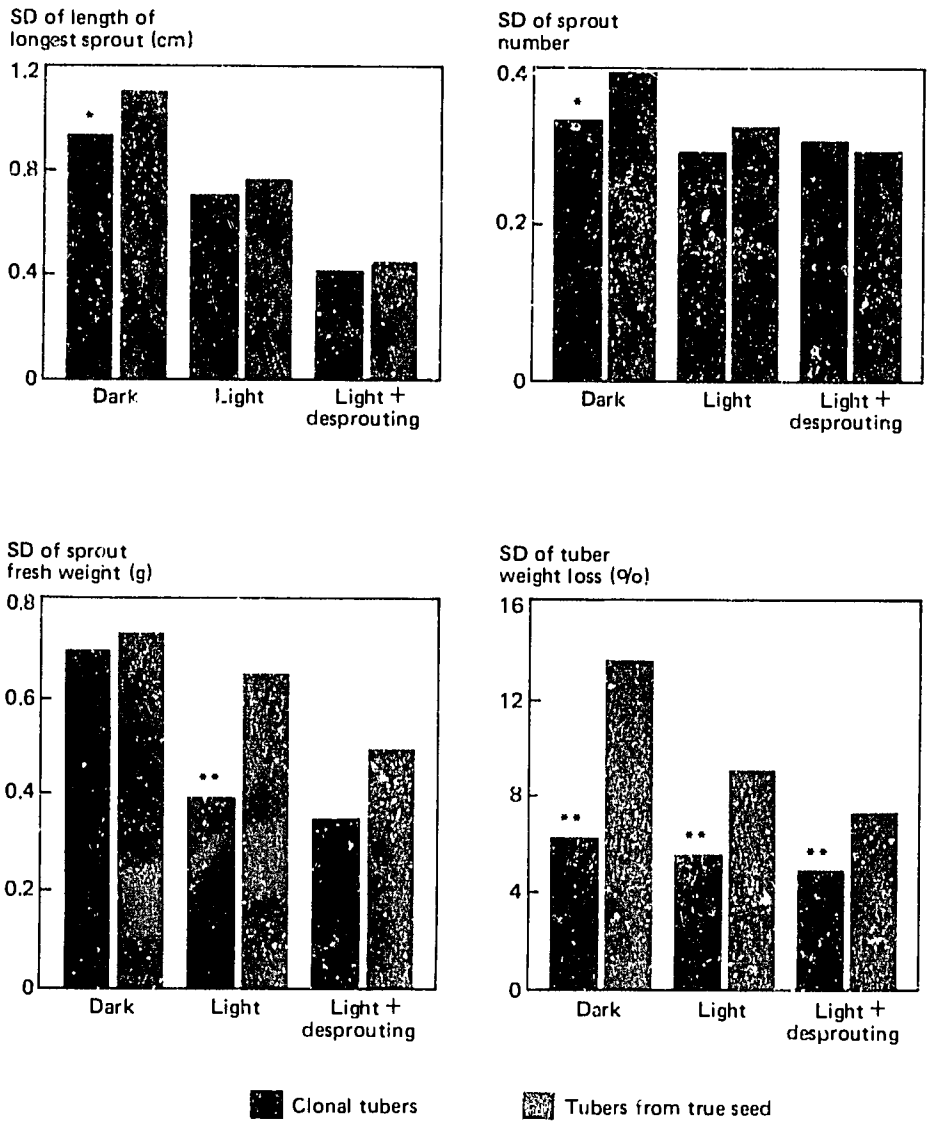


Figure 1. Tuber-to-tuber variability (standard deviation = SD) of length, number, and weight of sprouts and tuber weight loss in clonal tubers and tubers from true seed, compared within each of three storage conditions (SD sprout number based on square root transformation). ** = $P < 0.01$; * = $P < 0.05$; no indication = not significant.

tubers. Therefore, it is concluded that possible differences in variability in plant growth observed between the two types of seed tubers are not likely to result from differences in storage behavior.

In Chile, four experiments were performed at Osorno in collaboration with the National Agricultural Research Institute (INIA) to confirm previous results on the use of DLS, cut seed tubers, and different planting dates on the yield of variety Kennebec. At planting time, the seed tubers were seven months old and their physiological condition was excellent. There was no significant difference between the yield from seed tubers stored in DLS and that of seed stored in the dark. There was a clear advantage in planting whole seed tubers compared with cut seed, as the number of stems per unit land area was much greater with the whole seed tubers. As expected, the yield of the first crop planted in October was significantly better than later plantings. The results from several years of trials have been consistent and this research has now been concluded.

A new project in Brazil to compare storage of seed tubers in DLS and cold store was initiated in September 1986 at the National Center of Horticultural Research (CNPH). The tubers will be planted after six months of storage and evaluated.

Tropical Africa. In Burundi, the national potato program of ISABU has carried out three types of activities related to storage: 1) to record the length of dormancy of advanced clones; 2) to give advice to seed multiplication projects on appropriate methods of storage and seed distribution; and 3) to refine simple methods of dormancy breaking at the farm level.

In the first activity, nine varieties and clones harvested from a trial at Gisozi were stored in DLS and measurements were taken weekly of the growth of the apical sprout until it reached 3 mm. There were considerable differences in the length of dormancy of the varieties and clones used (Table 4). These different genotypes can be used effectively to fit the various cropping systems in Burundi, some where potatoes are planted almost continuously, and others where there is a long storage period between harvest and planting the next crop.

In the second activity, regular visits were made to all major seed production projects to advise on production, storage, and distribution. In addition, several low-cost stores for demonstration purposes are being constructed. The design falls between a truly rustic construction (storage costs less than US$0.01/kg/season) and an expensive all-concrete structure (US$0.07/kg/season).

For the third activity, the treatment reported previously (*Ann. Rep. 1984*) to break dormancy by using heat shock treatment above a fire in a hut was studied in combination with a period of pit storage. Twenty to 30 days in the hut with

Table 4. Length of dormancy of different genotypes adapted to Burundi conditions.

Genotype	Length of dormancy[a] (days)
Ndinamagara (720118)	33
Montsama (720049)	54
Kenya Baraka	64
Muruta (380506.10)	89
720088	89
Sangema (800849)	93
Kinigi (378699.2)	93
Muziranzara (378711.5)	103
Uganda II (720097)	131

[a]Dormancy is estimated as time taken from harvest until principal sprout attains 3 mm.

temperatures fluctuating from 8° to 47° C, followed by 20 days buried in a pit, was an efficient treatment to break dormancy in less than two months, and permitted seed tubers harvested in January to be planted in February or March. This method was not as effective for breaking the dormancy of tubers harvested in July because ambient temperatures were generally lower and dormancy lasted longer. Extra heat might be required to break dormancy in these circumstances.

Seven on-farm trials were set up to compare the traditional method of storing seed tubers in a dark room with the heat-shock treatment used to break dormancy. Tubers were heat-treated immediately after the January 1986 harvest and replanted in March. Data taken of sprout number, sprout length, and number of stems showed little difference between the two treatments; however, tubers given the heat-shock treatment yielded 440 g/plant compared with 366 g/plant when tubers were stored in a darkened room.

North Africa. In Egypt, the traditional *nawalla* storage method for seed tubers was further improved by the use of screens as a mechanical barrier for PTM (PTM damage with screens <10%; without screens 30-50%). This improved technique is now being transferred to farmers.

In Senegal, three storage methods (cold store, bag, DLS) were compared to assess losses in storage and subsequent field performance of the seed. Five cultivars (Premier, Desirée, Escort, Gigant, and Claustar) were stored for five months during which time ambient temperatures reached over 40° C in September. Storage losses in bags were not much higher than those in DLS and the tubers were in good condition after three months. Only cultivars Claustar and Desirée gave satisfactory results, especially the latter which stored well in diffused light.

EVALUATION OF CLONES AND VARIETIES

Fifty advanced clones were evaluated for storability as seed tubers and as consumer potatoes. Clones showed considerable differences in length of dormancy, incubation period (the time between tuber initiation in the field and sprouting during dark storage at ±18° C), rate of sprout-growth, number, length, and weight of sprouts, and tuber weight loss. The merits of different methods to evaluate the storability of both seed and consumer potatoes are being evaluated.

In Bangladesh, where it is necessary to store seed tubers for up to eight months, the possibility of long periods of storage in DLS is being investigated. Varieties Patrones, Cardinal, and Kufri Lalima, and local varieties Bograi and Dohazari Lal were stored in DLS, and after 150 days, half of the tubers were transferred to cold storage. Preliminary observations indicate that the large-sized tubers of Patrones, Cardinal, and Kufri Lalima become very shrivelled, whereas the small-sized tubers of the local varieties stored well. The tubers will be planted in the 1986-87 season to assess their field performance.

POTATO PROCESSING

Transfer of technology. To facilitate transfer of the technology used to produce dehydrated food mixes based on potato, the CIP pilot plant in Huancayo was made available to researchers of national institutions to gain practical experience with this technology. The processing plant was used by collaborating institutions for a total of 539 man-days in 1986 to experiment with potato-based food mixes. Some researchers modified CIP's original M6 mixture into a food mix (PAPACEL) that is based exclusively on Andean crops (Table 5), which should simplify the

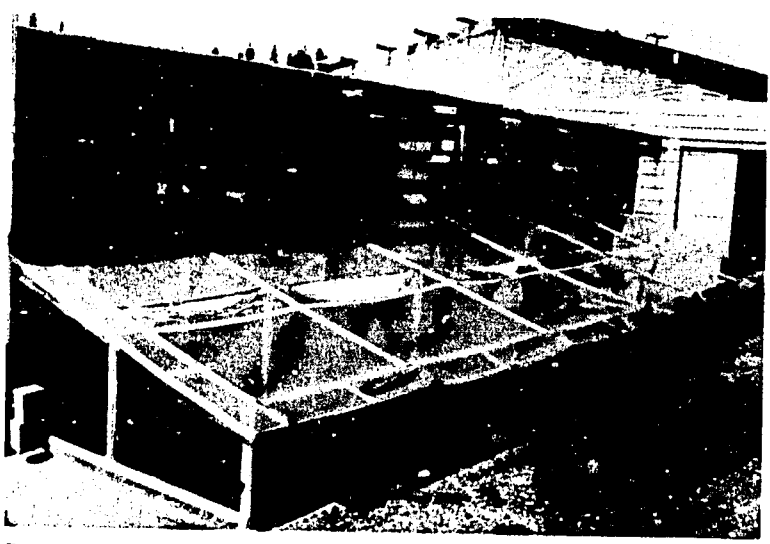
Table 5. Composition of two potato-based mixes (M6 and Papacel) developed by CIP and Peruvian national institutions.

Ingredients	M6 (%)	Papacel (%)
Wet, mashed potato	60	60
Broad bean flour	8	9
Rice flour	8	–
Oat flour	8	–
Maize flour	6	9
Barley flour	8	9
Salt	2	–
Quinua flour	–	4
Wheat flour	–	9
Total	100	100

preparation of the mix in Andean communities. In addition, several researchers concentrated on the use of discarded potatoes for preparation of the mix. One national institution (Centro IDEAS) has almost completed the construction of a small potato-processing plant with a capacity of 21 tons of dehydrated food mix per month. The Peruvian Ministry of Health has expressed interest in using potato-based food mixes in their food programs. The National Institute for Agricultural Research and Extension (INIPA) has developed construction plans for a processing plant of Andean crops, including potatoes.

In India, CIP continues to support a village-level processing project in Bareilly that has been set up by Compatible Technology, Inc. In this project potato processing is organized into a three-tier system. In tier 1, family or community members are making potato slices which are sun-dried. The dried slices are ground by a small mill (tier 2). Finally, in tier 3 the product is marketed. It is anticipated that about 10 units of tier 1 will supply material for tier 2. Presently, processing equipment such as a bicycle-powered slicer is being developed by the project.

Research. ***Drying.*** The efficiency of the drying chamber used in the processing plant in Huancayo was further increased by modifying the construction. A preheating chamber, where air is warmed up



Preheating chamber in front of solar dryer for higher drying efficiency at the CIP processing plant, Huancayo, Peru.

by solar energy before it enters into the main drying room, was constructed. The roof of the pre-heating chamber is made of frames with transparent plastic, while the floor consists of stones painted black. As a result of this modification, the mean maximum temperature in the main drying room increased from 35° to 48° C.

French fries. Dehydrated French fries were produced according to the following scheme: selection of tubers → washing → peeling → cutting → blanching → cooling → drying → packing. The best quality product was obtained when the tuber pieces were blanched at 89° C, first in a solution of sodium bisulfite and citric acid for eight minutes and then in a solution of sodium pyrophosphate for two minutes. The dehydrated product was reconstituted by soaking in water for six hours. After frying, the French fries were submitted to organoleptical analysis for evaluation of appearance, taste, texture, and color. These tests showed excellent consumer acceptability of the product.

Food system. Work on potato production from true seed in home gardens in conjunction with simple processing techniques was continued. As reported elsewhere (Thrust IX), tubers from TPS can be produced efficiently in seedbeds with a high production of dry matter per unit area. After successive harvests of bimonthly TPS plantings in seedbeds, different-sized tubers were processed into a dehydrated potato-based food mix. Results showed that tubers as small as 1-5 g could be used effectively for making the food mix. Several alternative production and processing combinations were developed, some of which would appear to be attractive in certain home-garden production situations in warm climates.

Traditional processing. An in-depth anthropological study of household potato processing technologies was continued in

Preparation and consumer testing of potato-processed products in an Andean village, Peru.

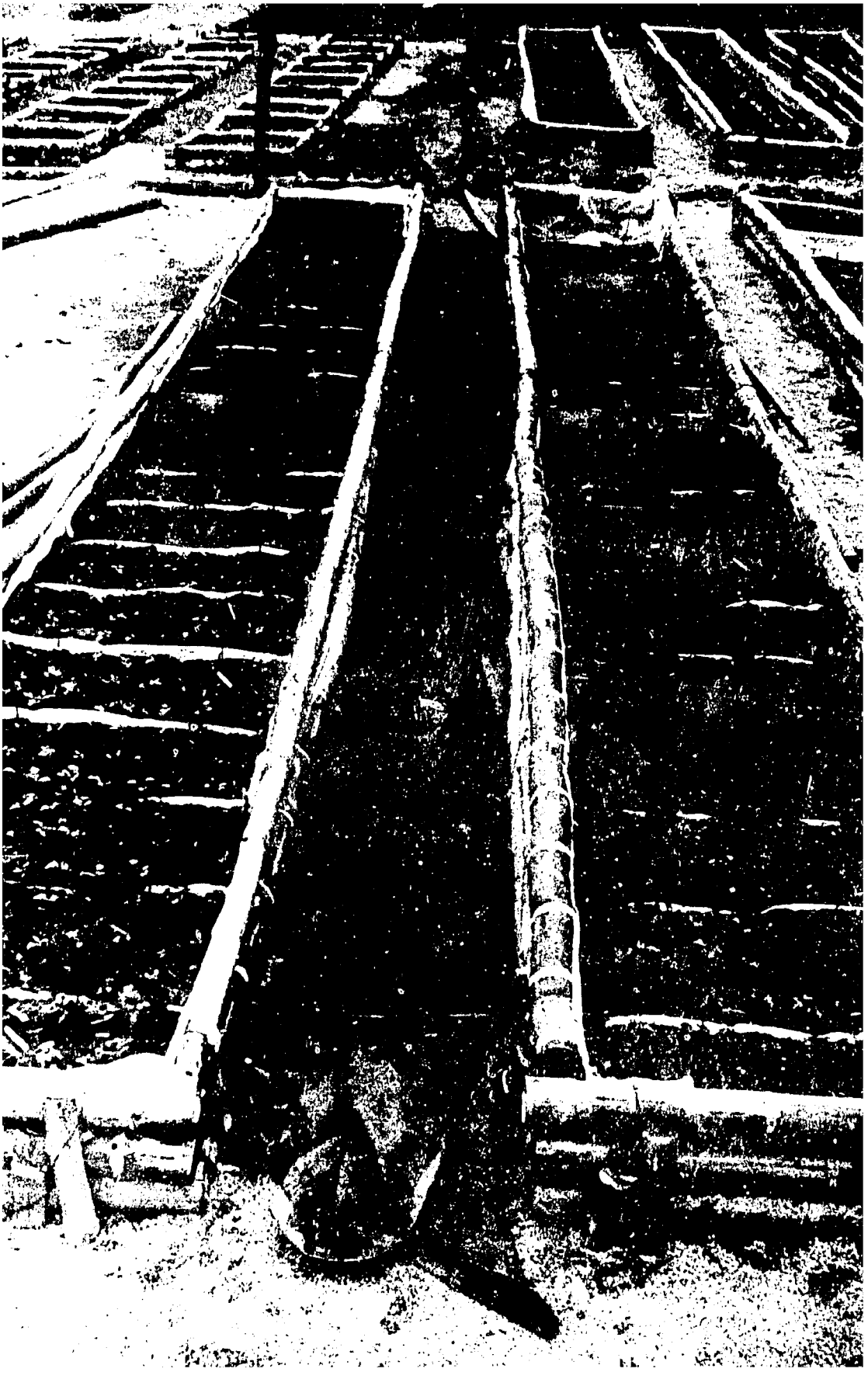
Workshop on potato processing in Huancayo, Peru.

Peru, Bolivia, and Argentina. The stages of boiling, freezing, soaking, fermenting, and drying for different potato processes have been described and categorized in the *Annual Report 1985*. Although most of these processing techniques were believed to be limited to the Central Andes due to the climatic conditions required for potato processing, similar potato processing techniques have been identified in other parts of the world (e.g., Japan). The diversity of potato processing techniques found in the Central Andes could provide essential information on appropriate techniques for low-cost processing in other developing countries.

TRAINING

In Africa, training again focused on low-cost technology for seed potato storage through in-country courses in Zambia, Ethiopia, and Tunisia, the latter as part of a production training activity.

The Bangladesh Agricultural Research Institute organized a regional course on postharvest technology attended by scientists from six Asian countries. A wide range of topics was taught from cold storage to low-cost DLS for seed tubers, diseases and pests, and simple processing methods. The latter topic was also the subject of a two-day course held at the processing facility of the Society for Development of Appropriate Technology at Bareilly, India. A three-day workshop was held at the CIP processing plant in Huancayo for 17 participants from different geographical areas in Peru. During the training activity, work plans for the transfer of processing technology were developed for each area.



THRUST IX

Seed Technology

Breeding efforts to improve TPS progenies concentrated on the incorporation of resistances to late blight, early blight, and potato virus Y (PVY), and on the identification of vigorous seedling growth under adverse environments. Preliminary results showed that selected progenitors with high levels of resistance to late blight and immunity to PVY were able to transfer these traits to a high percentage of their progeny.

Agronomic work continued on techniques for further enhancing transplant survival and average size of tubers, particularly in warm environments, as well as seedling tuber production and use. By using the system of raised beds, as used for vegetable production, and by increasing transplant density, the proportion of marketable-sized tubers was improved. Effective control of damping-off in potato seedlings caused by *Rhizoctonia solani* was achieved.

Important progress was made on improving the efficiency of large-scale production of true potato seed (TPS) as well as on methodology to ensure the production and maintenance of high quality seed. More than 12 kg of selected hybrid TPS was produced in Chile and distributed to approximately 50 countries. Through supplemental N applications during seed development, significant increases in TPS vigor were obtained. Also, optimal berry load, stem number per hill, and planting densities of mother plants were defined for selected progenitors. Increased berry maturity prior to harvest and improved management practices after TPS extraction resulted in the production of seed that did not require gibberellic acid as a presowing treatment for vigorous and uniform emergence. Drying mature TPS at 20° C followed by immediate storage under low moisture ensured maintenance of TPS quality.

Seed tuber research concentrated on evaluating diverse methods of potato propagation appropriate to self-sustaining potato production systems in warm environments. Results confirmed that faster field establishment is obtained from tubers, followed by rooted cuttings or TPS transplants. However, rooted cuttings showed a favorable tendency to produce lower number of tubers and hence larger and more uniform tubers. Warm-produced seed tubers also showed a marked reduction in yield as compared to that of cool-produced tubers. Research efforts continue on the adaptation of TPS and other propagation methods in various countries, especially in South and Southeast Asia. Several propagation methods are showing good prospects for expanding potato cultivation into warm environments.

Various potato propagation methods, e.g., stem cuttings, seedling tubers, TPS, being evaluated under warm environmental conditions in San Ramon, Peru.

TRUE POTATO SEED

Breeding for TPS. True seed progenies are being screened for their resistance to important diseases such as late blight and potato virus Y (PVY). Families, such as CFK-69-1 x 7XY.1, I-1035 x 7XY.1, 575049 x 7XY.1, and Tollocan x 7XY.1 (Table 1) provided progenies with a high percent of resistance to late blight and immunity to PVY. The families used in this screening were obtained by crossing progenitors with high general combining ability for yield and with resistance to late blight. Another group of 300 progenies, segregating for late blight and early blight, were evaluated for their resistance to these diseases.

In order to expand adaptation of TPS material to restrictive growing conditions present in areas of highest adoption potential (i.e., mesothermal tropical regions), methods for the identification of more aggressive progenies are being developed. The selection procedures aim to identify materials that germinate uniformly and vigorously under adverse soil and temperature conditions, and produce seedlings that can rapidly recover following transplanting. Advanced progenies from the TPS breeding program were evaluated for rate and uniformity of germination as well as for seedling growth under a controlled temperature regime of 25° C day and 23° C night (Table 2).

Another need is to improve the ability of seedlings to recover after transplanting. Improved ability to recover after transplanting was found to be strongly associated with regeneration of adventitious roots immediately after transplanting. Forty advanced progenies were subjected to a test developed to assess root regeneration. In this test, seedlings were evaluated for their root regeneration response to an induced shock of −15bar water potential by immersing the roots into a PEG 6000 solution for 15 minutes at 20° C. After the shock, the seedlings were mist-irrigated for 15 days in a wood chamber covered at the sides and ends to

Table 1. Proportion of seedlings resistant to late blight and segregation ratio for immunity to potato virus Y in a selected group of families.

Family	Resistant (%)	Segregation ratio (immune:susceptible)
I-1035 x I-1039	79	1:1
CFK-69-1 x I-1039	79	1:1
LT-9 x CEW-69-1	76	1:1
Atzimba x I-1039	71	1:1
CEW-69-1 x I-1039	71	1:1
I-1035 x 7XY.1	70	5:1
CEW-69-1 x 7XY.1	67	5:1
CFK-69-1 x 7XY.1	64	5:1
LT-8 x CEW-69-1	62	1:1
Tollocan x 7XY.1	53	5:1
LT-9 x 7XY.1	51	11:1
AVRDC-1287.19 x I-1039	33	1:1
LT-9 x 378676.6	11	3:1
Desirée	0	–
Renacimiento	2	–

Table 2. Seedling characteristics in a group of progenies evaluated for early growth under high temperatures (25°/23°C, day/night).

Family	Emergence		Seedling height		Seedling dry weight[b] (mg)	Rank
	Rate[a]	%	cm	$S\bar{x}$		
377891.19 x LT-7	1.28	60.0	10.3	2.2	54.0	1
80N37.11 x R-128.6	1.26	57.8	10.9	1.4	44.7	2
Tollocan x R-128.6	1.27	60.0	6.7	0.8	48.3	3
Atzimba x 4.1	1.26	62.2	8.2	1.2	36.7	4
Tollocan x 4.1	1.29	60.0	8.2	2.5	36.0	5
80JA22.1 x 4.1	1.19	57.8	8.2	1.5	33.3	6
CEX-69-1 x R-128.6	1.09	53.3	8.3	1.9	43.7	7
Atzimba x LT-7	1.34	67.8	6.4	2.1	33.0	8
80JA48.2 x R-128.6	1.01	51.1	8.4	0.4	35.7	9
Atzimba x 7XY.1	1.17	57.8	7.5	1.8	40.3	10
377935.27 x 377964.5	1.07	53.3	8.2	1.9	47.3	11
Atzimba x R-128.6	0.96	46.6	10.0	1.7	39.7	12

[a] Emergence per day over a period of 15 days.
[b] Dry weight 35 days after sowing.

exclude light (Fig. 1). Misting frequency was 5 seconds every 3 minutes. The average seedling response with respect to quantity of roots regenerated was used for characterizing superior progenies.

Selected TPS progenies are also being evaluated for general field performance and yield when either grown from transplanted seedlings or from seedling tubers in different environments. The yield

Figure 1. A bottom mist chamber used in root regeneration studies in potato seedlings.

ranking of progenies propagated by both methods was similar in the cool but not in the warm environment (Table 3). This suggests that under cool conditions the genetic potential for yield in progenies is less influenced by traits such as improved early growth and transplant survival. Although yield from transplants was lower, differences in progeny responses to transplanting were not expressed. On the other hand, in warm environments progenies that perform well as transplants would not necessarily have similar performances to seedling tubers, and vice versa.

International TPS progeny evaluation trial. The second international TPS progeny evaluation trial wa conducted in nine different locations (Philippines, Venezuela, Rwanda, Chile, Brazil, Bangladesh, Tunisia, and two sites in Peru), and included 27 advanced families. Improved traits included in the set were adaptation, high yield, uniformity, and earliness. For long-day adaptation, five sets of 30 progenies were sent to Japan and one set to Italy.

Progeny evaluation trials in countries. ***South America.*** Progeny trials were conducted in Brazil at the National Research Center for Vegetables (CNPH), Brasilia, during the dry season (June-October). These trials were followed by a second transplanting in September for the wet season. During the first season, even with sprinkler irrigation, transplant survival was low due to the dry climate; on the average only 40% to 50% were harvested. One progeny (384074) gave good yields in spite of the low plant population. In the second season, the seedlings were transplanted first to small plastic cups and when six weeks old planted in the field with the soil from the cup attached. The survival improved consid-

Table 3. Yield (t/ha) from TPS progenies used as seedling tubers or transplants in two locations, Huancayo (cool) and San Ramon (warm).

	Cool location				Warm location			
	Seedling tubers		Transplants		Seedling tubers		Transplants	
Progeny	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank
CFK-69-1 x 380701.12	68.6	1	45.8	1	34.3	2	26.2	4
Atzimba x 380701.12	64.2	2	41.7	2	26.4	8	31.6	1
80JA5.8.12 x R-128.6	62.5	3	36.0	5	25.6	9	14.3	11
I-931 x R-128.6	60.3	4	36.9	4	14.5	15	16.8	9
79D10.9 x 380701.12	60.0	5	41.4	3	25.1	10	10.3	14
Atzimba x R-128.6	59.4	6	36.6	6	19.7	12	30.4	2
Atzimba x DTO-28	58.1	7	28.8	12	30.8	4	18.3	8
377887.74 x 377877.9	57.9	8	33.5	8	18.2	13	21.7	5
Atzimba x LT-1	54.9	9	27.9	13	22.1	11	19.4	7
79G8.7 x R-128.6	52.4	10	31.8	9	36.4	1	11.1	13
Atzimba x 380700.79	52.0	11	34.7	7	30.0	6	28.3	3
Atzimba x XY14.7	49.1	12	31.4	10	33.5	3	16.5	10
377877.9 x 378017.2	42.3	13	14.6	15	16.4	14	19.5	6
LT-1 x DTO-33	30.3	14	30.6	11	28.1	7	12.3	12
TS-1 x R-128.6	35.2	15	19.8	14	30.3	5	9.7	15
Means	53.8		32.7		26.1		19.1	

erably and the majority of plants were harvested.

Five on-farm trials were effective in demonstrating the potential of using seedling tubers as yields of 40 t/ha were obtained. At the farmers' request, the trials will continue; however, better quality progenies are required as the tuber characteristics are still not suitable for the local market. Several of the progenies showed resistance to leafminer fly (*Liriomyza huidobrensis*).

North Africa. Several promising TPS progenies were selected in Egypt on the basis of their seedling vigor, seedling tuber yield, earliness, and tuber uniformity. During 1986 there has been a general shift of emphasis from station research to transfer of technology to the farmers' fields.

South Asia. Progeny evaluation trials in India included locally produced TPS hybrids that were transplanted at the Central Potato Research Station, Modipuram in early November 1985, and harvested in late February 1986. Hybrid HPS-I/13 gave the best yield and the most vigorous plants. Yields of transplanted seedlings of several progenies were poor (<100 g/plant). However, in subsequent trials with seedling tubers of the same progenies, yields were more than 400 g/plant, comparable with those from seed-size tubers of a standard Indian variety.

Evaluation of TPS progenies from transplants was also made at Deesa (Gujarat) and Chindwara (Madhya Pradesh), and small tubers produced in both these trials will be compared with those of the predominant local variety. At Mandra (Calcutta), the yield performance of three categories (<20 g, 20-40 g, and>40 g) of seedling tubers of progeny TPS-2 was assessed. All sizes gave yields of approximately 3 kg/m^2, while standard seed-size tubers of Kufri Jyoti yielded 3.5 kg/m^2. The size of the small tubers, however, influenced the tuber size of the harvested crop. The largest tubers (>40 g) yielded a slightly greater proportion of large-sized tubers (>80 g).

In Nepal, four hybrids and one open-pollinated (OP) progeny were evaluated in the lowland area at Janakpur. The seedlings were transplanted to the field, and the wide spacing (60 x 10 cm) resulted in a low number (100/m^2) of large-sized seedling tubers. The OP progeny yielded about 50% of the best hybrid progeny (HPS-I/13) that gave the equivalent of 23 t/ha. Thirty-four new female lines were identified on their flowering capacity and other desirable characters. These were crossed with one male tester and, on the basis of seed and berry characters, 23 lines were selected. Hybrids from these female lines will be evaluated in 1986-87.

In Bhutan, CIP hybrid 720045 x 750161 gave the highest yield per plant in trials at Yusipang. Most, but not all, hybrids gave significantly better yields than the OP progenies. A study of several TPS parents was made to determine the most suitable for TPS production under Bhutanese conditions. The best male parents were 676005, 376999.6, and 750161, and the best females were 720045, CPI-999, and I-1055. Clones 720084 and 800224 performed equally well as males and females.

Southeast Asia. The identification of TPS progenies suitable for the highlands, mid-elevation areas, and lowlands of the Philippines and Vietnam is being made possible through the breeding work at CIP's Sta. Lucia station in the Philippines (800 m). Twenty-four hybrids were produced from parents that were primarily bacterial wilt-resistant females and heat-tolerant males (LT-7, 7XY.1, DTO-33, DTO-2, and I-1035). A major problem in TPS production is the extreme sensitivity

of many parents to daylength; out of 27 parents, only 11 were used successfully as progenitors. It was also found that progenies with a parentage of *S. tuberosum* x *S. andigena* or *S. phureja* do best in the dry season (cool, short days). Hybrids derived from crosses between genotypes of ssp. *tuberosum* always tuberize too early, resulting in reduced canopy and yield. Emphasis has been placed on selecting clones with good tuber yields and heavy berry set to enable farmers to use OP seed. Ten clones were selected and seed has been distributed to Negros and Mindanao in the Philippines, Indonesia, and Vietnam.

TPS agronomy. ***South America.*** In Peru, CIP has continued research on practices that could lead to improved field establishment and to increases in the average sizes of tubers produced by plants from transplanted TPS seedlings. Transplanting seedlings to the field appears to be one of the most feasible methods of TPS use, particularly in warm tropical areas. In such areas, field practices used for transplanting may not necessarily be the same as those used when growing the crop from tubers, but they may resemble those used with other vegetables. Thus, production in 1.5-m wide raised seedbeds in which seedlings were transplanted into transversal furrows at 0.60 m apart showed great applicability and greatly improved yields under San Ramon conditions. The yields obtained by the raised-bed system were significantly higher than those obtained when the plants were transplanted on ridges. When the transplant density in raised beds was doubled in the dry season, yields were further improved. A favorable tendency towards increase in the proportion of marketable-sized tubers (>3.5 cm diameter) was also noticed during production in raised beds. This was possibly due to the lower hilling in those plots, which would in turn reduce the number of tubers and increase their size.

Planting seedlings at close spacing for seedling tuber production has given, in some progenies, problems with hilling-up. Planting in rectangular patterns instead of square patterns (maintaining the same plant population) reduced hilling problems but affected plant height and early ground cover by foliage. Planting in rectangular patterns also reduced significantly the number of 1-5 g tubers and total tuber number, but not total tuber weight. This suggests that maximum tuber production from TPS in nursery beds would be achieved from planting in square patterns.

Data from different plot sizes suggest that for a reliable determination of differences in tuber number when evaluating progenies, a plot size of 0.80 m^2 with 4 replications, or a plot size of 1.20 m^2 with 3 replications is required. For tuber yield differences larger plots or more replications are needed.

In seedbeds, *Rhizoctonia solani* is one of the major problems causing damping-off. This year's data confirmed control of this disease by three soil fungicides: Benomyl (Benlate 50WP at 4.0 g a.i. per m^2), Tolclofos methyl (Rizolex 50WP at 3.5 g a.i. per m^2), and Dazomet (Basamid 98% at 30 g a.i. per m^2). In warm areas of Peru, the *R. solani* Anastomosis group AG-4 is predominant in potatoes. Results indicate that the AG-4 group causes greater seedling mortality at high temperatures than the AG-3 group, i.e., the group normally affecting potatoes in cooler, highland conditions (Fig. 2).

Through on-farm research conducted in the Mantaro Valley of Peru (3200 m), where virus spread is relatively low and therefore seed tubers can be maintained in good sanitary condition for several field multiplications, the performance of crops propagated by transplanted seedlings or

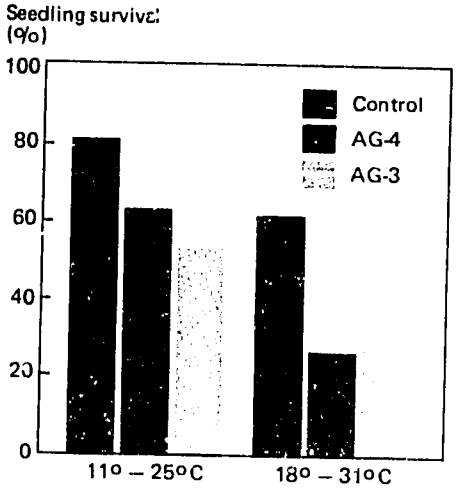


Figure 2. Seedling survival as affected by two Anastomosis groups of *R. solani* in a cool *(left)* and a warm *(right)* environment.

tubers from TPS after one (G-1) and two (G-2) field multiplications was compared to a crop from seed tubers of the commercial variety Yungay. The seedlings and seed tubers G-1 and G-2 were from OP seed of Yungay. No yield reductions were observed between generations G-1 and G-2, and yields were similar to those obtained with the variety. The yield of transplanted seedlings, although lower than the yield when tubers were used for planting, represented a satisfactory value if this is considered as a method for producing seedling tubers in the field for further propagation.

In Venezuela, an experiment was made to test whether growing TPS at high altitudes (Paramos) for seedling tuber production was feasible during December-February when frosts of −3° to −5° C are common. Three treatments were used: plastic cover with black stones to preserve heat, cover without stones, and no cover. The respective yields and numbers of seedling tubers were 5.3 kg (805), 2.8 kg (571), and 1.3 kg (185) from the three treatments. The average temperature under the plastic cover was 4.4° C higher than the outside temperature.

The potential use of TPS in Paraguay, Brazil, Argentina, and Chile appears to be limited to producing seedling tubers for further propagation. During the 1985-86 season, the National Agricultural Institute of Argentina (INTA) studied such aspects as yield of seedling tubers, uniformity, color, and dormancy. Tuber uniformity was satisfactory, but yields per unit area were low (100 to 300 tubers/m^2) compared with those obtained from other countries. Sprouting, measured 180 days after harvest, was considerably less in progenies with Serrana than in those with DTO as a parental clone.

In collaboration with Chile's Austral University (UACH) and the Institute of Agricultural Research (INIA), several on-farm trials using TPS were conducted, including the effect of different spacings in the seedbeds (Table 4). Yields, number of tubers, and tuber size were extremely good and comparable to those obtained at CIP, Lima. The variety of TPS used was OP Desirée, which gives tubers segregating for red skin, the preferred color in the Chilean markets. The interaction of seed size (<35, 35-45, and >45 mm) with in-row plant spacing over the range 15-40 cm was tested with seedling tubers originating from OP Desirée. The large-sized tubers planted at the normal 30-cm spacing in the row produced the highest yields and the largest proportion of commercial-sized seed tubers. This research will be continued by UACH with support from the International Development Research Centre (IDRC) of Canada.

Africa. In Egypt, the research program to refine appropriate techniques for the use of TPS continued. When transplants were compared with seedling tubers for the production of consumer potatoes, the seedling tubers generally gave higher and

Table 4. Yield and number of tubers/m^2 at four TPS sowing densities in seedbeds in two localities in Chile, 1985-86.

			San Juan			Paucho		
Spacing (cm)	Seeds/ hill	Seeds/ m^2	Yield (kg/m^2)	Tubers/ m^2	Average tuber wt (g)	Yield (kg/m^2)	Tubers/ m^2	Average tuber wt (g)
8 x 15	1	833	12.73	1056	12.06	6.56	770	8.52
8 x 3	1	416	11.09	750	14.80	7.97	445	17.91
8 x 8	4	625	12.45	989	12.60	7.66	745	10.28
Broadcast		938	10.96	971	11.30	8.59	603	14.25

more reliable yields. The cost of preparing nursery substrates was reduced considerably by replacing the mixture containing expensive imported peat moss by a well-rotted mixture of manure, wheat straw, and sand.

Daylength in Egypt decreases from 13 hours in August to 10 hours in December. Thus, extension of the daylength from October to December resulted in more than double the yield from nursery beds. Additionally, the use of plastic sheeting to raise the temperature in the beds resulted in improved seedling growth. Seedling tubers harvested in December do not reach their optimum physiological stage for the spring planting in February. The early breaking of seedling tuber dormancy by chemicals such as gibberellic acid (GA_3) and thiourea accelerated emergence and resulted in higher yields.

Research on TPS agronomy was also carried out in Morocco at the Complexe Horticole (Agadir), in Senegal, at the Center for Horticultural Development (CDH), and in Tunisia. Increasing interest in the use of TPS has come from Cameroon, Equatorial Guinea, Togo, and the Cape Verde Islands. In North and West Africa, the scheme that appears most likely to be adopted at higher latitudes is seedling tuber production in the spring season, storing the tubers at ambient temperatures in summer, and planting them for a second crop later in the year.

In fall 1985 in Tunisia, marketable yields of seedling tubers remained lower than those for the variety Spunta, which yielded over 23 t/ha, but the latter crop had been obtained by planting large commercial-sized seed tubers.

In Senegal, CDH evaluated the storability of seedling tubers and their subsequent performance in the field. Tubers were kept either in diffused-light store (DLS) or cold store, the latter treatment was included because tubers must be stored through the hot summer. DTO-33 OP (16.6 t/ha) and DTO-33 x R-128.6 (18.1 t/ha) stored well in DLS, and yields were only 15% less than when kept in cold store. However, Desirée OP seedling tubers did not store well in DLS and yielded between 26% and 42% less than those from cold store.

In Rwanda, the socioeconomic aspects of TPS use were examined in 19 on-farm experiments conducted in four communes. The trials compared the use of seedling tubers with traditional seed tubers. On the average, crops from seedling tubers yielded 25% higher than the traditional crop.

South Asia. Three areas in Pakistan were chosen to evaluate the potential of TPS: Kalam (2300 m) and Hunza (2450

m) in North West Frontier Province, and Quetta (1700 m) in Baluchistan. Initial impressions are that seedling tuber production in nursery beds would be adopted by farmers easier than transplanting seedlings to the field. Seedlings were severely affected after transplanting by damping-off. In trials with Desirée OP, the number of seedling tubers produced was 320/m^2 at Kalam and Hunza, and 750/m^2 at Quetta. However, the mean tuber weight was 17, 14, and 8 g at Kalam, Hunza, and Quetta, respectively. In an evaluation of ten hybrid progenies from CIP and OP progenies of Desirée and Kufri Sindhuri, five of the hybrids gave more than 4 kg/ n^2. Atzimba x 7XY.1 gave the best yield with 348 tubers of 22 g mean weight.

In India, several trials were conducted on farms and at various institutions on the use of TPS for seedling tuber production. In five on-farm trials at Atghara, West Bengal, farmers produced between 2.4 and 4.0 kg/m^2, and two trials in Mandra (Calcutta) yielded 1.6 and 3.3 kg/m^2. On riverbed soil at Deesa, Gujarat, five TPS progenies gave between 1.4 and 5.6 kg/m^2; the best genotype was HPS-I/13. This genotype and HPS-I/III gave the best yields of the five progenies at Pusa, Bihar, averaging 2.1 kg/m^2 (521 tubers) and 2.0 kg/m^2 (752 tubers), respectively. The results of these and similar trials are summarized in Table 5.

Experiments conducted by the Bangladesh Agricultural Research Institute (BARI) during the past three years have demonstrated that TPS can be used as an alternative technology for potato production, and a number of promising TPS lines have been identified. Further research is still needed to overcome the main problem of improving flowering of parental clones for seed production. Under the short-day conditions, additional artificial light of 5 hours helps flower induction. Thirty-four on-farm trials were conducted by BARI in Munshiganj using the transplanting system (Table 6). Farmers in this area do not use imported or improved seed tubers and, since TPS progenies produced about three times the yield of the local variety Lal Pakri, there is potential for the adoption of this technology. Some farmers are already trying out TPS, but a regular supply of seed still has to be organized.

Southeast Asia. Research on the use of TPS is only part of a more extensive program to provide good planting materials for resource-poor farmers of Southeast Asia who cannot afford expensive imported seed. In Mindanao, Philippines, 20

Table 5. Seedling tuber production at five different locations in India during the Rabi season of 1985-86.

Progeny	Yield (kg/m^2) at five locations					Average yield (kg/m^2)
	Modipuram	Chindwara	Deesa	Pusa	Pant Nagar	
TPS-2 (OP)	3.04	2.00	1.37	0.61	0.65	1.53
MF-I (OP)	3.92	3.53	3.92	1.10	0.72	2.64
HPS-I/III	4.11	4.04	5.27	2.05	0.79	3.25
HPS-I/13 (S)	4.43	–	–	–	–	–
HPS-I/13 (K)	4.44	5.16	5.56	2.12	1.08	3.67
HPS-II/III	4.11	3.44	2.74	0.85	–	2.79
CD (0.05)	0.75	–	1.08	–	–	–

progenies were evaluated as transplants in three experiments and yields of over 40 t/ha were obtained. Four superior progenies were identified from the crosses Greta x AVRDC-1287.19 and 381064.3 x 7XY.1, and these had uniform tuber shape, good color, and earliness under the longer days of Mindanao (January-May). TPS of these crosses was produced at CIP's germplasm center at Sta. Lucia and supplied to farmers of a local cooperative who produced an average of 400 seedling tubers/m^2 in nursery beds. Those weighing less than 3 g (38%) were replanted in a screenhouse to produce more tubers. The first trial with these seedling tubers was planted in a farmer's field in double-row beds at a rate of 55,000 plants/ha. The tubers were planted according to size, and the smallest size only needed 200 kg seed/ha. Yields varied between 32 and 44 t/ha (Table 7). Over six tons of seedling tubers have been stored and distributed within the cooperative. This cooperative has been able to develop a workable system of producing planting material from TPS. However, there is still the problem of developing a cropping system that is not based on continuous forest clearance, and of obtaining optimum yields with limited fertilizer inputs. At present, CIP remains the cooperative's main supplier of TPS.

Another area in the Philippines unable to obtain good quality seed tubers is the island of Negros where yields are only 6 to 10 t/ha. In late 1985, ten farmers were supplied with TPS of progeny Greta x AVRDC-1287.19. Seven farmers successfully germinated the seed in small pots made of leaves, transplanted the seedlings in the field, and obtained yields of 7.5 to 15.2 t/ha even though typhoons and early blight cut the growing season to only 70 days. The more successful growers stored their produce in diffused-light stores (DLS), and the subsequent crops planted

Table 6. Results of 34 on-farm trials with TPS progenies and commercial varieties at Munshiganj, Bangladesh (1985-86).

Progeny or variety	No. of times included	Yield (t/ha)	Range (t/ha)
Atzimba x R-128.6	18	18.85	14.3-24.2
Serrana x DTO-28	22	18.58	12.3-22.4
Serrana x DTO-33	22	16.52	21.1-25.1
Dohazari (OP)	2	11.70	10.8-12.6
Patrones (tubers)	20	19.07	14.5-27.0
Lal Pakri (tubers)	17	5.97	3.4-8.7

Table 7. Influence of seedling tuber size on the yield of the TPS progeny Greta x AVRDC-1287.19, Bukidnon, Mindanao.

Seedling tuber size (g)	Yield (t/ha) per seed size					
	Extra large	Large	Medium	Small	Scramble	Total yield (t/ha)
>25	5.0	14.5	13.9	8.4	2.9	44.8
15-25	5.9	13.5	15.0	8.6	1.8	44.9
10-15	5.3	13.0	16.0	7.2	1.7	43.6
5-10	2.7	9.0	15.4	8.4	1.9	37.4
3-5	1.3	6.1	13.5	8.3	3.3	32.4
Cosima (50 g)	3.8	7.4	9.0	4.2	2.6	27.7
CV (%)	57	23	19	35	47	11
LSD (5%)	3.2	3.3	3.8	3.7	1.6	5.8

in March 1986 yielded from 12.2 to 23.6 t/ha.

In Vietnam, over 20 kg of TPS seed from open-pollinated Atzimba and CFK-69-1 was collected in the highlands of Dalat by the Food Crops Research Institute and distributed to 35 cooperatives in the Red River Delta. A total of 40 ha were successfully transplanted with TPS and an average of three million seedling tubers/ha was produced. In the 1985-86 season, the first commercial crops using seedling tubers were grown. In comparison to cultivars Ackersegen and Mariella, these crops bulked just as rapidly and had better resistance to late blight and viruses, with yields ranging from 15 to 20 t/ha.

Farmers expressed satisfaction with the technique of utilizing TPS for seedling tuber production because storage losses were only 15% to 20% and the small-sized tubers required less space—an important consideration. Another important factor was the large numbers (20-30) of small tubers produced per hill, with 60% weighing over 3 g. Yields were always superior to variety Ackersegen by at least 50%.

The progenies presently available in Vietnam are extremely sensitive to short cool days; they tuberize early, limiting canopy development and giving low yields. The nine-month storage period for seedling tubers is problematical and progenies with longer dormancy periods are needed.

TPS production. To ensure TPS availability and extensive use in the tropics, research on techniques for efficient large-scale production of quality seed at low cost is being emphasized. Important progress was made on field practices that could improve both the efficiency of TPS production and seed quality.

Acquired knowledge is being applied in large-scale TPS production in Osorno, Chile, through a continuing contract with the National Agricultural Research Institute (INIA). More than 12 kg of TPS of seven selected hybrids were produced under the long-day and ideal environmental conditions for production in that location. The TPS produced was distributed to more than 50 countries. Trained plants (Fig. 3) used for hybrid seed production resulted in improved fruit set under the adverse climatic conditions (wind and heavy rain) during the pollination period. Another important practice was the application of supplemental nitrogen (N) during the berry development period. Supplemental N applications (in addition to the 150 kg/ha applied at planting) in three partial rates of 80 kg/ha to the female parents during the seed development period maximized TPS yield per berry and increased the 100-TPS-weight.

TPS vigor, expressed as emergence rate and early growth rate of seedlings, was also shown to be significantly enhanced by N levels higher than those used in production of tubers. The TPS produced by mother plants that received half of the total N rate at planting and the other half in supplemental applications during TPS development achieved faster emergence, and seedlings were of higher weight at increasing rates of N (up to a maximum of 600 kg/ha). The TPS vigor at this rate, indicated by the weight of seedlings achieved 25 days after sowing, was increased even further when supplemental N was divided into six applications as compared to three.

In Peru, studies on berry load per plant have shown that increasing the number of berries per inflorescence from 2 or 3 to 6 or 9 berries reduced average berry size and 100-seed-weight. In one clone, CEX-69-1, increasing the berry load per inflorescence also reduced the number of seeds and total seed weight per berry. The decrease in 100-seed-weight was due

Figure 3. Production of hybrid TPS in Osorno, Chile.

mainly to a reduction of the fraction of large seeds (≥1/15"). Increasing the berry load increased the total seed production per inflorescence in weight and number.

In six varieties, TPS production in inflorescences with 25% fruit set, accomplished by pruning flowers, was compared with that of inflorescences with maximum possible fruit set (around 85%). More berries per inflorescence did not reduce the average berry weight or the percentage of large berries in the varieties Renacimiento and Serrana. In the other four varieties berry weight and percentage of large berries were reduced, but the total production of large- and medium-sized berries was increased. Tests conducted on the seed indicated that position on the plant and the size of the berry from which the seed was obtained did not affect TPS quality.

To evaluate the feasibility of hybrid TPS production in warm tropical environments, a preliminary experiment was conducted in San Ramon during the 1986 dry season. The seed that was produced germinated well but production efficiency was low. In Atzimba, the maximum berry set ranged from 40% to 60% and in DTO-33 from 65% to 70%. Decreasing the number of berries per inflorescence by pruning flowers showed little effect on the average berry weight. Berries developed on secondary inflorescences were smaller and weighed less than those produced on primary inflorescences, although the berries matured on the plant for the same period.

A preliminary evaluation conducted in Huancayo on the relationship between stem density, berry size, and seed characteristics showed that one-stem plants produced larger berries and larger and heavier seed than three-stem plants. For further studies on the effect of plant density on flowering and TPS production, tubers of

the varieties Atzimba, Yungay, and Renacimiento were planted at a distance of 15, 30 and 60 cm in the row and 150 cm between rows, which resulted in high, intermediate, and low stem densities. Flowers of Atzimba and Yungay were pollinated with R.128.6 pollen, whereas flowers of Renacimiento were left to form open-pollinated berries. Different planting distances did not affect the initiation or length of the flowering period, but higher plant density decreased the number of inflorescences and flowers per plant. In the varieties Yungay and Renacimiento, fruit set decreased with increasing plant density. Treatments with higher stem density produced smaller berries and smaller seeds. In Atzimba the total seed production per unit area was not significantly different for the three density treatments. The largest production of seed was obtained from the intermediate stem density in the variety Yungay and from the high stem density in the variety Renacimiento.

Greater understanding of TPS dormancy has prompted research to develop a practical method to overcome this problem in TPS use. Dormancy not only imposes limitations due to the need of using GA_3, which is difficult to obtain in developing countries, but also the use of GA_3 was demonstrated to adversely affect vigor and uniformity during early seedling establishment. TPS of progenies produced and handled in the same way have shown different speeds of germination. In experiments with freshly extracted TPS of two hybrid progenies produced and handled similarly, about 70% of the seedling emergence was achieved only three days after sowing Atzimba x DTO-28 seed; the other progeny, Serrana x DTO-28, showed slower and irregular emergence (Fig. 4).

In environments that limit flowering and fruit setting, such as in San Ramon and

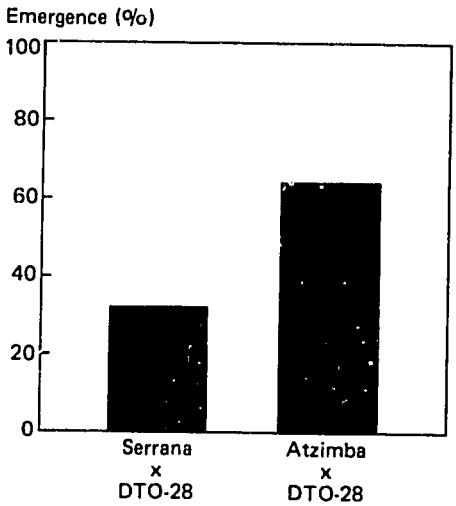


Figure 4. Seedling emergence in two progenies three days after sowing TPS without gibberellic acid.

Lima, experiments have continued on methods for improving TPS production efficiency. Studies included the use of growth regulators and environmental factors (light intensity and duration) in relation to the flowering/berry setting and pollen fertility response.

Increased berry maturity was found to enhance the speed of emergence of TPS seedlings and hence their successful field establishment. Seedling emergence three days after sowing the TPS from berries that matured on the plant for 11 weeks was approximately 70% higher than that of TPS from berries that matured seven weeks prior to harvest. Stored TPS treated with GA_3 were of lower vigor than untreated seed.

Seed stored dry (2-5% moisture content) has also shown improved emergence rate when compared to seed stored in ambient humidity conditions but at the same (5°-10° C) temperature (Fig. 5). In another experiment, the optimal temperature for drying TPS of Atzimba x DTO-28, with respect to speed of seedling

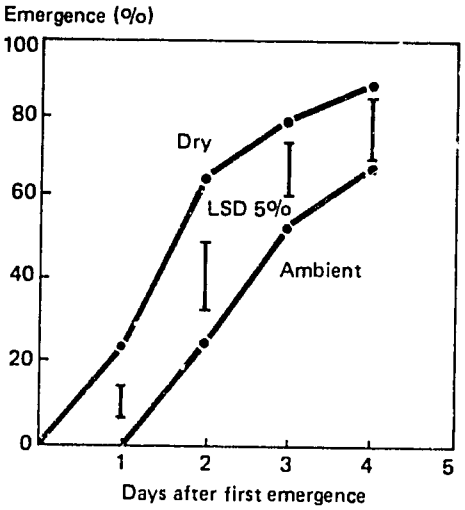


Figure 5. Effect of type of storage conditions on emergence of TPS (Atzimba x R-128.6).

emergence, was found to be approximately 20° C.

PRODUCTION COSTS OF TPS

For a second consecutive year, a cooperative project between CIP and INIA was established for producing large quantities of TPS for distribution. The project was carried out at INIA's Remehue experimental station at Osorno in the southern part of Chile. Production costs of four TPS progenies were calculated: Atzimba x DTO-28, Atzimba x R-128.6, Serrana x DTO-28, and Serrana x LT-7. According to this year's results, the average production cost per kilogram of TPS produced (including data from all progenies) was US$149 when emasculation was performed. Costs varied from US$128 for Serrana x DTO-28, the most efficient combination in fruit setting, up to US$188 for Serrana x LT-7. Of the total production costs, emasculation accounted for 33%, pollination 22%, and seed extraction and processing 19%. Due to the experimental nature of the TPS production process, technical management is the most expensive input. As more experience is gained on production practices, costs will be reduced through a substantial increment of labor and management productivity.

SEED TUBER PROPAGATION

Latin America. Different methods of potato propagation were evaluated under summer conditions in CIP's experimental stations at San Ramon and Lima. The project aimed to improve seed technology components that could be used for developing self- sustaining potato production systems in warm environments. Growth readings for different planting materials with respect to early canopy development and ground cover confirmed previous findings of earlier field establishment of plants derived from tubers, followed by transplanted rooted cuttings and transplanted TPS seedlings. Rooted cuttings have shown a marked tendency to produce a lower number of tubers (Fig. 6), a condition that needs further attention when higher multiplication rates are desirable. This tendency did not vary with mother-plant age or by extending day-

Table 8. Yield (g/hill) obtained in a warm location (San Ramon, Peru) by using various planting materials produced either in cool or warm environments.

Planting material	Production environment	
	Cool	Warm
Seed tubers	511.5	287.3
Tubers from cuttings	423.6	299.7
Seedling tubers	501.3	354.4
Transplanted seedlings	–	419.0
F-Test (P = 0.05)	**	**

length. The yield from tubers derived from the three types of planting materials grown in either warm or cool climates was influenced by the conditions under which they were produced (Table 8). When tubers were produced and used in warm areas they yielded 29% to 44% less than those produced in cool and later planted in warm areas.

Practices developed for seedling tuber production in nursery beds have shown great applicability for seed tuber production with delicate propagating materials such as micropropagated plantlets and small tubers produced in vitro. In beds of peat moss and sand, in vitro plants have shown survival rates of 95%, and small tubers of less than 1 g showed emergence close to 100%. Growth and multiplication rate of plants from various methods of propagation showed that those from in vitro plantlets exhibited slower early growth than those from in vitro tubers, and produced more tubers per stem and per unit planted.

Figure 6. Tubers produced by rooted cuttings transplanted into nursery beds at a high density of 66 cuttings/m^2.

Early plant vigor and ground cover were least in plots with in vitro plantlets. In vitro plantlets produced more tubers per unit area, especially of smaller sizes, than in vitro tubers. The ratio of total number of tubers harvested to number of units planted was highest in in-vitro plants. The highest yields and multiplication rates were obtained at 48 plants/m^2.

In another experiment, the performance of different seed tuber sizes (1-5, 5-10, 10-20, and 40-60 g) was compared, based on the same sprout density to give similar stem densities. Results indicated that with increasing seed tuber size, faster ground cover by foliage was achieved. Although tuber yield per unit area was greater in plants from larger seed tubers, tuber yields per stem in plants from 5-10 g, 10-20 g, and 40-60 g seed tubers were similar, but significantly greater than those in plants from 1-5 g tubers. Tuber number per stem was lower in plants from larger seed tubers, presumably due to the greater degree of clumping of stems causing increased stem competition.

The program to produce pre-basic seed for Peru, financed by the Swiss Development Corporation, now has a total of 4 ha at five sites: Huancayo, Ayacucho, Cuzco, Puno, and Cajamarca. Production in 1986 from 0.4 ha at Cuzco alone exceeded 8.5 t from tubers and cuttings. Basic seed derived from the above totalled more than 850 t from 12 regional centers. Nontechnical problems that need to be solved are insufficient funds at regional stations for basic seed multiplication and a lack of infrastructure such as storage facilities. In the 1986-87 season, further efforts will be made to improve the number and quality of seed producers handling the later stages of multiplication.

Socioeconomic studies were made to define actual production costs of the Peruvian basic seed program. The internal rate of return (IRR), i.e. the average rate of interest at which the project might be expected to repay the investment, was found to be 50% when seed is produced from in vitro plantlets. When only stem cuttings were used the IRR was 24%.

The Peruvian national potato program, in collaboration with the extension service of INIPA, harvested over 50 on-farm trials to measure the agroeconomic returns from the high quality seed produced by the program. Analysis of the data from 29 of the trials showed that improved seed (30.1 t/ha) gave significantly more yield than farmers' seed (26.0 t/ha). There was a slight price advantage of the improved seed crop as the percentage of higher priced grades was greater. Partial budget analysis showed that 22% of the trials had a negative net benefit, in 19% the rate of return was 0 to 1.5 and in 59% it was above 1.5.

Among the additional information gathered from the trials, it was noted that, on the average, farmers renew their seed every seven years. Only 21% of this seed had been originally obtained from seed growers. A major factor complicating the study was that the basic seed had been stored in DLS, whereas the farmers' seed was stored mostly in the dark, and, therefore, both virus infection and storage conditions would have affected the yields. Three on-farm trials were laid out to separate these effects; virus infection accounted for only one fourth of the yield difference, the rest being due to storage conditions and general handling of the seed. However, in a separate experiment studying the reactions of the variety Yungay under three levels of fertilization and virus infection, it appeared that virus infection limited the response of Yungay to higher fertility.

In Paraguay, a new technical collaboration project was started in 1985 with the

Ministry of Agriculture and selected farmers. In 1986 the first demonstration crops of potatoes grown from seed produced in Uruguay and Argentina were harvested. The seed of varieties Baraka, Crystal, Famosa, and Hertha had been stored for eleven months in a cold store before planting, but still gave yields of 16-21 t/ha. The results impressed farmers who normally plant diseased seed potatoes purchased from the local market.

Central and North Africa. A new strategy is being pursued in Burundi to protect seed at the main seed farm at Mwokora from becoming infected with bacterial wilt. At Gisozi, varieties are maintained in vitro and multiplied in screenhouses before being sent to the seed farm at Munanira, where conditions favor the expression of wilt symptoms in the field, thus facilitating roguing. Seed will then be multiplied once or twice at Mwokora for distribution to other projects. Two varieties, Sangema and Kinigi, are being withdrawn from the seed program due to extreme late blight susceptibility. Field crops continue to be screened for potato leafroll virus (PLRV) and PVY by ELISA tests and have been found entirely free from both diseases; however, viruses PVX and PVS are known to be present in the field and methods for reducing these are being investigated.

At Mwokora, 8 ha were planted for seed production for two consecutive seasons. Less than 2% off-types and diseased plants were eliminated, although subsequent serological examination showed a heavy latent infection by bacterial wilt in the variety Kinigi.

Farmers find it difficult to obtain improved seed for the dry season in the valley bottoms, which is probably the most important crop in Burundi. This is because the crop is sold as consumer potatoes due to heavy bacterial wilt infestation that makes it impossible to retain seed for a second crop. Two demonstrations (1.5 ha) of producing cheap seed were made on a tea estate by planting potatoes in September and harvesting in February prior to replanting tea. Minimum inputs were used, but all direct costs were covered by the value of the seed produced. A further 4 ha were planted in September 1986 to confirm these results and to demonstrate this method to other projects. A similar demonstration on a peat-cutting project during the dry season produced quality seed tubers with no sign of bacterial wilt or nematode infestation, as the land is completely flooded for nine months of the year.

Farmers in Egypt need good quality seed for spring and autumn plantings. In a series of experiments, imported seed was compared with once-grown local seed of imported varieties and seedling tubers of Atzimba x R-128.6. In general, the once-grown imported seed gave slightly better yields (26.4 t/ha) in autumn than either the farmers' own seed (24.7 t/ha) or seedling tubers (24.1 t/ha). In the spring, a comparison was made of newly imported and locally multiplied seed of five varieties. Newly imported seed gave an average of 3 to 5 tons higher yield. The main problem with locally produced seed in Egypt for the spring crop is that it is physiologically young, since it is harvested only three months before planting.

South Asia. The Bhutanese national potato program continued its program for improved production of pre-basic, basic, and foundation seed. At Phubjikha, 123 tons of seed of CIP clones in these three categories were produced in screenhouses and in the field for distribution to registered seed growers. During 1986, registered growers produced 670 tons of certified grade seed which was distributed to commercial growers. At the rates of

multiplication presently being obtained in the pre-basic and basic stages, there should be sufficient quantities of improved seed for planting the total potato area of 10,000 ha every four years.

In Bangladesh, development of the basic seed production scheme continued at the northern seed farm of Debiganj. Four stages of clonal selection and multiplication have been organized on 14 ha. In the 1985-86 season, 107 t of seed potatoes were produced from 12 different varieties and clones. The Bangladesh Agricultural Development Corporation distributed 43 t to contract growers for further multiplication and small tonnages were supplied to other collaborating institutions.

Southeast Asia. In the Philippines and in several other countries of the region, methods are being developed to produce seed and consumer potatoes directly from cuttings. Although the use of cuttings for rapid multiplication of basic seed is well established throughout Southeast Asia at the experimental station level, its use by farmers is determined by local conditions. The use of sprout cuttings in Vietnam is an example of the savings that can be made in the cost of seed tubers through planting only 15% of the normal seed rate. Cuttings are used successfully by farmers in the Philippine highlands but management of mother plants is a problem in that area.

YIELD REDUCTION BY VIRUSES

Latin America. In studies on the effect on yields of the common viruses found in the highlands of Peru, no reduction in yield could be found in plants infected with PVS, PVX, APMV, or APLV, nor combinations of these viruses. However, PVY and PLRV reduced yields significantly, as did combined infection with PVX and PVY. There was no evidence that healthy plants adjacent to diseased plants compensated for the lack of competition. Since Andean varieties in general have long stolons it is suspected that some of the tubers apparently harvested in the root zone of infected plants were actually produced by adjacent healthy plants.

In a study being conducted in Uruguay on yield reduction in a crop with 50% plants infected with PLRV, yield per plant was slightly lower in 1986 than in the previous year, but the reduction of yield from diseased plants was even greater (84% in 1986 vs. 66% in 1985). The mean yield of adjacent healthy and diseased plants was used to indicate the overall loss in the field; 37% in 1986 and 23% in 1985. Yield compensation by healthy plants amounted to only 10% compared with 21% in 1985.

TRAINING

The importance of seed production programs in developing countries has been demonstrated by the continuing requests for CIP's assistance with training courses. CIP responded to these requests in 1986 by collaborating with national programs and the Southeast Asian country network SAPPRAD in eight regional and in-country courses: three in South America, three in Africa, and two in Asia. Most national programs now have a strong commitment to training, and 80% of the instructors for these courses have been from national potato programs.

The use of rapid multiplication techniques in basic seed programs and for the commercial production of rooted planting materials received attention through individual training of 15 scientists, 10 of whom were trained at CIP's Regional Germplasm Distribution Center at Sta. Lucia in the Philippines. These ten, including six scientists from Vietnam, were also trained

in TPS agronomy. In Vietnam, where there is an increase in the acreage of crops grown from TPS, an in-country course was attended by 40 participants. The first course on TPS in Africa was held in Kenya and Rwanda, and four scientists from East and Central Africa also received individual training.

THRUST X

Potato and Sweet Potato in Food Systems

A computerized Root Crop Data Bank, containing up-to-date production and use statistics, has been established at CIP, and an analysis of potato and sweet potato production trends has begun. During 1986 the International Potato Reference Files were expanded to include information on 103 countries. Farming systems surveys were carried out in Bhutan and Peru. In Bhutan, where the potato crop is expanding rapidly, seed growers are reaching the limit of potato-growing land in the recommended three-year rotation plan. In Peru, where potatoes are the principal highland crop, fallow systems and fertilization methods were studied. Results from Peru could be applicable in other highland areas such as the Himalayas. In Peru and Bhutan, most commercial farmers plant their land with two or three main potato varieties. Older varieties, valued for their culinary quality and storability, are grown on a small scale mainly for home consumption.

A Rwanda study indicated the value of decentralizing varietal testing and maintaining genetic diversity at the farm level. Applied research in Central Peru showed the feasibility of actively involving small farmers in seed production and distribution schemes. A study revealed that farmers used true potato seed as a source of disease-free initial seed stock and kept tubers for seed up to eight generations. Marketing surveys in Central Africa revealed that farmers there sell less than half their output. In Zaire, due to high transport costs and marketing margins, farmers receive less than 10% of the price consumers pay in Kinshasa. A study in Bangladesh showed that farmers sell about 75% of their harvest and receive between 50% and 60% of the retail price.

Potato programs were assessed in Tunisia, South Korea, and the Philippines to document the costs and benefits of successful programs and to learn how these and other programs may be improved in the future. Country-level studies were conducted jointly with national institutions on: farming systems, adoption of new technologies, farmer participation in seed systems, marketing, demand and performance of potato programs. Options have been discussed with appropriate governmental officials for improving potato production, marketing, and the performance of national programs.

This child in China is carrying home sweet potato foliage as a valuable source of nutrition for the family's livestock.

PATTERNS AND TRENDS IN ROOT CROP PRODUCTION

Root crop data bank. A computerized bank has been established with national level data on production and use of potatoes, sweet potatoes, cassava, yams, and cocoyams and to lay the groundwork for several statistical serial publications. A computerized data base has been established for statistics obtained from FAO's Basic Data Unit for all countries and regions of the world. Annual statistics are included for the period 1961-1985. Variables include population, GNP per capita, total food production, total cropland area, and the area, production, yield, and farm-gate prices of all root crops. Food balance sheet statistics on the diverse sources and uses of each root crop have also been included for selected years. These include production, imports, exports, net change in stocks, total domestic availability, and use for feed, seed, industry, and food. Initial data processing has been completed for potatoes and sweet potatoes.

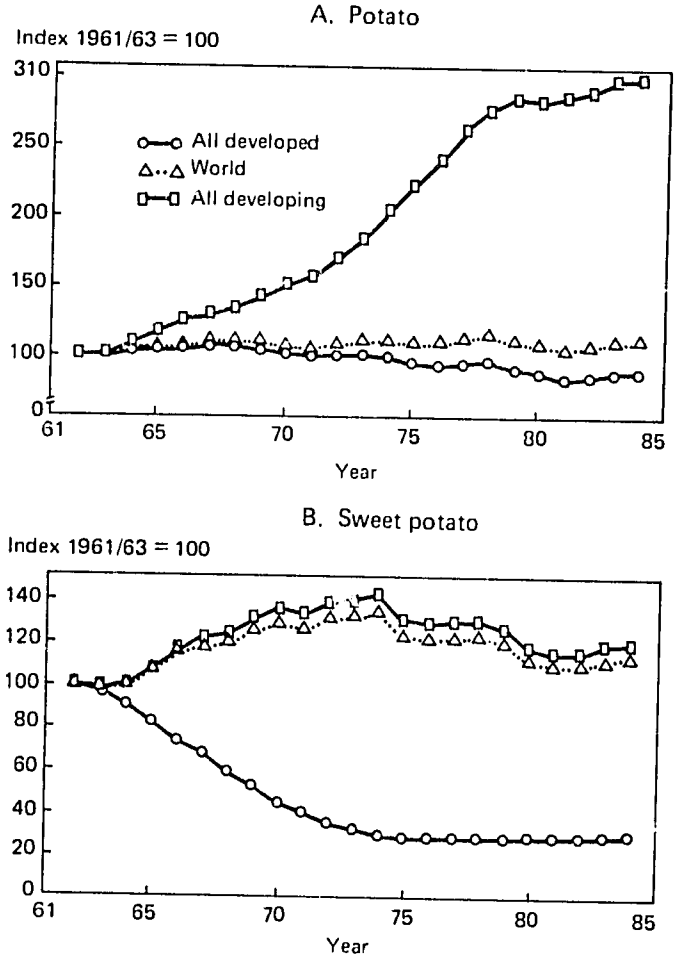


Figure 1. World trends in (A) potato and (B) sweet potato production, 1961-1985.

Since the early 1960s, potato production has tripled in developing countries, but has remained about constant in developed countries (Fig. 1A). Potato production continues to increase rapidly in most of Africa and Asia, with a slower increase in Latin America. China and India are the largest potato-producing countries in the developing world. China produces nearly 60% of the developing regions' potatoes, whereas other Asian and Middle Eastern countries produce about 25%, Latin America is just under 15%, and Africa less than 5% (Table 1). Annual potato production averages 175 kg per head in developed countries compared to only 25 kg per head in developing regions. Most of the potatoes in developed countries are used for livestock feed or are processed, whereas in developing countries most are consumed fresh. Since the early 1960s, production per head has dropped about one quarter in the developed countries, but has increased by 80% in the developing regions.

World sweet potato production has remained relatively constant since the 1960s (Fig. 1B). Production has fallen by about 70% in developed countries and increased by about 20% in developing regions. About 80% of the world's sweet potatoes are grown in China (Fig. 2) and virtually all (98%) are grown in developing countries (Table 2). Hence, world trends in sweet potato production and use are dominated by trends in China. Among the developing regions, other Asian countries account for about 6% of production, Africa for 5%, and Latin America 2%. Annual sweet potato production per head averages only 2 kg in the developed countries versus 32 kg in developing countries. China's per capita production is about 90 kg, while in all other developing countries it averages less than 10 kg. Some countries, however, including the Solomon Islands, Tonga, Rwanda, Burundi, Papua New Guinea, and Uganda, report annual production of over 100 kg per head.

International Potato Reference Files. During 1986, information on six additional countries was acquired for the files, bringing the total to 103. The International Potato Reference Files have been

Table 1. World potato production, area, yield, and production per capita for 1983-85 and percent change in these variables from 1961-63 to 1983-85.

	Average 1983-85				Percent change 1961-63 to 1983-85			
Region	Area (000 ha)	Yield (t/ha)	Production (000 t)	Production/capita (kg)	Area	Yield	Production	Production/capita
World	20,333	14.7	299,446	63	−14	31	13	−25
Africa	741	8.3	6,185	11	159	14	194	60
Asia	5,894	12.7	74,939	27	48	114	217	100
Europe	5,298	20.0	106,151	216	−41	26	−25	−34
Oceania	49	25.4	1,243	51	−6	67	57	7
North/Central America	744	27.7	20,639	52	−0	36	36	−4
South America	893	11.0	9,814	37	−7	58	47	−13
All developing countries	7,421	11.8	87,324	25	48	105	203	83
All developed countries	12,912	16.4	212,122	176	−31	29	−10	−26

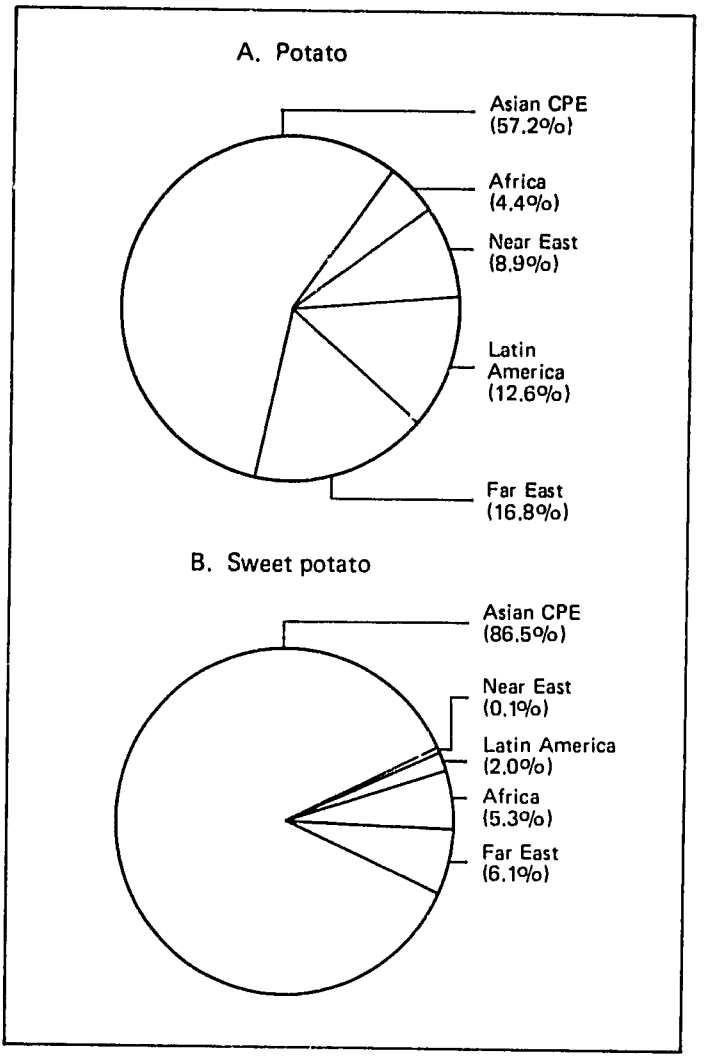


Figure 2. Ten largest potato and sweet potato producing countries in the developing world, 1981-1983.

expanded to accommodate sweet potato and a few entries have now been made. At an international CGIAR-FAO conference in Rome on agroecological characterization and mapping, information was acquired on programs, cartography needs, and types of data base analysis needed for optimal exploitation of information in the files. Regional studies on Yurimaguas, Cañete, and Chanchamayo (San Ramon) in Peru have been prepared for publication.

POTATO FARMING SYSTEMS

Bhutan. A study of the potato in the farming system of Bhumthang District was conducted as part of a 1986 evaluation of the Bhutan national potato program. Potatoes are a rapidly expanding crop in Bhu-

Table 2. World sweet potato production, area, yield, and production per capita for 1983-85 and percent change in these variables from 1961-63 to 1983-85.

Region	Average 1983-85				Percent change 1961-63 to 1983-85			
	Area (000 ha)	Yield (t/ha)	Production (000 t)	Production/capita (kg)	Area	Yield	Production	Production/capita
World	7,998	14.3	114,185	24	−33	70	13	−25
Africa	1,094	5.6	6,100	11	69	5	78	−3
Asia	6,413	16.3	104,603	38	−41	89	−44	−51
Europe	10	11.1	108	0	−44	1	−44	−51
Oceania	116	4.8	560	23	35	12	52	3
North/Central America	213	6.8	1,442	4	11	−1	10	−23
South America	153	9.0	1,371	5	−32	−7	−37	−63
All developing countries	7,867	14.2	111,979	32	−32	76	20	−27
All developed countries	131	16.8	2,206	2	−70	−2	−70	−76

tan and government authorities are becoming concerned that farmers are not practicing a three-year rotation, since farmers are planting more and more of their land to potato. A survey of 73 farmers in Bhumthang District was undertaken to explore present cropping patterns.

Figure 3 illustrates the cropping pattern of the land under cultivation for Bhutan's five main crops. It does not include land that is fallow, in pasture, or under other crops such as maize and mustard. Potatoes, wheat, and bitter buckwheat each occupy approximately one fourth of the

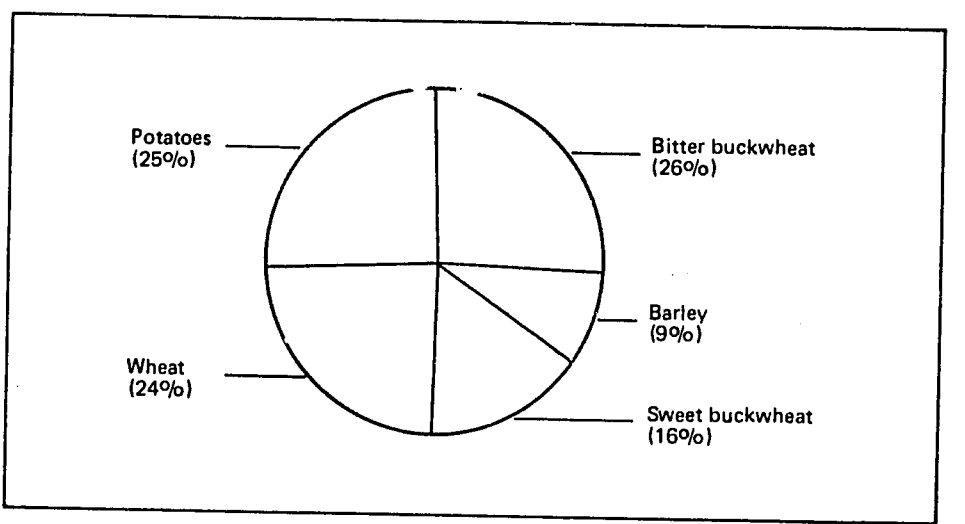


Figure 3. Cropping pattern in Bhumtang District, Bhutan, 1986.

cultivated areas, followed by sweet buckwheat and barley. This illustrates the great importance potatoes now have in Bhumthang's cropping system.

The survey data were analyzed to compare seed program and nonprogram growers. Seed growers have approximately 30% of their land planted to potato and sow less wheat and barley than nonprogram growers. There is little difference between seed growers and nonprogram growers in the percentages of land sown to bitter and sweet buckwheat (43% in each case). Seed growers are beginning to reach the maximum land area that can be planted to potato under a three-year rotation plan. A recommendation was made by the evaluation mission that future research should be undertaken on proper rotations and alternative cash crops.

Peru. In addition to an in-depth study of potato systems in the highland Peruvian community of Marcapata (reported in *Ann. Rep. 1985*), a comparative study was also conducted in several regions of the southern Central Andes to characterize the Andean potato farming system and technological change. An important and

This farm family in the Peruvian highlands near Cusco are preparing their land for a potato crop, using an Andean foot plow (chaquitaclla).

Table 3. Results of soil surveys for the Marcapata Valley and Titicaca high plateau, Peru, 1981.

Variable	Min. level for growing potato	Valley Marcapata Series[a]		High plateau Titicaca Series[a]		With dung[b]
		A	B	C	D	
Depth (cm)		0-20	0-20	0-20	0-20	0-20
NO_3NC (mg/100 g)	10.0	2.0	<2.0	4.0	<1.0	25.0
P_2O_5 (mg/100 g)	5.0	2.0	2.5	10.0	2.8	20.0
K_2O (mg/100 g)	5.0	0.0	0.0	0.0	3.0	15.0
CaO (mg/100 g)	15.0	<70	<70	100	150	150

[a] Note: A and B = fields fallowed for four years; C = field fallowed for eight years; D = field fallowed for three years.
[b] Fertilized with dung using movable corral.

little-studied aspect of the farming system is a fallow system associated with potato cultivation. This fallow system is the most pervasive form of land management in the Andean highlands and is considered to be an important means for effective recovery and maintenance of soil quality.

Preliminary analyses of soil samples from Marcapata and the Lake Titicaca regions indicated that fallowing did not significantly increase soil fertility (Table 3).

The use of animal dung as fertilizer is critically important for most potato producers, not only in the Andes but in other highland areas such as the Himalayas. Therefore, farm-level fertilizing methods as well as fallow systems practiced by Andean farmers should be studied and analyzed. Fertilization using movable corrals could be an appropriate technique for agropastoralists in highland areas throughout the developing world. Farmers using this method keep their sheep at night in movable corrals in fallowed fields that will later be planted with potatoes. In the Andes, these corrals are about 10 m^2 and are moved from place to place every few days. Thus, in the course of one year, the potato field will be intensively fertilized with animal urine as well as dung.

ADOPTION OF NEW TECHNOLOGIES

Potato varieties in Peru and Bhutan. Farm-level adoption of potato varieties was investigated in Peru and Bhutan in 1986. In Peru, 159 farmers were interviewed in several regions, while in Bhutan 73 were surveyed in the Bhumtang District. Although both countries possess high mountain ecologies, they represent contrasting types of potato production systems. Peru has thousands of native and improved varieties grown in complex production systems, while Bhutan is only now expanding its production with a few European varieties introduced over the past two decades. In the Peruvian highland areas the potato is a staple food crop but in Bhutan it is considered a vegetable. In both countries, commercial production is expanding rapidly and the need for improved potato technology is great. In Bhutan, potatoes are the key crop in generating a transformation from a subsistence to a cash economy in the rural sector.

Although Peruvian farmers have access to a far greater number of potato varieties than the Bhutanese, they still put most of their land in two or three main varieties if production is for the market. In both countries, local or older varieties are

valued for their culinary quality and storability and are planted in small stands or kitchen gardens. Due to higher yields and disease resistances, improved varieties are grown for the market. Despite their reliance on a few varieties, both Peruvian and Bhutanese farmers constantly seek and experiment with new varieties. The farmer's interest in, and adoption of, varieties is not always in accordance with the varieties being supported by the national seed programs; for example, the variety being promoted by Bhutan's seed program, Kufri Jyoti, is not in as much demand as the varieties Desirée or Maritta.

Potato varieties in Rwanda. Two dozen local cultivars collected from farmers and planted at the Rwandese experiment station at Ruhengeri (1850 m) were harvested in March 1986. These local varieties, as well as others previously harvested on the research station, were then planted in on-station late blight trials. Data from a survey of 186 potato farmers in four agroecological zones are being analyzed. On the basis of this work, the following recommendations were presented to the national potato program (PNAP) and to the Institute of Agronomic Sciences (ISAR).

- It would be desirable to increase decentralization of potato germplasm screening in order to include sites in more of the important potato production zones (particularly the lateritic soil, the zone of the Buberuka highlands, or the forest soils of the Zaire-Nile Crest).
- It would be important for extension and training efforts to emphasize the need for varietal diversity to counter the trends toward specialization in one or two commercially popular varieties with declining late blight resistance.
- It is necessary to give greater emphasis in the germplasm screening program to cultivars with shorter vegetative cycles and shorter dormancies.

Peruvian highlanders maintain several potato varieties for their preferred culinary qualities, storability, and adaptation to local growing conditions.

Table 4. Results of seed diffusion trials in the central highlands of Peru, 1985-86.

Farmer location	Altitude (m)	Variety	Amount planted (kg)	Amount harvested (kg)	Yield (t/ha)
La Libertad	3700	Mariva	200	1356	17
Chiche	3760	Mariva	146	1358	20
Chiche	3820	Mariva	200	1225	18
Jarpa	3780	Yungay	200	1010	9
Cauquian	3900	Perricholi	200	1127	16
Palcomayo	3500	Tomasa Condemayta	150	1112	25
Shacamarca	3850	Tomasa Condemayta	50	715	25
Ulcumayo	3860	Perricholi	100	914	22
Ulcumayo	3880	Perricholi	140	2593	30
Ulcumayo	3880	Mariva	100	2112	45
Acopalca	3660	Perricholi	200	1895	2[illegible]
Cochambra	3350	Perricholi	200	1651	17

- It would be desirable to develop additional means of distributing seed of the new varieties released by PNAP.

True potato seed use in China. A survey on farmer acceptance of true potato seed (TPS) was conducted in Southwest China where approximately 14,000 ha of potatoes are grown from TPS and its subsequent tuber generations. This figure includes 23 ha from TPS transplants and the remainder are tubers going up to the eighth generation. It was found that most farmers do mass selection by grouping tubers according to similar shape and color and multiply these as a unit. All farmers surveyed expressed an interest in continuing the use of TPS; their major problem, however, is the supply of good quality TPS with a high germination rate.

SMALL FARMER PARTICIPATION IN NATIONAL SEED PROGRAMS

Research in Peru's central highlands has explored the potential of small farmers and communities for producing high quality seed and has studied possible means of linking the existing informal seed systems of the small farmer with formal seed programs.

Results of 12 trials in 1986 indicate an untapped potential of small farmers and communities for seed production. As Table 4 shows, overall yields were good, especially when compared with the averages for the region. The notably poor result in the community of Jarpa was due to severe attack of the Andean tuber weevil (*Premnotrypes suturicallus*), hail, and a low level of community enthusiasm. This site was chosen for *negative* reasons, i.e., not for the presence of existing seed flows but for the shortage of seed and farmers' practice of obtaining poor quality seed tubers from a distant market. It is mainly a livestock zone with potatoes grown for subsistence consumption. A different strategy may be necessary in such areas.

The transfer of knowledge about seed has also been generally encouraging. Use of diffused light for seed storage has been taken up in 6 of the 12 experimental sites. Because of high altitudes and planting

schedules it was not appropriate in some of the other sites. There is a high level of enthusiasm for continuing seed multiplications with the same variety and also for obtaining new varieties. In only 2 of the 12 sites, some seed was sold as consumer potatoes. In one of these, the farmer failed to understand the value of the seed; even though he achieved one of the highest yields, he was worried that the variety would not sell as "colored" potato for the higher price. In the other site a family member who had not been directly involved in the experiment sold the seed.

It is still too early to evaluate the potential of this approach for diffusing seed through existing informal channels. Distribution this year was limited to exchange within communities, as was expected and intended. In all sites the community itself has maintained part of the seed for further multiplication. At the time of writing, eight cooperating farmers had sold, loaned, bartered, or given the seed to a further 34 farming families, with exchanges for the coming planting season still taking place. This is a slightly lower level than expected, partly because some farmers failed to pursue traditional diffusion practices with a nontraditional, high-value seed. Also, demand may have been limited by the lack of communication concerning the quality of the new seed.

MARKETING AND DEMAND

Marketing surveys for Central Africa (Burundi, Rwanda, and Zaire) and Bangladesh were completed during 1986.

Central Africa. The total area planted to potato in the three African countries is around 90,000 ha. About half of this total is in Rwanda where the area planted doubled in the last ten years. In Zaire, the area planted increased from 13,500 ha in 1973-74 to 35,000 ha in 1983-84. The average per capita potato consumption in Rwanda has nearly doubled in the last ten years to about 50 kg. In Burundi and Zaire, potato consumption is more widespread than previously believed, although the average per capita consumption levels remain modest (about 2 kg/year in Burundi, and 4 kg/year in Zaire).

Growers in Burundi, Rwanda, and Zaire sell approximately 10%, 45%, and 25% of their potato production, respectively. Potato sales are an important source of cash income for potato producers in all of these countries. Growers receive about 40% of the retail price in Burundi and Rwanda, and in Zaire they receive less than 10% of the price paid by consumers in the capital of Kinshasa. This reflects the small volume sold, high marketing costs, and risks and the extended marketing chain.

Recommendations have been made available to national program leaders in each of these countries. Common themes include the importance of sustaining increases in potato production to feed expanding rural populations, as well as the need for applied research and extension to improve potato marketing and to promote greater urban consumption.

Bangladesh. Potato production increased in Bangladesh from 759,000 tons in 1973 to over 1.1 million tons in 1985, and the area planted expanded by 20,000 ha. Yields increased modestly from 9.6 t/ha to 10.0 t/ha. Principal contributing factors to the growth in production have been the availability of imported, high yielding varieties, growth in cold storage capacity, an effective seed multiplication program, and an expanding rural and urban demand for food. The average per capita potato consumption in Bangladesh is about 15 kg. This represents a 200% increase since the mid-1970s and reflects the desire for a more diversified diet, increased

In Rwanda, potatoes are often hauled over long distances to urban markets in specially made baskets.

availability of potatoes on a year-round basis, and a sharp decline in the relative price of potato versus other foods.

Growers sell about 75% of the potatoes they produce, with a minimum of exports. Instead, the bulk of the potatoes are sold in local, rural marketing channels. Despite the rise in current wholesale prices for potatoes, average monthly wholesale prices in real terms (current prices deflated by the index of wholesale food prices) were 50% lower in 1982-84 than a decade earlier. Seasonal price fluctuations have also declined. Nevertheless, the expansion in cold storage capacity—by over 200,000 tons since 1980—has helped keep storage costs and profit margins relatively low. In 1985 growers received, on the average, between 50% and 60% of the final retail price of potatoes.

Recommendations to improve future marketing prospects for potatoes in Bangladesh emphasize the need to:

- Reduce production costs by lowering seed costs and improving fertilizer use
- Release adapted varieties that give growers greater flexibility in setting planting and harvest dates
- Improve coordination between government agencies in granting licenses to construct new cold stores
- Expand activities of the Bangladesh Agricultural Marketing Department to include preparation of crop situation reports, a broader dissemination of market information, and an expansion in postharvest extension work.

ASSESSMENT OF POTATO PROGRAMS

During 1986, CIP collaborated with Tunisia's Groupement Interprofessionnel des Legumes (GIL), Korea's Rural Development Administration (RDA) Korea, and the Southeast Asia Program for Potato Research and Development (SAPPRAD) in conducting case studies of potato programs.

Tunisia. The Tunisian seed potato program has generated an extraordinarily high

economic rate of return of about 70%. Private farmers using program seed and others who have learned to improve their own seed management practices have increased their incomes, and the seed program has become a viable component of Tunisia's agricultural research and extension system.

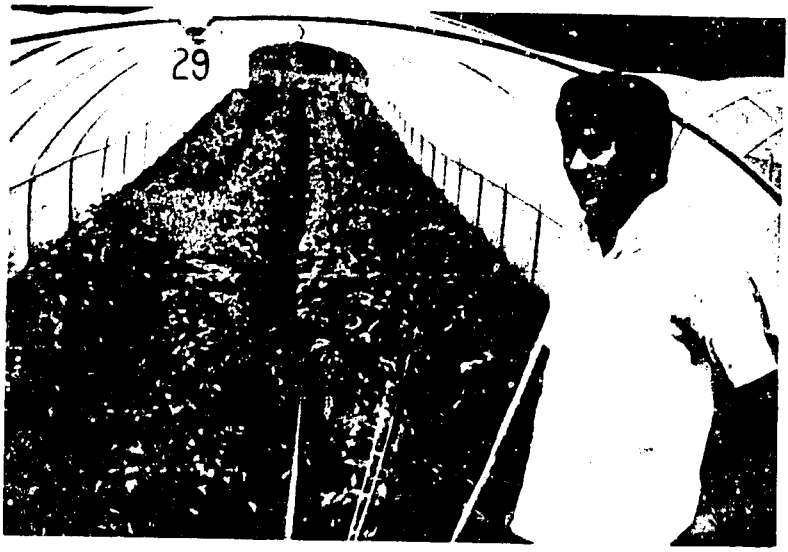
Several factors have contributed to the program's success: working within the existing institutional framework; establishing a Technical Committee to coordinate activities of the various institutions involved; following problem-solving approach; and using on-farm research to set priorities and test potential solutions. The program was patterned on a model to meet local needs, and a relatively simple technical scheme was implemented that economized on scarce capital resources and personnel.

Korea. Formerly, most potatoes were grown during the summer in South Korea's mountainous areas, but over time a growing share of the crop has been grown in the lowlands. In the 1960s and early 1970s, average potato yields remained low, mainly because farmers could not obtain good quality planting material. From 1975 to 1978, potato yields dropped about 40% and total production fell by more than half due to a collapse of the seed potato certification program.

In the late 1970s, the government reorganized its seed program and established a basic seed scheme in which tissue culture was used for producing, storing, and rapidly multiplying virus-free planting material. Techniques for field multiplication, inspection, and pathogen testing of foundation, registered, and certified seed were also improved, and quality checks became more systematic throughout the system.

As a result of the new seed program, virus disease symptoms in farmers' fields have been sharply reduced and yields have increased spectacularly—from an average of 11 t/ha in the 1970s to over 18 t/ha at present. A conservative estimate is

Tunisia's seed program has contributed to a significant increase in potato yields, production, and farmers' incomes.



A Korean scientist shows one of over 200 screenhouses in which basic seed is grown. South Korea's seed program has helped farmers to double their yields over the last ten years.

that the seed program's net benefit in 1984 was around US$20 million. For every dollar spent, the program generated about $25 in increased farm incomes. Consumers also benefited from a reduction in potato prices.

While the new seed program has been a technical and economic success, some institutional issues remain. Only 15% of the seed potatoes that farmers use each year are certified; the rest come from an "informal" seed system which runs parallel to the "official" seed program. The total benefits of the seed program could perhaps be increased by improving the integration of the official and informal systems.

Philippines. The Philippine government is committed to diversifying lowland crop production and expanding potato production as a means of increasing poor farmers' incomes and poor consumers' diets. A preliminary study of the potential impact of the Philippines' lowland potato project was carried out in 1986. It was concluded that expanded lowland production could make potatoes available to people in many rural areas for the first time. It would also reduce potato prices and stimulate increased consumption in the cities. These two factors together could allow the potato to raise nutritional standards in the country's rice-based diet, as well as to provide an important new source of rural employment and income.

The most critical barrier to expanded potato production in the lowlands was found to be the lack of planting material. Pest management problems will need to be addressed on a continuing basis through research and extension. Special credit and marketing programs may be needed in the initial stages to stimulate farmers to rapidly expand lowland potato acreage. A dual system is likely to evolve in the lowlands, with many small farmers producing potatoes for local consumption in small garden plots and a few large producers supplying major urban markets.

National Human Resource Development - Biotechnology

Researchers, extensionists, and educators from national institutions are paramount to improving food availability worldwide. How well this important task is performed depends largely on their capacity to access and receive information on improved technologies and adapt what is appropriate to their farmers' environments. The application of biotechnology techniques for crop improvement requires that particular emphasis be placed on ensuring that necessary skills exist in national institutions. It is for this reason that this section concentrates on CIP's past efforts on human resource development in biotechnology.

Introduction

CIP's program for national human resource development is designed to complement its headquarters and regional research efforts. The activities of this program are designed to enable national collaborators to conduct basic and applied research and to respond to farm-level production problems. A summary of activities associated with each CIP research thrust is included in the respective thrust chapter, and a list of all training undertaken in 1986 is given in Table 1.

Biotechnology is an important part of CIP's research base, and collaborating national programs have been requesting training in this topic. In response to this need, biotechnology and its application have been integrated into CIP's human resource development program. This section focuses on the contributions made to this Center-wide effort by CIP's Training Program, Communications Support, and Information Services.

Training Program

Each year the training program provides opportunities for personal interaction between CIP's scientific staff and large numbers of national collaborators. In 1986, there was a total of 953 participants in training activities worldwide. Some of these activities concentrated on specific areas of biotechnology, such as the course held in Peru on potato, sweet potato, and cassava micropropagation techniques. This course was a joint activity with CIAT, and was part of a UNDP-sponsored root and tuber crops training project also involving IITA.

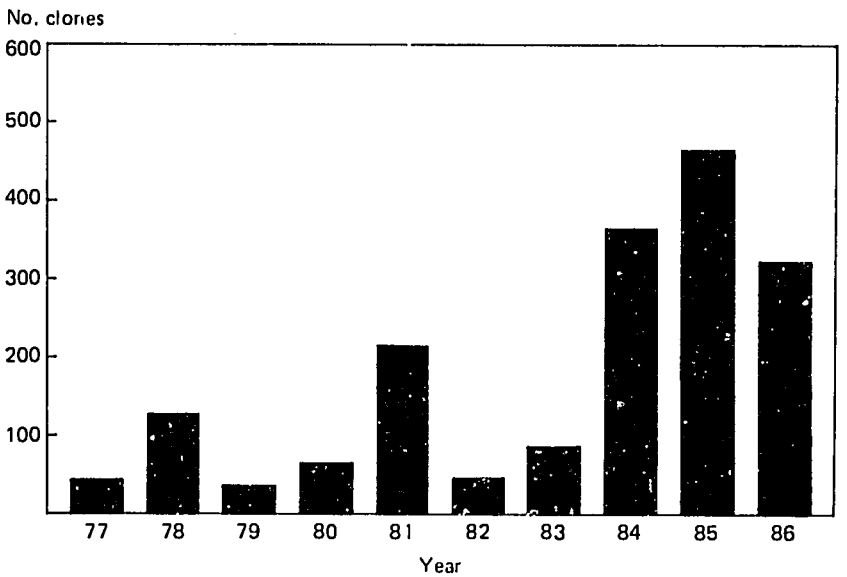


Figure 1. Number of in vitro clones distributed to national programs between 1977 and 1986.

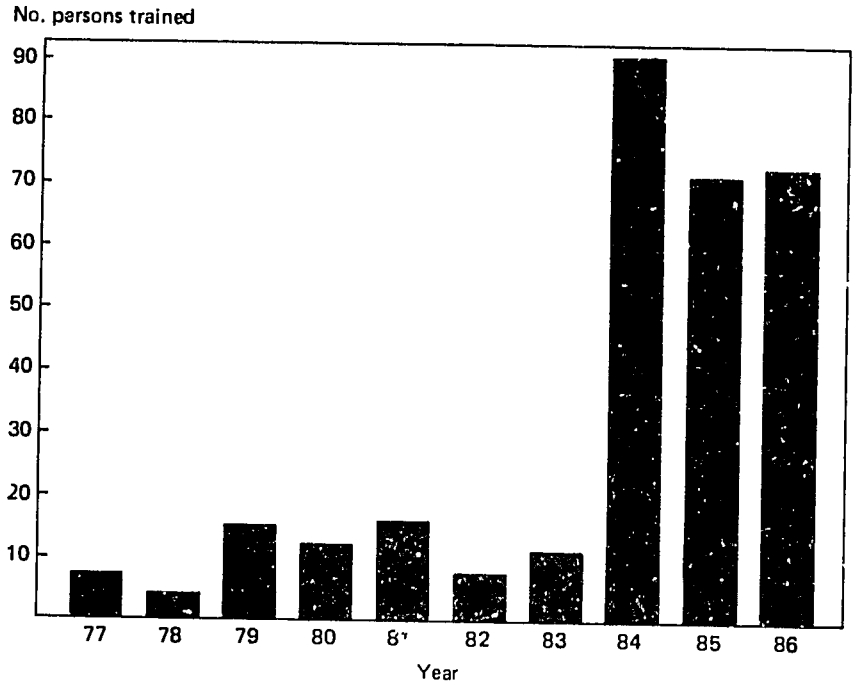


Figure 2. National collaborating scientists trained by CIP in micropropagation and rapid multiplication techniques between 1977 and 1986.

Some biotechnological techniques, such as micropropagation and serology, have been included in seed production courses. Additionally, because rapid multiplication of in vitro plantlets is necessary in national seed production systems, this technique is closely linked with training on micropropagation.

Training conducted on biotechnological techniques has had an effect on the amount of in vitro material distributed to national programs from headquarters in Peru and CIP's germplasm redistribution centers in the Philippines and Kenya. From Peru, in 1977, 44 clones were sent to three national programs. This number increased to 213 clones to seven national programs in 1981, and to 321 clones to 15 countries in 1986. To date, more than 1700 clones have been distributed to 33 national programs (Fig. 1).

Concurrently, the number of persons receiving training each year in micropropagation and rapid multiplication techniques increased from 7 in 1977 to 76 in 1986 (Fig. 2). During this period, 310 persons from 42 countries have received training.

As early as 1976, CIP began receiving visiting scientists at headquarters in Peru for individual training on micropropagation and in vitro pathogen elimination. In the past 11 years, 40 scientists from 19 countries have been trained. Between 1981 and 1986, CIP conducted eight courses, three of which were in collaboration with CIAT and two with IITA. There were 66 CIP participants from 29 countries in these courses.

Table 1. CIP training activities for CIP headquarters and Regions I-VI, 1986.

Region	Activity	No. of participants	No. of countries
Headquarters-Peru			
	Tissue culture of potato, cassava, and sweet potato (CIP/CIAT)[c]	14	9
	Workshop on processing of potato-based-mixes	20	1
Visiting scientists[a]		63	29
Scholarships		20	9
Student assistantships		26	1
Preprofessional practice[b]		55	5
Region I			
Bolivia	Nematodes of potato	20	2
Colombia	Integrated pest management	12	9
Peru	Production with special emphasis on seed production[c]	15	7
Region II			
Argentina	Seed production and certification[c]	20	3
Brazil	Production	33	3
Chile	Production[c]	20	8
Panama	Nematodes of potato	17	8
Paraguay	Production	28	1
Region III			
Burundi	Production	8	1
Burundi	Production	3	1
Ethiopia	Storage	27	1
Kenya and Rwanda	Potato production from true seed	9	7
Madagascar	Seed tuber production conference[c]	38	10
Zaire	Production	25	1
Zambia	Storage	18	1
Region IV			
Jordan	Production	30	1
Turkey	Serological detection of potato viruses	12	1
Turkey	Germplasm management	14	6
Region V			
Senegal	Production	17	8
Tunisia	Seed production and storage	22	1
Region VI			
Bangladesh	Storage in warm climates and utilization workshop[c]	34	6
India	Village-level processing	9	1
India	Modern methods in potato production	37	4
Nepal	Field-level virology	14	3

[a] 35 trained at headquarters and 28 in the regions.
[b] 48 from Peru; 7 from developed countries.
[c] United Nations Development Programme (UNDP).

Table 1 (cont.). CIP training activities for CIP headquarters and Region VII and SAPPRAD,[d] 1986.

Region	Activity	No. of participants	No. of countries
Region VII			
Burma	Seed potato production	45	1
Laos	Production[c]	15	1
New Caledonia	Potato production technology for the Pacific[c]	20	5
Philippines	Nematology research planning workshop	9	7
Philippines	Potato production in the warm tropics	21	8
Philippines	Second international workshop on biological control of nematodes	49	11
Vietnam	True potato seed and rapid multiplication	40	1
SAPPRAD			
Philippines	Lowland potato conference and development workshop	35	1
Philippines	Marketing workshop	11	1
Philippines	Southeast Asia and Pacific seed potato production	28	6

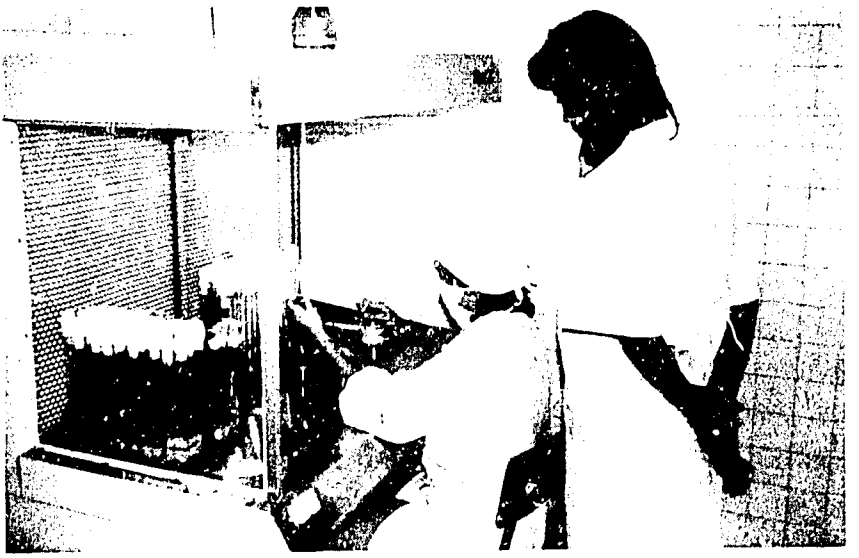
[c] United Nations Development Programme (UNDP).
[d] Southeast Asian Program for Potato Research and Development.

Follow-up and refresher training is important in biotechnology, particularly as it relates to new and more efficient methods for virus detection. These methods are fully integrated in the activities organized for visiting scientists. The degree to which the methods are addressed depends on national capacity to make use of them. Numerous visiting scientists have received instruction on the nucleic acid spot hybridization test for the detection and elimination of potato spindle tuber viroid and on the production of antisera for use in the enzyme-linked immunosorbent assay to detect viral and bacterial pathogens.

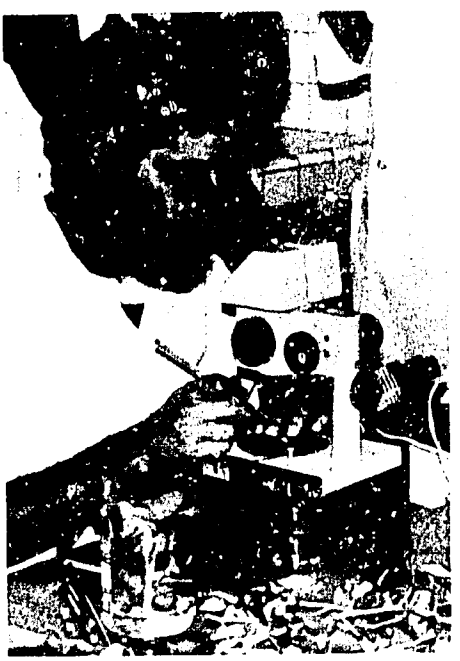
An example of training on new biotechnological methods was that given to a geneticist from Argentina's national research institution (INTA): to enable ploidy manipulation, experience was provided on haploid extraction, an inheritance study was carried out on 2n pollen production, and a new method for megasporogenesis observation was developed. These methods will be applied in making more efficient use of native and wild potato species for virus resistance breeding in Argentina.

Communications Support

In order for national researchers to make effective use of the latest biotechnological research results, the findings must be converted to information which should reach them in a usable form. This communication process hinges on close cooperation between CIP's scientists and staff of the Training



Although some national programs are using rustic facilities and equipment designed on the principles of sophisticated equipment, some have demonstrated the value of biotechnology techniques to their governments and have acquired modern equipment to improve seed production, as shown here in Cuba.



Much of the successes enjoyed by national programs in incorporating biotechnology techniques into potato improvement efforts have been due to individualized instruction received under close supervision by CIP scientists. This type of experience is usually given at CIP headquarters in Lima and is not only intensive but also of sufficient duration to permit visiting scientists to see the results of their work prior to their departure.

An example in the use of biotechnology techniques is the collaboration received from the Universidad Nacional Pedro Ruiz Gallo in Lambayeque, Peru, on a cassava, potato, and sweet potato tissue culture course. The University permitted the use of their facilities and participation of their professorial staff to teach part of the course. This particular course was conducted jointly between CIAT and CIP as part of a special training project funded by the United Nations Development Programme.

and Communication Department. In addition to editing several scientific papers and preparing visuals for presentations and poster displays at international conferences, a wide range of materials have been produced for use in training and for general distribution. The following have been prepared in English, Spanish, and French:

- slide set and guidebook on micropropagation techniques,
- poster on micropropagation techniques,
- three specialized technology documents on micropropagation techniques,
- four slide sets with accompanying guidebooks on rapid multiplication techniques,
- one set of ten flip charts on rapid multiplication techniques.

An instruction booklet to accompany each shipment of in vitro plantlets was produced in English and Spanish. Also, the quarterly *CIP Circular* has

CIP feels the best learning laboratory for applying biotechnology techniques is one where learning conditions are similar to those of the participants' home countries and where instructors have received training from CIP and had opportunities to apply what they have learned in their home countries.

included main features or research briefs from collaborating national programs on biotechnology and its application. Examples are

- "Tissue Culture: Past, Present, and Future"
- "CIP Collaborative Research on Tissue Culture and Genetic Engineering for Potato Improvement"
- "Induction and Use of In Vitro Potato Tubers"
- "A New Use for Tissue Culture and Rapid Multiplication: Potato Production for Vietnamese Farmers"

Information Services

National collaborators must have access to the latest research results from CIP, as well as from other sources, to assist them in keeping abreast of the latest research activities and technological advances in their field. In 1985, a special project, funded by the International Development Research Center

Training away from headquarters in Peru permits CIP to conduct training in environments where conditions are more relevant to participants' research and production activities.

of Canada, was initiated to expand library services to national programs. The project is based primarily on the development of a computerized database of CIP's library collection and on providing access to a wide range of external databases. Additionally, the project is intended to encourage exchange of information among national programs, e.g., support the publication of potato research by national programs in regional scientific journals.

The following information service activities related to biotechnology have been completed:

- Subscriptions to journals such as *Agricell Reports*, *Plant Cell Reports*, *Plant Cell Tissue and Orga.. Culture*, *Plant Molecular Biology*, and *Trends in Biotechnology*. At the same time, a large number of books, reprints, and articles have been acquired.
- Numerous on-line bibliographic searches have been made in databases such as AGRICOLA, AGRIS, BIOSIS PREVIEWS, and CABI.
- Selective dissemination of information has been offered on a trial basis to CIP staff on topics such as "tissue culture of potato and sweet potato." This service will be extended to national research collaborators for accessing information held in external and CIP databases.
- A potato and sweet potato thesaurus for computer indexing and retrieving information from CIP's bibliographic database has been completed.
- A branch library was implemented at CIP's San Ramon experiment station and new acquisitions were placed in the library at the Huancayo station.
- Direct support to national scientists visiting CIP headquarters in Peru has been increased. Simultaneously, follow-up support upon return to their home countries has improved through photocopy services now available directly from the library.

Impact of Human Resource Development Efforts

While the impact of CIP's input is difficult to ascertain, the overall effect of applying biotechnological techniques may be seen in three national programs with whom CIP has had strong interaction.

Ecuador. Production of improved seed using clonal selection was taking seven to eight generations, and the resulting certified seed, not significantly better than traditional seed, was meeting less than 1% of the amount required.

Since 1976, 11 potato specialists from the National Agricultural Research Institute (INIAP) have undergone training on micropropagation and rapid multiplication techniques. In 1982, a building was converted to a simple in vitro laboratory, and a large planthouse was donated by the Ford Foundation. CIP provided in vitro pathogen-tested plantlets of three Ecuadorean varieties. The plantlets were multiplied to produce mother plants from which stem

cuttings were made and transplanted directly to the field. With this system, in four generations, approximately 4% of the certified seed requirements are being met and farmers are attributing a 25% increase in production to the improved seed now available. In order to promote continuity to this effort, an INIAP staff member is conducting research at CIP headquarters on biotechnological applications in seed programs for a Master's Degree at the National Agrarian University at La Molina, Lima.

Venezuela. In 1985, CIP provided in vitro plantlets of three varieties to the National Agricultural Research Institute (FONAIAP). These were multiplied to produce large quantities of mother plants from which single-node cuttings were made. These were transplanted to beds for mini-tuber production. Mini-tuber production is now continuous throughout the year at four regional sites.

Using this system, FONAIAP produced, in 1986, 1.25 t of pre-basic seed (mini-tubers), 24.7 t of basic seed, and 84.5 t of foundation seed. By late 1987, they expect to meet 40% of the certified seed demand for the high-altitude crop which comprises 49% of the country's 17,000 ha under potato production.

Since 1980, six researchers from FONAIAP and a national university have participated in training on micropropagation and rapid multiplication techniques. Additionally, a FONAIAP staff member conducted research at CIP headquarters on the variability of potato leafroll virus for a Master's Degree at the University of Costa Rica.

Vietnam. Two entirely different systems using biotechnology have evolved in Dalat and the Red River Delta, the two principal areas of potato production.

In the Dalat area, a few selected farmers produce large quantities of in vitro plantlets using rustic facilities in their homes. From these, nodal cuttings are rooted in nursery beds at high densities to become first generation mother plants. Apical cuttings are made from these to produce a larger generation of mother plants. From all these mother plants, apical cuttings are then taken and rooted in small bamboo or banana-leaf pots and sold to farmers who transplant them directly to the field. This material is used for up to four generations before it is replaced with new rooted apical cuttings.

In the Red River Delta, seed storage is difficult during the nine months of hot weather. National research proved that sprout cuttings taken from tubers stored seven to nine months rooted well, and when transplanted to the field gave yields of up to 20 t/ha. By using tubers and sprouts, investment in seed tubers is only 15% of the costs of planting tubers alone. In 1986, 100 ha of potatoes were grown using this system.

The impact that has been made using biotechnological techniques has been possible due to intensive training of scientists, technicians, and farmers. Since 1981, more than 100 Vietnamese have participated in CIP training activities on micropropagation and related topics. Of these, six have received individualized training at CIP's regional site in the Philippines and two have gained experience in adapting biotechnological techniques through research with CIP for a Master's Degree at the University of the Philippines at Los Baños ■

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Research and Consultancy Contracts

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

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

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

Thrust II — Production and Distribution of Advanced Breeding Material

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

4. North Carolina State University, United States — Breeding and adaptation of cultivated diploid potato species. *F. L. Haynes*

5. I.V.P. Agricultural University, Netherlands — A breeding program to utilize the wild *Solanum* species of Mexico. *J. G. Th. Hermsen*

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

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

8. Agriculture Canada — A proposal to evaluate modern potato breeding materials and their nutritional values. *T. R. Tarn*

9. University of Tacna, Peru — Evaluation of sweet potato germplasm for tolerance to certain abiotic stresses under arid conditions. *R. Chávez*

10. Instituto Nacional de Investigación Agraria (INIPA), Peru — Evaluation of advanced clones from CIP and the national potato program of Peru. *D. Untiveros*

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

12. Aegean Regional Agricultural Research Institute (ARARI), Turkey — Potato germplasm evaluation and multiplication. *K. Temiz and B. Gomec*

13. Consorzio "Mario Neri" (ERSO), Italy — Selection of potato clones with high starch content. *A. Ferraresi and L. Concilio*

Thrust III — Control of Bacterial and Fungal Diseases

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

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

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

17. Department of Agriculture, Sri Lanka — Development of resistance and control of bacterial wilt for the mid and high elevations of Sri Lanka. *M. Velupillai*

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

19. National Agricultural Laboratories, Kenya — The reaction of selected potato clones to two races of *Pseudomonas solanacearum* in Kenya. *A. H. Ramos*

20. Institute for Potato Research, Poland — Breeding potatoes resistant to potato leafroll virus (PLRV). *E. Kapsa*

Thrust IV — Control of Virus and Virus-Like Diseases

21. Swiss Federal Agricultural Research Station, Switzerland — Development of monoclonal antibodies for potato virus identification. *P. Gugerli*

Thrust V — Integrated Pest Management

22. University of the Philippines, Los Baños, Philippines — Integrated control of nematodes and weeds by the use of biological control agents and solarization. *R. Davide*

23. North Carolina State University, United States — Evaluation of potato lines for resistance to the major species and races of root-knot nematodes (*Meloidogyne* spp.). *J. N. Sasser*

24. Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador — Evaluation of clones resistant to potato cyst nematode (*Globodera* spp.) in Ecuador. *R. Eguiguren and I. Revelo*

25. Universidad Nacional Agraria-La Molina, Peru — Consultancy on *Pratylenchus* spp. as important nematode pests of potatoes. *M. Canto*

26. Universidad Nacional Agraria-La Molina, Peru — Consultancy on biological and selective chemical control of insect pests of potato and sweet potato. *J. Sarmiento and Colleagues*

27. Institute for Pesticide Research, Netherlands — Isolation, identification, synthesis, and field testing of the sex pheromone of *Scrobipalpula absoluta*, *Symmetrischema plaeseosema* (Lepidoptera: Gelechiidae). *S. Voerman*

Thrust VI — Warm Climate Potato and Sweet Potato Production

28. Universidad Nacional Agraria-La Molina, Peru — Management of soils, fertilizers, and mineral nutrition of the potato under adverse soil and climatic environments. *S. Villagarcía*

29. Universidad Nacional Agraria-La Molina, Peru — Training and consultancy research on the effects of soil management and fertilization on flowering, fruit setting, and seed quality of the potato. *S. Villagarcía*

30. Universidad Nacional Agraria-La Molina, Peru — Consultancy contract on efficient use of nutrients by the potato plant. *U. Moreno*

Thrust VII — Cool Climate Potato and Sweet Potato Production

31. Instituto Colombiano Agropecuario (ICA), Colombia — Consultancy on potato breeding to obtain frost-tolerant clones adapted to Andean countries. *N. Estrada*

Thrust IX — Seed Technology

32. Victoria Department of Agriculture, Australia — Production of pathogen-tested potato germplasm for Southeast Asian and Pacific countries. *P. T. Jenkins*

33. Instituto Agropecuario (INIA) and Universidad Austral de Chile (UACH), Chile — Use of true potato seed in commercial potato production. *J. Santos Rojas and J. Banse*

34. Instituto di Agronomia, Universita de Napoli, Italy — Selection of TPS parental lines in high seed production. *L. Monti and L. Fruscianti*

35. Instituto de Investigaciones Agropecuarias (INIA), Chile — Production of true potato seed in Chile. *A. Cubillos and J. Kalazich*

Thrust X — Potato and Sweet Potato in Food Systems

36. International Potato Center, Peru — Consultancy on small-scale food production. *V. Niñez*

Support Department

37. International Potato Center, Peru — Consultancy on management of sweet potato germplasm. *R. del Carpio*

38. Consultancy Contract, Lima, Peru — Possible causes of damage to potato plants in CIP greenhouses. *U. Moreno*

Regional Research and Training

39. International Agricultural Center, Netherlands — Consultancy for regional research and training. *H. P. Beukema*

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Moreno Patiño

REPORT OF INDEPENDENT ACCOUNTANTS

March 6, 1987

To the Board of Trustees
International Potato Center - CIP

In our opinion, the accompanying information, presented in Exhibits 1 to 6 is stated fairly in all material respects in relation to the basic financial statements, taken as a whole, of the International Potato Center - CIP for the year ended December 31, 1986, which are covered by our report dated March 6, 1987 presented in the first section of this document. Our opinion in such report is qualified as to the method of accounting with respect to commitments as explained in the middle paragraph of such report. Our examination was made for the purpose of forming an opinion on the basic financial statements taken as a whole. This accompanying information is presented for purposes of additional analysis and is not a required part of the basic financial statements. Such information has been subjected to the auditing procedures applied in the examination of the basic financial statements.

Moreno Patiño

Countersigned by

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

INTERNATIONAL POTATO CENTER – CIP
BALANCE SHEET (NOTES 1 AND 2)
AS OF DECEMBER 31, 1986 AND 1985
(Expressed in U.S. dollars)

	1986	1985
ASSETS		
CURRENT ASSETS		
Cash and short-term deposits	3,215,983	1,224,653
Accounts receivable		
Donors	1,609,037	1,429,498
Advances to personnel	20,592	36,493
Loans to executives and employees – current portion (Note 3)	119,064	104,333
Others (Note 4)	229,280	202,137
	1,977,973	1,772,461
Inventories of laboratory and other supplies	517,495	469,613
Prepaid expenses and other assets	81,075	102,415
Total current assets	5,792,526	3,569,142
RESTRICTED FUNDS (Note 3)	300,000	400,000
LOANS TO EXECUTIVES AND EMPLOYEES – NON-CURRENT PORTION (Note 3)	357,034	411,792
FIXED ASSETS (Note 5)	10,487,260	9,271,377
	16,936,820	13,652,311

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

INTERNATIONAL POTATO CENTER – CIP

	1986	1985
LIABILITIES AND FUND BALANCES		
CURRENT LIABILITIES		
Bank overdrafts and current portion of long-term debt (Notes 3 and 6)	483,071	105,558
Accounts payable and other liabilities	1,871,373	1,035,118
Grants received in advance	–	643,992
Other payables and accrued expenses	197,253	50,225
Total current liabilities	2,551,697	1,834,893
LONG-TERM DEBT (Note 3)	283,760	403,576
PROVISION FOR SEVERANCE INDEMNITIES, net of advances of US$78,372 (US$42,039 in 1985)	457,411	385,512
FUND BALANCES		
Funds invested in fixed assets (Note 5)	10,487,260	9,271,377
Unexpended funds –		
Operating funds – Unrestricted	34,928	(1,784)
– Restricted	172,643	–
Working funds	1,300,000	880,000
Special projects	1,637,393	807,666
Cooperative activities	11,728	71,071
	3,156,692	1,756,953
GRANTS PLEDGED (Note 7)		
	16,936,820	13,652,311

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

INTERNATIONAL POTATO CENTER – CIP
STATEMENT OF REVENUE, EXPENDITURES AND CHANGES IN UNEXPENDED FUND BALANCES (NOTES 1 AND 2) FOR THE YEARS ENDED DECEMBER 31, 1986 AND 1985

(Expressed in U.S. dollars)

	1986	1985
REVENUE		
Operating grants:		
Unrestricted	8,881,253	6,100,959
Restricted	2,631,441	3,018,047
Other restricted core	582,945	–
	12,095,639	9,119,006
Special project grants	2,530,864	1,340,569
Grants for fixed asset additions	837,054	627,981
Grants for cooperative activities	251,506	274,460
Working fund grants	350,000	51,000
Other income, net	433,729	303,970
	16,498,792	11,716,986
EXPENDITURES		
Operating costs:		
Potato research program	3,455,313	2,560,824
Research services	1,489,915	1,263,528
Research program and training	2,817,074	2,842,433
Library, and information service	736,799	408,997
Administration cost	1,280,125	1,054,012
Other operating costs	2,060,486	1,344,496
	11,839,712	9,474,290
Other restricted core	615,706	–
Special projects	1,636,624	998,609
Grants returned	19,275	4,767
Cooperative activities	293,466	246,685
	14,404,783	10,724,351
Additions to fixed assets	837,054	627,981
	15,241,837	11,352,332
Excess of revenue over expenditures	1,256,955	364,654
Unexpended fund balance, beginning of year	1,756,953	1,392,299
Addition of SAPPRAD balances	142,784	–
UNEXPENDED FUND BALANCE, END OF YEAR	3,156,692	1,756,953

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

INTERNATIONAL POTATO CENTER – CIP
STATEMENT OF CHANGES IN FINANCIAL POSITION
FOR THE YEARS ENDED DECEMBER 31, 1986 AND 1985
(Expressed in U.S. dollars)

	1986	1985
SOURCE OF FUNDS		
Excess of revenue over expenditures	1,256,955	364,654
Decrease in inventories	–	90,797
Decrease in other assets	21,340	9,667
Increase in accounts payable and other liabilities	1,360,796	–
Increase in grants received in advance	–	643,992
Decrease in restricted funds	100,000	100,000
Decrease in loans to executives and employees non-current portion	54,758	159,923
Provision for severance indemnities	113,810	101,899
Assumption of SAPPRAD fund balance	142,784	–
Increase in funds invested in fixed assets	1,215,883	786,896
	4,266,326	2,257,828
APPLICATION OF FUNDS		
Purchase and replacement of property, plant and equipment		
– Core acquisitions	837,054	627,981
– Special project	98,733	104,013
– Net cost of replacement	280,096	54,902
Increase in accounts receivable	205,512	292,338
Increase in inventories	47,882	–
Decrease in accounts payable and other liabilities	–	129,892
Decrease in grants received in advance	643,992	–
Decrease in long-term debt	119,816	150,366
Payment and advances of severance indemnities	41,911	10,654
	2,274,996	1,370,146
Increase in cash and short-term deposits	1,991,330	887,682
Cash and short-term deposits, beginning of year	1,224,653	336,971
CASH AND SHORT-TERM DEPOSITS, END OF YEAR	3,215,983	1,224,653

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

INTERNATIONAL POTATO CENTER – CIP
NOTES TO THE FINANCIAL STATEMENTS
AS OF DECEMBER 31, 1986 AND 1985

(Expressed in U.S. dollars)

1. Operations

The International Potato Center (CIP) is a non-profit organization centered in Lima, Peru, with programs located throughout America, Near and Middle East, Asia and Africa. The CIP's principal objective is to contribute to the development of the potato and other tuberous roots through scientific research programs, preparation and training of scientists, dissemination of research results in publications, conferences, forums, and seminars and other activities, in accordance with its objectives.

The CIP was established in 1972, in accordance with an Agreement for Scientific Cooperation with the Government of Peru signed in 1971 and expiring in 2000. The Center is a member of the group of International Agricultural Research Centers which is supported by the Consultative Group for International Agricultural Research.

In accordance with existing legislation and provisions of the Agreement described above, the CIP is exempt from income tax and other taxes. If for any reason the Center's operations are terminated, all of its assets are to be transferred to the Peruvian Ministry of Agriculture.

2. Summary of significant accounting policies

The principal accounting policies are as follows:

a. Foreign currency —
The books and accounts are maintained in U.S. dollars. Transactions are mainly in U.S. dollars. Assets and liabilities denominated in currencies other than the U.S. dollar are expressed at year-end exchange rates. Exchange gains and losses are included in the statement of revenue, expenditures and changes in unexpended fund balances.

b. Revenue —
Grant transactions are recorded as revenue on the basis of donor commitments.

Core unrestricted grants, capital and working fund grants are pledged on an annual basis and as such are recognized as revenue in the year in which the grant is pledged as long as it is deemed to be probable of collection.

Restricted operating and special project grants are accounted for in the period stipulated by the donor. Other income, net, is recorded when earned and is comprised primarily of interest on investments, proceeds from sales of fixed assets and translation gains and losses.

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

d. Investments —
Short-term investments are principally comprised of certificates of deposit bearing interest at current bank rates and are valued at cost.

e. Inventories of laboratory and other supplies —
Inventories of laboratory, spares and other materials are valued at estimated market value, which approximates cost.

f. Fixed assets —
Fixed assets (Note 5) are stated at cost. Addition to fixed assets recorded as grant expenditures and replacement additions reported as operating expenses in the statement of revenue, expenditures and changes in fund balances and added to the related equity account. Upon the sale or retirement of fixed assets, their cost is removed from the fixed asset and related equity accounts.

Fixed assets are not depreciated.

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

g. Vacations —
Employee vacation expenses are charged to operating expenses as they are taken.

h. Provision for severance indemnities —
Employees' severance indemnities are accounted for on an accrual basis. The amount accrued represents the amount that would have to be paid to the employees if they were to terminate as of the date of the financial statements.

In 1986, the CIP began including the operations of the SAPPRAD projects as part of their financial statements, including unexpended fund balances as of the beginning of the year totalling US$142,784. Certain reclassifications have been made to the 1985 balances for comparative purposes.

3. Loans to executive and employees and long-term debt

The CIP provides loans to certain of its executives for the acquisition of homes and/or vehicles. These loans are funded by a term loan of US$425,000 from Citibank N.A. - New York and in certain instances with the CIP's own funds. The bank loan is repayable in 42 monthly installments bearing interest at the New York prime rate plus 1.5%.

Loan balances with executives and employees at December 31, are as follows (in U.S. dollars):

	1986	1985
Loans funded by Citibank N.A. line of credit, secured by related homes and/or vehicles, repayable under the same conditions as advances under the term loan at no direct cost to CIP	380,611	490,167
Loans funded by CIP, repayable over a five year-period, non-interest bearing, secured by employees homes	95,487	25,958
	476,098	516,125
Less current portion	(119,064)	(104,333)
	357,034	411,792

Amounts outstanding under the term loan at December 31, are as follows (in U.S. dollars):

	1986	1985
Current portion (Note 6)	96,851	86,591
Non-current portion (maturing 1987-1990)	283,760	403,576
	380,611	490,167

The term loan is guaranteed by a deposit of US$300,000 (US$400,000 in 1985) in the aforementioned financial institution, which bears interest at 5% per annum (7% in 1985).

4. Accounts receivable — Other

This balance is comprised of the following at December 31 (in U.S. dollars):

	1986	1985
Advances to organizations for research work	102,199	148,805
Travel advances	40,564	9,131
Advances to contractors and others	19,035	35,886
Others	67,482	8,315
	229,280	202,137

5. Fixed assets

Fixed assets at December 31, comprise the following (in U.S. dollars):

	1986	1985
Buildings and construction	2,902,754	2,536,964
Research equipment	1,338,529	1,154,784
Vehicles and aircraft	2,219,541	1,811,483
Furniture, fixtures and office equipment	1,095,839	965,092
Operating farm equipment	402,482	354,726
Installations	1,302,915	1,126,284
Site development	667,215	607,532
Communication equipment and other	531,024	364,512
Construction in progress	26,961	350,000
	10,487,260	9,271,377

Vehicles and other fixed assets replaced, retired or sold are transferred from the fixed asset and related equity accounts to a memorandum account. The balance of this memorandum account at December 31, 1986 is US$860,154 (US$605,635 in 1985).

6. Bank overdrafts and current portion of long-term debt

At December 31, this balance is comprised of the following:

	1986	1985
Bank overdrafts	386,220	18,967
Current portion of long-term debt (Note 3)	96,851	86,591
	483,071	105,558

The CIP has various credit lines and demand loan arrangements with banks totalling US$459,000, which bear interest at the New York prime rate plus 1.5%. As of December 31, 1986 unused amounts under these credit facilities totalled US$65,657.

7. Grants pledged

During 1986 the following donations were pledged to the CIP for special projects in 1987 through 1990: (in U.S. dollars):

	1987	1988	1989	1990
International Development Research Centre – Canada	153,000	48,000	–	–
Swiss Development Cooperation and Humanitarian Aid	573,000	27,000	–	–
United States Agency for International Development	167,000	246,000	263,000	341,000
Netherlands Government	120,000	120,000	–	–
Belgian Government	189,000	180,000	–	–
Federal German Government	12,000	–	–	–
	1,214,000	621,000	263,000	341,000

Such amounts are not reflected in the accompanying financial statements.

The CGIAR: A Global Agricultural Research System

The Consultative Group on International Agricultural Research (CGIAR) was established in 1971 to bring together countries, public and private institutions, international and regional organizations, and representatives from developing countries in support of a network of international agricultural research centers. The basic objective of this effort is to increase the quantity and improve the quality of food production in developing countries. The research supported by the CGIAR concentrates on the critical aspects of food production in developing countries that are not covered adequately by other institutions, but which are of global importance. Currently, the CGIAR network is involved in research on all of the major food crops and farming systems in the major ecological zones of the developing world.

The CGIAR consists of approximately 46 donor organizations who meet twice a year to consider program and budget proposals as well as policy issues of the 13 international agricultural research institutes supported by the group. The World Bank provides the CGIAR with its chairman and secretariat, while the Food and Agriculture Organization (FAO) of the United Nations provides a separate secretariat for the group's Technical Advisory Committee (TAC). The TAC regularly reviews the scientific and technical aspects of all center programs and advises the CGIAR on needs, priorities, and opportunities for research.

Of the thirteen centers, ten have commodity-oriented programs covering a range of crops and livestock and farming systems that provide three-fourths of the developing world's total food supply. The remaining three centers are concerned with problems of food policy, national agricultural research, and plant genetic resources.

CIAT
International Center for Tropical Agriculture
Cali, Colombia

CIMMYT
International Maize and Wheat Improvement Center
Mexico City, Mexico

CIP
International Potato Center
Lima, Peru

ICARDA
International Center for Agricultural Research in the Dry Areas
Aleppo, Syria

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
Hyderabad, India

IITA
International Institute of Tropical Agriculture
Ibadan, Nigeria

ILCA
International Livestock Center for Africa
Addis Ababa, Ethiopia

ILRAD
International Laboratory for Research on Animal Diseases
Nairobi, Kenya

IRRI
International Rice Research Institute
Manila, Philippines

WARDA
West Africa Rice Development Association
Monrovia, Liberia

IBPGR
International Board for Plant Genetic Resources
Rome, Italy

IFPRI
International Food Policy Research Institute
Washington, D.C., U.S.A.

ISNAR
International Service for National Agricultural Research
The Hague, Netherlands