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POTATOES for the DEVELOPING WORLD

A Collaborative Experience

With a 12-page précis

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

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Most photographs are from CIP's files, although some were provided by staff members from their working collections.

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COVER PHOTO: Take your pick of size, shape, or color of these potatoes grown in the Andes of South America. The potato originated in this region. Varieties are now numbered in the thousands.

Foreword

Both CIP and the CGIAR system, well into their second decade, are taking a look at themselves. One result is this publication by the International Potato Center (CIP). A comprehensive impact study for all centers of the Consultative Group on International Agricultural Research (CGIAR) system is scheduled for publication in 1985.

The question being posed is, "What have been the results of research and training conducted by the International Agricultural Research Centers?"

Agricultural research usually needs a long time for benefits to show in farmers' fields or in consumers' diets. However, in taking a close look at CIP after some 12 years of potato research we found exciting consequences of our efforts.

Increases in potato production have made this vegetable the most rapidly expanding major food crop in the third world — and its fourth most valuable crop in monetary terms. Potato consumption is doubling every 10 to 15 years.

The story, however, is not so much about *what* production increases are taking place, but *how* they are being accomplished at this early date in the life of the potato Center.

At an early meeting of CIP's Board of Trustees, the decision was made to give highest priority to assistance and collaboration with national programs and let institutional facilities and the research program at CIP develop with time. This early, close, and genuine peer relationship with national scientists around the world has been the single most important factor in CIP's success.

A major part of CIP's philosophy is permanence. The Center's organizational base depends on national potato programs and the people within them — the driving force that provides permanence, flexibility to change with conditions, a reaching for new national attainments, and collaboration.

As you read this study use a different measure of CIP's impact than such items as numbers of countries involved, amounts of germplasm distributed, varieties released, or yield increases. These are included in this study report merely to indicate the scope of CIP and national program collaboration.

Gauge the impact of research and training primarily in terms of institutional capacity to sustain future agricultural growth by solving problems as they arise.

What has been the impact of the Center on national research institutions?

What relevant technologies have been developed and transferred?

What technology has reached farmers' fields and had an impact on production?

Do national programs view the Center as a competitor for scarce resources?

Do national programs take part in Center decision making?

You will notice this study goes beyond the usual center annual progress report. It covers several years' work and it emphasizes the means by which progress was made through involvement of national programs in all Center activities. We believe many lessons we learned can be usefully applied to other research centers.

We have included quotations or paraphrased statements from national program personnel and government officials. Also included are what we term "illustrative case studies" which detail how certain advances have been made and benefit people or country programs. Short statements in "boxes" describe CIP and national program activities that you would seldom find in a formal research report.

All CIP personnel would like for you to study this volume. It tells how one International Agricultural Research Center has attained an enviable impact in a short time.

Richard L. Sawyer
Director General

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Harvesting potatoes,
Peru.

PART I

The First 12 Years

A group of forward looking scientists, policy makers, and donors concerned about food production problems in the world's developing countries in 1971 founded the Consultative Group on International Agricultural Research (CGIAR).

The potato was included in the list of commodities to be investigated by international agricultural research centers because of its:

- potential value as a food crop in the tropics and subtropics, and,
- rapid increases in production responding to the interests of developing country consumers and producers.

Today, three billion people — three-quarters of all humankind — inhabit the 95 potato producing countries of the developing world. China alone produces 56 million tons of potatoes, India 9 million tons and Turkey 3 million tons.

The potato has moved into the tropics, the attraction being demand for a nutritious, rapid growing, and highly productive food crop.

CIP was organized in 1971 to meet that demand.

During the past 20 years, the rate of increase in potato production in developing countries has outpaced growth rates of all other major food crops. At present, potato consumption is doubling every 10 to 15 years. In some areas, such as the Far East, consumption is doubling every 9 years.

The adaptability of the potato to a wide range of growing conditions and dietary patterns are major reasons for the rapid increase in potato production in recent years. Coming originally from the highland tropics of South America, taken to Europe by the Spaniards, the potato went through a process of genetic adaptation to the temperate climate of Europe where it became a staple food. From Europe, potato production spread throughout the world. The crop is now grown in more countries than any other food crop except maize.

European varieties are not specifically adapted to tropical growing conditions. Only recently has potato breeding become a part of research in developing countries. Nevertheless, potatoes have

already become the developing world's fourth most economically valuable food crop.

CIP, in collaboration with national potato programs of developing countries, is rapidly bridging the gap in research and development between tropics and subtropics and northern latitude countries. CIP's objective is to fully exploit the potato's potential as a food crop in the developing world.

The exploitation "gap" between developed and developing countries is reflected in differences in levels of potato consumption. On the average, northern latitude consumption is more than 50 kilograms per capita per year compared to under 20 kilos annually in developing countries. In some developing areas the potato is already a staple food with consumption levels similar to those of developed countries. But in most developing areas potatoes are consumed as a high-cost vegetable.

It is in these places that research leading to improvements in cultivation, post-harvest management, marketing, and agricultural policies will pay the greatest dividends in terms of increasing production and consumption of potatoes at ever lower cost levels.

An international agricultural research center can take one of two routes to conduct its program: one is for the center to "go it alone," establishing its research program, developing its new varieties and technological packages, and then "transferring" them to developing country programs, or directly to farmers. The second route is for the center to work with national programs from the start.

CIP has successfully followed the second route.

Strategies

CIP's philosophy is to involve institutions and scientists throughout the world in research, training, and potato improvement while keeping its own program modest in scope and sharply focused on developing country needs. Several strategies helping to accomplish this are discussed below.

Board of Trustees

Members of the Board of Trustees represent diverse countries, disciplines, and experiences. The 30 individuals who have served on CIP's board are from 16 different nations; 14 from developing and 16 from developed countries. The board has an active role in management, and evaluates the programs and budget annually.

Social Science

CIP's social science program provides management and research scientists with up-to-date information on potato production and use in developing countries. Through their participation in interdisciplinary teams, social scientists also keep the interests of producers and consumers foremost in research and training programs.

Internal Reviews

Progress in all research projects and training is reviewed in a

week-long annual meeting of all CIP scientists, representatives of national programs, and board members.

Planning Conferences

Planning Conferences periodically review progress and establish guidelines for future research in each major research area. To date, 27 conferences have had 273 invited participants from 41 countries attending.

Long-Term Planning

Based on planning conferences, assessments of developing-country needs and CIP's comparative advantages, a long-term plan, "Profile 1972-2000," was issued in 1979. This plan, the first developed by any center, goes to policy makers and potato scientists around the world. It is periodically updated to reflect research progress as well as changing perceptions of developing country needs and capabilities.

Management Approach

CIP management is highly decentralized, participatory and flexible. It aims at solving routine problems at the level of individual research projects, departments, or regional programs. Senior management concentrates on major policy issues and formal relations with donors and other institutions. Decentralized management allows CIP scientists, particularly in regional programs, to respond quickly to opportunities for collaborative research or training activities.

Regional Programs on Core Funding

CIP was the first center to establish regional programs on core funding. This ensures continuity of scientific contacts with country programs. CIP maintains seven regional offices — two in Latin America, three in Africa, and two in Asia. Regional staff members collaborating with national scientists are responsible for identifying key production problems, testing and adaptive research, multiplication and distribution of genetic materials, training, and related institution-building activities.

CIP scientists communicate regularly with scientists and program leaders in 90 developing countries. In 1983, CIP staff members visited 61 developing countries, and scientists and policy makers from 44 and 32 national programs visited CIP regional offices and CIP headquarters, respectively. These figures are indicative of the continual contacts maintained worldwide.

The "Third Dimension" Approach

When country leaders seek external funding for a potato program, CIP attempts to link the country with a donor agency and a locally-based international agency which can administer the funds and implement the project. This strategy allows CIP to minimize the administrative burden of handling large numbers of special projects. Three of these "Third Dimension" projects now operate in Bangladesh, Nepal, and Pakistan.

> *The food problem exists in the real world of the small farmers, in the real world of the imperfect economies, and that is where the success of any research program is tested.*
>
> — **Josette Murphy, U.S. Agency for International Development.**

Research Networks

Many developing countries unable to afford a comprehensive potato research program solve their problem through CIP-sponsored collaborative research networks. These country programs pool their resources to establish their own integrated research programs which investigate problems of mutual interest.

Five collaborative networks are now functioning: two in South America and one each in Central America, Central Africa, and South East Asia.

Collaborative Research Projects

Direct research collaboration between scientists in CIP and national programs is achieved by working jointly in research projects. A total of 111 such projects was underway in 30 developing countries during 1983.

Research Contracts

Research contracts link CIP headquarters research to scientific expertise and research facilities throughout the world. Contracts motivate researchers to work on priority problems of developing countries, and provide operating funds for conducting needed research. Flexibility is provided for changing research priorities without incurring major changes in headquarters staff and facilities.

Training

CIP's training program is based on the philosophy that research and extension efforts conceived and executed collaboratively with national programs are more appropriate, effective, and longer lasting than those conceived and executed independently by CIP. All general production training and many specialized courses are conducted in regional and national programs. As a result, approximately 45% of the training budget is used for training activities away from headquarters.

Since 1978 CIP has trained or facilitated training for more than 2,500 researchers and extensionists from 102 countries.

Eighty percent of respondents in a survey of former trainees indicated that after their CIP training, they had trained 25,000 others, including 13,000 farmers, 6,000 local researchers and extentionists, 5,000 university students, and 1,500 potato workers from abroad.

Research begins and ends with the farmer (below). Peru.

"Farmer-Back-to-Farmer" Research Model

Experiences in development and dissemination of seed storage technology led CIP's post-harvest team to formulate the "Farmer-Back-to-Farmer" research model. Based on the belief that problem-solving agricultural research should begin and end with the farmer, this model relies on interdisciplinary teamwork in all phases of a continuous research/diffusion process. The model is now serving as guide to applied potato research in a number of technological areas in several countries. Moreover, agricultural policy makers and development specialists working on other crops and problem areas have expressed great interest in the model, as a guiding framework for applied research and development.

Research Results

CIP research aims to solve priority problems of potato production and utilization in developing countries. Integration of head-

quarters and regional research programs ensures a two-way flow of information between national programs and CIP headquarters. Local evaluations of technologies and extension are primary responsibilities of national programs.

The World Potato Collection

Through sponsorship of collecting expeditions and as a repository of donated collections from other sources, CIP has assembled a reservoir of germplasm of the potato. This World Potato Collection includes 5,000 classified cultivated accessions and 1,500 wild accessions — the material used by scientists to breed new combinations of plants. It is the most complete and diverse collection of primitive potato cultivars in existence.

Wild species in CIP's collection are used to develop populations with new sources of resistance to diseases and pests. Continued maintenance, exploitation, and use of the germplasm collection are major aims of CIP's long-term plan. Research involving the World Potato Collection has only begun, with an estimated 90% of the available genetic diversity of the gene pool of tuber-bearing *Solanum* awaiting future evaluation.

Difficult crossability barriers between species within the germplasm collection have been broken through use of modern tissue culture techniques in combination with traditional methods. As a result, previously inaccessible genes of the wild potato species are now becoming accessible to modern breeding programs.

Breeding Strategy

Interbreeding produces a new array of genotypes. In initial screening for pest and disease resistances and agronomic characteristics, desirable genes are at a low frequency. Selected individuals are intermated again, creating a new gene pool with an increased frequency of genes controlling desirable attributes. This process of recurrent selection is repeated several times, the selection pressure increasing in each cycle leading to development of advanced clones.

CIP decided on this strategy, known as population breeding, to meet its objectives in producing genetic material adapted to developing country situations. It ensures a breeding population with wide genetic diversity to assure high yields and stability of performance and it increases the frequency of genes controlling adaptation, yield, and resistance or tolerance to biotic stresses.

Seventy developing country potato programs have received germplasm distributed through CIP for evaluation under their conditions. Thirty-six selected clones have been multiplied and released to growers by 22 national programs. Eighteen of these 36 have been given specific names, often colorful adaptations of botanical, local or historical significance.

CIP does not name varieties but encourages developing country programs to provide appropriate variety designations on material they evaluate and release.

> *This is one major area [distribution of advanced lines] where Bhutan has benefitted from its association with CIP. On the basis of the country's requirements, suitable germplasm has been supplied from CIP and we have material in advanced stages of testing.*
>
> — **Pema Wangchhuk, Bhutan.**

Results so far confirm the effectiveness of CIP's breeding strategy.

Germplasm Distribution

CIP has a collection of 150 pathogen-tested highly selected clones which originated either from CIP's breeding program or are introductions from other institutions.

CIP attempts to match the genetic nature and potential of its improved germplasm to the needs of countries requesting material. The form in which genetic material is exported must also match the capability of recipient countries to assure its efficient use.

Genetic material transfer is through CIP's regional germplasm redistribution centers which test, multiply, and then distribute selected clones to national programs. CIP provides intensive training in germplasm management to increase efficiency of this system.

Tropical Agronomy

Highland zones have fragile ecologies and limited areas suitable for crop production. Consequently, policy makers in many developing countries hope to expand potato production rapidly in warmer lowland areas. This would help alleviate pressures on fragile ecologies as well as place more potato production nearer to consumers — half the world's population lives in these warmer lowland areas. This requires both adapted varieties and appropriate agronomy.

Several national programs and CIP have collaborated since 1979 in tropical agronomy studies to generate practical solutions to problems of potato production in warm environments. Key factors for success are use of high quality seed tubers — to give vigorous emergence and early ground cover — and control of bacterial wilt through use of resistant varieties or appropriate agronomic practices.

Virus and Viroid Detection and Elimination

At least one viroid and 25 different virus diseases have been identified on potatoes. Potato leafroll virus (PLRV) and potato virus Y (PVY) cause greatest yield losses and are the most widespread. The potato spindle tuber viroid (PSTV) is primarily of quarantine significance, although in some locations it may become epidemic.

Control of virus and viroid diseases is based on exclusion and prevention rather than cure. Hence, sensitive and reliable methods for detection are needed. Several detection methods have been developed at CIP for use in the center's own breeding work, virus testing, and seed multiplication for export.

CIP provides a Phytosanitary Statement with all export material assuring sanitation standards exceeding those required for commercial quarantine acceptance by importing countries. CIP's quarantine statement is unique among international agricultural research centers.

Simplified serological techniques made available by CIP permit developing countries to use ultrasensitive methods of virus and viroid detection, with a consequent improvement in health of their crops. Since a large amount of virus antisera is needed, CIP is assisting some countries (Brazil, Colombia and Tunisia) to produce antisera for their own and other country use. In Peru, national potato program scientists produce their own antisera using CIP facilities, technology and supervision. Through seven virus training courses at least one member from each developing country seed potato program has been trained in techniques for virus detection and elimination.

The wide applicability of CIP's virus detection methods is indicated by many requests for training personnel working with other crops. Requests for training in viroid detection techniques have also been received from developed countries. An advanced method for viroid detection, using genetic engineering techniques, was developed jointly by CIP and USDA. European countries, Canada, and the U.S. have requested antisera samples from CIP for use in quarantine services for several viruses.

Safe, Effective Pest Control

Pest damage in field and storage is a major source of crop loss in the developing world. Pesticides are a costly input and overuse contaminates the environment.

Development of resistant varieties and management techniques that improve control while reducing pesticide use are emphasized by CIP. Regional research, consultants, and national potato programs form a network of information exchange for pest identification, control, and for establishing research priorities.

Insect Control

Potato tuber moth currently receives major attention from CIP because of its heavy damage worldwide in field and in storage.

Although barely 5 years old, CIP research on potato insects, particularly potato tuber moth, has established creditability in building an effective pest management program. A total of 22 primitive and 21 wild resistant potato accessions has been selected after screening thousands of clones in CIP's World Potato Collection and from a U.S. university. They are now used in resistance breeding to prevent both tuber damage and successful pupation of the pest.

As part of an integrated control program, CIP developed a simple laboratory procedure to impregnate small rubber caps with sex pheromones (attractants), which are used in trapping male tuber moths. These are now being evaluated in at least 23 developing countries.

In collaboration with Peru's national potato program and the Peruvian National Agrarian University, CIP has also identified two potential potato tuber moth parasites which offer promise for biological control of this insect.

Biological Control of Nematodes

Dependable biological control is a long-sought goal to help reduce danger of using toxic nematicides.

CIP scientists discovered a fungus, *Paecilomyces lilacinus*, infecting eggs of the root-knot nematode, *Meloidogyne incognita*, in a potato field in the highlands of Peru. Early studies showed the potential of the fungus as a consistent and efficient biological control agent of root-knot nematodes, a cosmopolitan pest of many important food and fiber crops.

CIP collaborates with the International Meloidogyne Project (IMP) which includes more than 100 workers in nematology in 70 countries. IMP helped distribute *Paecilomyces lilacinus* to nematologists in 46 countries for evaluation: 21 countries in Latin and North America, 8 in Africa, 12 in Asia, and 5 in Europe. So far, six countries reporting from Asia, Central and South America have all indicated the fungus is effective.

Tissue Culture and Rapid Multiplication

Tissue Culture. CIP is the first institution to use tissue culture methods on a large scale for potato crop development. Tissue culture has developed into a unit responsible for basic and applied research plus training tissue culture specialists from national potato programs. In addition to these responsibilities, the unit is in charge of the disease-free maintenance and distribution of in vitro (in glass) potato germplasm.

"Meristem tip culture" is now routine at CIP to free valuable genetic material from viruses. This service is available for CIP materials as well as those sent by national programs to be "cleaned up." The rapid, in vitro propagation of clonal material is another area where tissue culture techniques have become routine.

Potato germplasm stored in vitro is a source of pathogen-free material for propagation; and, if properly handled, will remain free from contamination by microorganisms. CIP scientists, in collaboration with other investigators, have developed methods to prolong the intervals between in vitro transfers, thus permitting storage for 16 to 24 months without transfer and changing the growing medium.

CIP has transferred about 250 clones to in vitro conditions.

> *These varieties have neither indicated symptoms of breakdown of resistance over about 10 successive multiplications nor have the cultivators reported decline in yields over the 2 years of their multiplication.*
>
> — Director of Agriculture, Sri Lanka.

These clones are in demand by many national potato programs and meet the strictest quarantine standards worldwide.

Through training, at least 16 national programs now use tissue culture techniques and are able to receive in vitro materials from abroad. CIP is the major, but not the only, source of training and of in vitro potato germplasm for developing countries.

Rapid Multiplication. Single node and sprout cuttings, stem cuttings and leaf bud cuttings have been developed over the years for use in screening germplasm, disease elimination, and seed programs. These rapid multiplication techniques, which have been simplified for use in developing countries to accelerate the multiplication of their seed, are being used routinely by over 20 national seed programs.

True Potato Seed

Research on true potato seed (TPS) which started at CIP in 1977 has increased both at headquarters in Peru and with cooperating institutions. Use of true potato seed by developing-country farmers has several advantages:

- reduces cost of planting material,
- minimizes spread of tuber-transmitted diseases,
- releases for human consumption the large volume of potatoes previously used for seed,
- reduces transport costs,
- simplifies seed storage and makes high-quality planting material available at optimal planting times.

Because of these advantages, farmers, scientists, and policy makers in many developing countries are eager to put true potato seed to practical use. Use of true potato seed began in parts of China in 1972 as a source of planting material in a basic seed system. After the first generation, conventional tuber multiplication is used.

In the last 5 years, 36 developing country programs have begun true potato seed research in collaboration with CIP. In seven of these, true potato seed is now being evaluated in on-farm trials, and in four countries — Sri Lanka, Western Samoa, the Philippines, and Rwanda — farmer use of TPS has begun.

Post-Harvest Technology

Traditional farm storage of seed tubers usually causes problems

True potato seed (TPS) is at lower left (below); a seed tuber at upper right.

of sprouting, storage losses, and poor tuber vigor and field performance.

Within 3 years of experiment station and on-farm trials, the effectiveness of natural diffused light was demonstrated in reducing sprout elongation, increasing sprout number, reducing total storage losses, and increasing total yields because of improved seed vigor. The average yield increase from use of natural diffused light in storage was found to be approximately 20% in trials both on the experiment station and on farms.

Illustrative Studies

Instead of attempting to quantify the production impact of CIP-generated technologies at the farm level, we have chosen another method: depict collaborative efforts with seven brief studies illustrating how CIP and national programs work together to solve problems of potato production and use. They tell how various types of benefits have been generated, ranging from training and institution building, to development of an effective model for inter-

disciplinary problem solving, to yield increases and intensification of cropping systems.

The seven cases:

1. **Relations with the host country: Peru.** Illustrates the reciprocal nature of CIP's relationship with its host country and the resulting mutual benefits.

2. **Farmer-Back-to-Farmer Model.** Describes how interdisciplinary research led to a model and guiding principles for problem-solving teamwork.

3. **Learning from a Developing Country: Tissue culture and rapid multiplication in Vietnam.** Shows how CIP and national programs can learn from the experiences of innovative researchers and farmers in a developing country.

4. **A small, effective seed multiplication program: Tunisia.** Demonstrates how a seed multiplication scheme can be quickly institutionalized and generate substantial economic benefits.

5. **Building an effective country program: Rwanda.** The case of PNAP in Rwanda illustrates how a simple, yet effective potato program, with breeding, seed multiplication, on-farm research, and training, can be established in a short time.

6. **Changing a post-harvest system: Diffused light potato stores in Sri Lanka.** Documents how collaboration of an international agricultural research center, a national research program, and the extension service has led to rapid improvement in seed potato storage practices which are having far-reaching effects on cropping patterns.

7. **PRECODEPA: A collaborative research network.** Describes the establishment, organization, research accomplishments, and farm-level and institutional benefits of this pioneering country network in Central America and the Caribbean.

PART 2

Potatoes in the Developing World

The potato, one of mankind's most valuable foods, is produced in 130 countries where three-fourths of the world's population live. In volume of production (290 million tons annually), potatoes rank fourth in the world after wheat, maize, and rice. As a crop in the developing world potatoes also rank fourth in dollar value (Table 1). Among major foodcrops, potatoes currently have the highest rate of production growth in most developing countries (Figure 1).

Potato tubers contain high quality protein and substantial amounts of essential vitamins, minerals, and trace elements. The potato provides more nutritious food from less land in less time — and often under more adverse conditions — than other crops such as wheat, maize or rice.

The first part of this publication tells of the potato's nutritional value, global distribution, trends in production and use, as well as special features of growing potato in developing areas.

Production and Use

Statistical data and specialized reports on major cereals and other cash crops, such as soybeans, sugar, and coffee, are more

Table 1. Production and economic value of 10 leading food crops in all developing countries.

Crops	Production (million t)	Area (million ha)	Yield (t/ha)	Value (billion US$)
Rice	382.6	139.5	2.7	65.0
Wheat	162.4	142.1	1.1	24.0
Maize	153.9	78.3	2.0	18.3
Potatoes	91.1	8.7	10.5	12.9
Sweet Potatoes	137.0	9.3	14.7	12.2
Cassava	127.4	14.4	8.9	8.9
Bananas + Plantains	61.9	no data	no data	6.6
Sorghum	43.7	40.1	1.1	5.4
Groundnuts	16.9	18.0	0.9	5.0
Millet	26.9	40.2	0.7	3.9

Sources: Estimates of 1981 Chinese production of cassava, potatoes, and sweet potatoes are from Stone, B. Notes on interpreting PRC root and tuber crop data, *The China Quarterly* (forthcoming). All other production estimates are 1980/82 averages derived from FAO. Farm-level prices for 1977 are from FAO.

. . . potato scientists are not given prominence as for those working in rice . . . a situation that must improve if more young scientists are to engage in potato research and production.

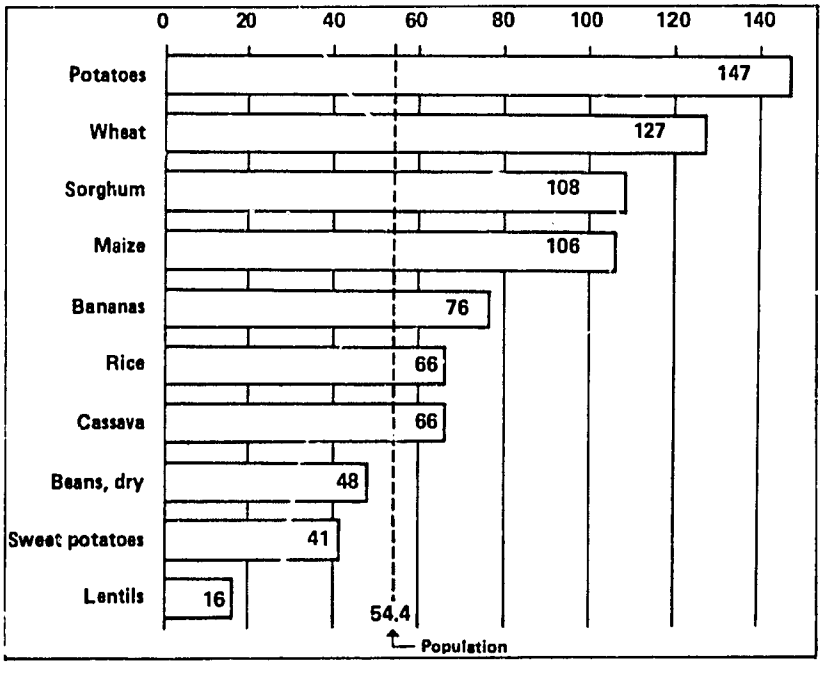
— V. Yogaratnam, Sri Lanka.

complete than those on root crops and vegetables. This is largely because agencies publishing data on world crop production and use concentrate on commodities traded internationally, virtually neglecting those produced and consumed locally, such as potatoes.

Potatoes appear in routine tables of the *FAO Production Yearbook* and a few other statistical publications, but specialized reports on nutritional aspects of the potato, production systems, consumption patterns, and trade are lacking.

The International Potato Center (CIP) in 1975 began assembling and analyzing statistics to compile information on potato production and use, especially in developing areas. Extensive literature reviews and research on potato consumption and nutrition, produc-

Figure 1. Percent increase in production of selected food crops and population in all developing countries, 1961/65 (average) to 1981.



Source: FAO data for all crops and countries except potatoes, sweet potatoes, and cassava in China. Stone, B. Notes on interpreting PRC root and crop tuber crop data, *The China Quarterly* (forthcoming) for potatoes, sweet potatoes, and cassava in China.

Bogra harvest, Bangladesh.

tion systems, and marketing resulted in much of the information presented in this publication.

Nutritional Value

The potato contains high quality protein and substantial amounts of essential vitamins, minerals, and trace elements.

Raw cereals and beans yield substantially more energy than potatoes, but the difference is much less if comparisons are made on a cooked basis.

Protein content of potato is equal to yam and is almost twice that of sweet potato and cassava. Moreover, **on a cooked basis,** the potato compares with other major staples, such as boiled rice and cereals cooked as porridges.

The average amount of potato protein required for maintenance of nitrogen balance in adults is similar to the amount in an egg, and is less than that required by many other foods including beef, tuna fish, wheat flour, soybean, rice, corn, and beans. If a whole egg has a protein score of 100, potatoes have a score of 70. This compares with 75 for sweet potatoes and rice and scores of 40 to 60 for wheat, maize, beans, and peas.

Peruvian studies also show that infants and small children can consume up to 80% of their nitrogen requirements as potato. The quality of potato dietary nitrogen for feeding humans is high. Even a small quantity (100 grams) of boiled potato supplies up to 13% of the FAO/WHO recommended daily allowance of protein for children and up to 7% of the adult allowance.

The potato has a well-balanced protein-to-calorie ratio. If you eat enough potato to supply a significant amount of energy, a significant quantity of protein will also be provided.

The advances in recent years are direct evidence that Indonesia has been in an excellent position to demonstrate the impact of the CIP program on our potato production.

— **Sadikin Sw., Indonesia.**

For feeding children, bulky staples such as roots, tubers, and cereals need an addition of energy-dense and protein-rich supplements. Potato requires less of these expensive additional supplements than other roots and tubers and about the same amount necessary for adding to cereals.

Potatoes are a good source of ascorbic acid (vitamin C) and some B vitamins, especially thiamin, niacin, and vitamin B_6. Consumed as a staple on a regular basis, potatoes provide more vitamin C than citrus fruits, which tend to be eaten less frequently. Among staples, potato is perhaps the richest source of total niacin.

Minerals and trace elements in the potato provide a moderate source of iron, a good source of phosphorus and magnesium, and a rich source of potassium. Its low sodium content is useful in salt-free diets.

Distribution, Trends in Production, Use

Until recently, most world potato production was concentrated in Europe. Many people continue to view the potato as a northern-latitude crop important only in the industrial countries. In fact, the potato has rapidly migrated into tropical and sub-tropical areas where it is now grown extensively (Table 2).

In developing regions over the last two decades potato production has increased sharply — the rate being nearly twice that of total food production and substantially higher than that of most other major food crops (Figure 2). Potato production has increased most rapidly in the Far Eastern countries such as China, India, and Indonesia. Asia now accounts for 84% of the 91 million tons of potatoes produced in developing countries. The five largest producers are China (56 million tons), India (9 million tons), Turkey (3 million tons), Brazil (2 million tons), and Colombia (2 million tons).

Developing countries are expanding potato production for several reasons. One is that a potato crop produces more edible energy and protein per hectare and per unit of time than practically any other crop (Table 3). This is particularly important for small subsistence farmers who can fit the potato into their multiple cropping systems. Other reasons include strong consumer demand for potatoes and the high profitability of commercial crops. Rapid technological progress with potatoes in developing countries reviewed below is now stimulating expansion of production in non-traditional environments.

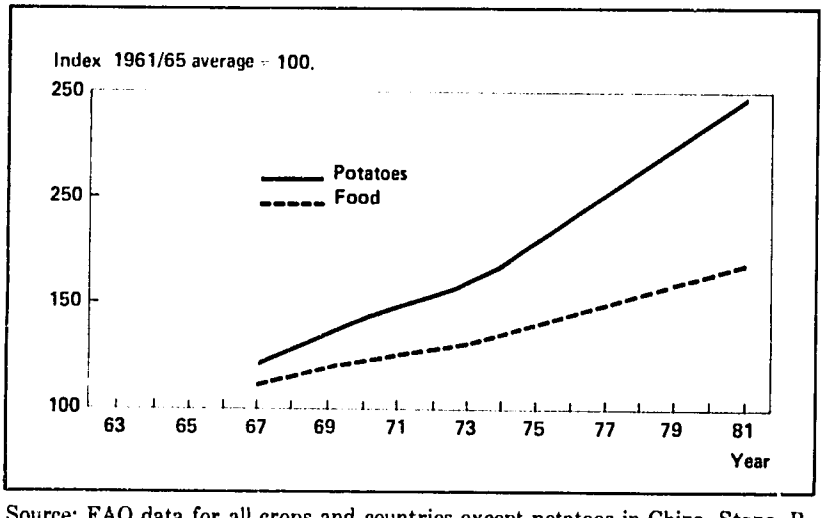
Developing country people consume 70% to 75% of annual potato

Table 2. Potato production, harvested area, and yield 1980/82 and percent change 1961/65-1980/82: World.

	Average 1980/82			% Change 1961/65-1980/82		
	Area (000 ha)	Product. (000 t)	Yield (t/ha)	Area	Product.	Yield
WORLD	22,007	287,793	13.9	-5	4	10
Developed Market Economies	2,954	71,210	24.1	-41	-22	31
North America	605	17,627	29.1	-10	22	35
Western Europe	2,111	48,052	22.8	-47	-34	25
Oceania	43	1,093	25.4	-16	36	65
Other	195	4,438	22.8	-26	4	41
Developing Market Economies	2,918	32,492	11.1	39	103	46
Africa	423	3,008	7.1	112	121	4
Latin America	1,066	11,222	10.5	2	49	46
Near East	429	6,238	14.5	71	127	32
Far East	999	12,015	12.0	68	177	65
Other	1	8	7.6	217	187	-9
Centrally Planned Economies	16,135	184,091	11.4	0	9	9
Asian CPE	5,855	58,101	9.9	108	177	34
Eastern Europe and USSR	10,280	125,990	12.3	-23	-15	10
All Developed Countries	13,234	197,200	14.9	-28	-18	14
All Developing Countries	8,773	90,593	10.3	79	145	27

Sources: FAO data for all countries except China. Stone, B. Notes on interpreting PRC root and tuber crop data, *The China Quarterly* (forthcoming) for China.

Figure 2. Trends in potato production and total food production in all developing countries.



Source: FAO data for all crops and countries except potatoes in China. Stone, B. Notes on interpreting PRC root and tuber crop data, *The China Quarterly* (forthcoming) for potatoes in China.

Actually, [collaboration with CIP] permits us to enter into the world network of investigation being done in potatoes.

— Eduardo Ortega, Venezuela.

Table 3. Top food crops of developing market economies in megajoules of edible energy and kilograms of protein per hectare per day.

Energy production Crop	MJ	Protein production Crop	Kg
Potatoes	216	Cabbages	2.0
Yams	182	Dry broad beans	1.6
Carrots	162	Potatoes	1.4
Maize	159	Dry peas	1.4
Cabbages	156	Eggplants	1.4
Sweet potatoes	152	Wheat	1.3
Rice	151	Lentils	1.3
Wheat	135	Tomatoes	1.2
Cassava	121	Chickpeas	1.1
Eggplants	120	Carrots	1.0

Source: Horton, D., and Fano, H. "Potato Atlas," International Potato Center, Lima (in press).

production in their countries, percentage figures that are considerably higher than for developed countries or central economy countries (Figure 3). An additional point to note in this figure is the *waste* category. Developing countries waste an estimated 12% of potato production. This is due largely to poor storage and distribution systems. National potato programs collaborating with CIP have recorded remarkable progress in farm storage of seed potatoes. Methods for improving storage of consumer potatoes are also being sought by CIP and several developing countries.

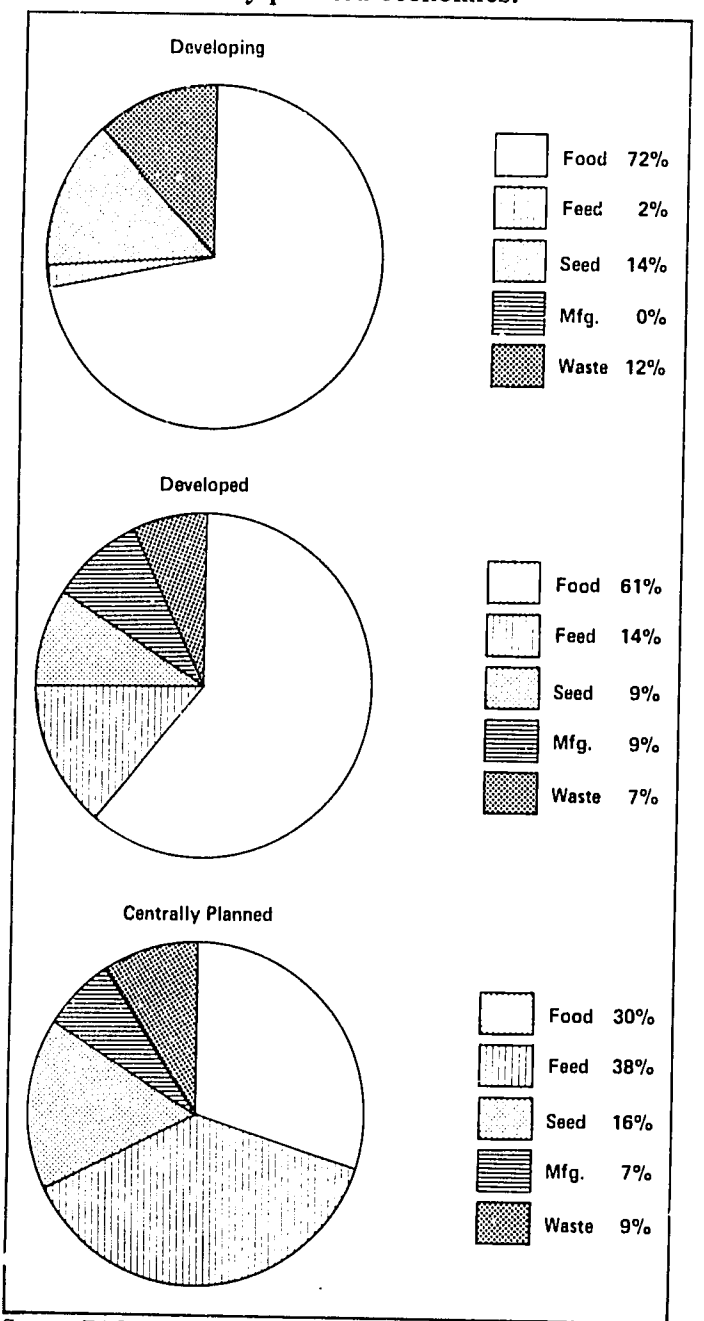
Annual per capita consumption differs widely among regions. Estimated annual human consumption:

Eastern Europe and USSR ..... **94 kilograms.**
Western Europe, North America, and Oceania ..... **65 kilograms.**
Latin America ..... **23 kilograms.**
Other Developing Areas ..... **16 kilograms.**

Put in a graphic form, annual consumption patterns appear as in Figure 4. The substantial gap between present consumption levels in the developed countries (65-95 kilograms) and developing countries (15-25 kilograms) reflects the potential for future expansion of potato consumption in developing areas of the world where millions of hungry people reside.

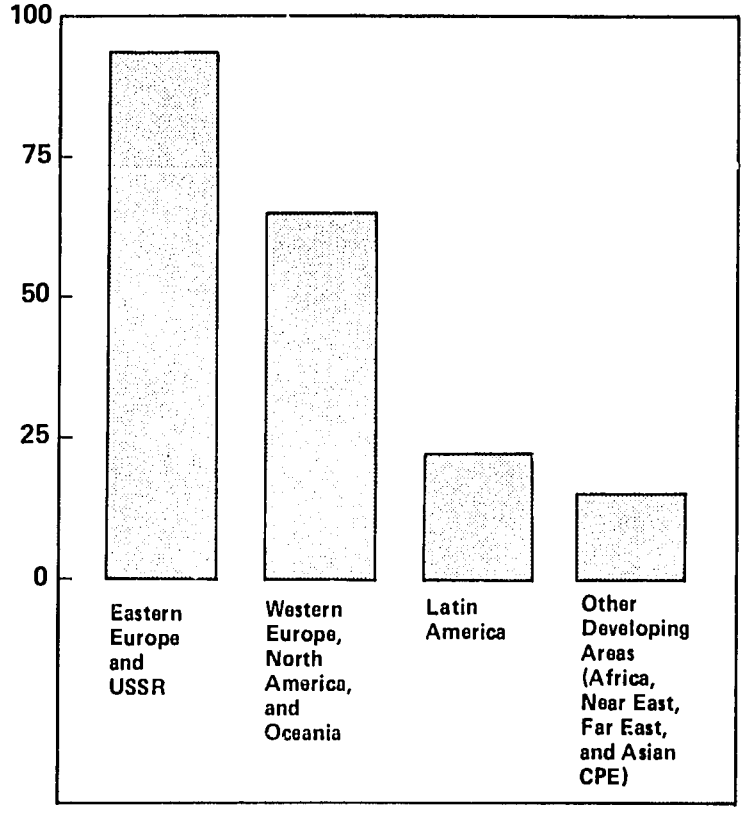
In contrast to Europe and North America, in most developing areas potatoes are expensive relative to other foods. This is mainly because of high production and marketing costs. In response to high prices, many households limit their potato consumption to special, festive occasions. In many developing areas consumption

Figure 3. Use of potatoes in developing and developed market economies and centrally planned economies.



Source: FAO

Figure 4. Per capita consumption of potato (kilogram/year).



Source: FAO data and Stone, B. Notes on interpreting PRC root and tuber crops data, *The China Quarterly* (forthcoming).

levels are highest among well-to-do urban groups and rural potato producers. Many poor urban and rural households not producing potatoes can seldom afford them.

The potato, which generally plays the dietary role of a staple food in most developed countries, is consumed as a vegetable in most developing countries.

Consumers in developing countries respond quickly to changing potato prices. Hence, if potato prices can be reduced the potato can be expected to play an even greater role in third world diets.

Technology Needs of Developing Areas

It is often assumed that farmers in developing countries could significantly improve their yields and incomes by adopting modern technologies available in the developed countries. This assumption, the cornerstone of most technical assistance in the 1950s and 1960s, continues to influence much development thinking today. The resulting extension-oriented programs often fail because the *physical environment* (soils, climate, pests and diseases) and the *socioeconomic environment* (land tenure, market prices, credit, capacity of research and extension agencies) in which agricultural

activities take place in most developing areas — and hence their technology needs — differ markedly from those in developed countries. For this reason, rapid and sustained production improvements in developing areas require an understanding of local conditions and development of technologies which are tailored to them.

Collaborative studies organized by developing country scientists and CIP staff have provided the necessary information to identify the major technology needs of potato producers in developing areas.

Potato Growing in Developing Areas

Production Systems. Small highland farmers in the potato's traditional mountain-side environment generally cultivate 1 to 2 hectares of this crop on several distinct parcels of land. The crop is typically rainfed and subject to hazards, including drought, excessive rain, frost, and hail, depending upon the location and season. Highland farmers generally retain a substantial part of their harvest as seed for the next season.

Where potatoes are a relatively inexpensive food (the Andes, Central Africa, and the Himalayas) most farmers store a large share of production for home consumption. Where potatoes are relatively expensive (Central America and South East Asia) farmers usually consume less of their own potatoes, sell the harvest, and purchase other, cheaper foods.

In recent years potato production in developing countries has spread gradually out of its traditional, mountainous environment into warmer, generally drier, areas. Introduction of new varieties and improvements in seed systems, storage, and pest control are speeding the movement of the potato crop into such non-traditional cultivation areas as Peru's coastal valleys; the plains of India, Bangladesh, and Pakistan; and the irrigated oases of North Africa.

Potatoes have become a commercially attractive winter crop in many irrigated, arid areas. But harvesting in these areas at the beginning of summer results in storage and marketing problems for this perishable crop.

Expansion of potato production into relatively warm, humid zones brings more pest and disease problems than in traditional

---

TAC particularly commends CIP's achievements in terms of output and influence on institution building, through its imaginative interaction with national programmes. Another aspect of the Centre's operation . . . is the flexibility and cost-effectiveness of its use of contracts, funded from core resources to fulfill many of its specialized research requirements. TAC considers that some aspects of CIP's operational strategy might well be adapted to other parts of the system.

— Guy Camus, Technical Advisory Committee report, CGIAR.

> *[the most relevant, most successful thing] that CIP has done in Venezuela is supply valuable materials that have permitted us to approach the future by producing our own varieties, and reducing our dependence on costly importations of potato seed.*
>
> — **Eduardo Ortega, Venezuela.**

areas of production. For this reason, farmers are eager to obtain varieties resistant or tolerant to pests and diseases. Potato production in warm, humid areas is generally on a small scale, forming part of complex multiple cropping systems. Low-input, low-yielding slash-and-burn systems are found where land is abundant. Intensive horticulture systems employing high levels of fertilizers and pesticides are more common where land is scarce.

In most areas, average returns to commercial potato growers are high, but returns are highly variable. For this reason, few farmers specialize in potato production, and those who do tend to be large, and financially well-off. Most developing country farmers who grow potatoes are diversified and plant a small proportion of their land to potatoes with a dual purpose: home consumption and market sale.

Costs and Inputs. Current potato production technology is costly in most developing areas. Studies in numerous developing countries indicate that variable production costs for potatoes are generally more than US $1,000 per hectare.

The potato crop's single most costly production input in most developing areas is planting material — seed tubers. In South America and tropical Africa, seed tubers generally account for about 30% of the total variable cost of production; in Asia and Central America they account for 40% to 50% of the total. Even where growers do not purchase seed but retain it from the previous harvest, seed has a high "cost," since potatoes could have been eaten or sold if it had not been necessary to plant them.

Other important production costs for potatoes are labor, fertilizers, and pesticides. Where these inputs are beyond the reach of farmers, actual farm yields are generally a fraction of potential yields.

Priority Areas for Technological Improvement

Future production and use of potatoes will be strongly influenced by potato prices, which reflect production and marketing costs. Applied research is needed to reduce production and marketing costs on a per-kilogram basis to make potatoes more profitable for farmers and more attractive to consumers with limited household budgets.

Based on physical and socioeconomic environments in which potatoes are produced and used as well as technologies currently

> *Seed stocks locally produced will be available in the right physiological condition at planting time and at much cheaper rate than the imported seed.*
>
> — Kazi Badruddoza, Bangladesh.

employed in developing countries, national decision makers and scientists emphasize four key areas for technological improvement:

- varieties,
- seed systems,
- pest control,
- post-harvest technology.

In each of these areas production problems in developing countries differ markedly from those in developed countries.

New Varieties. A highly effective way to reduce unit costs of potato production is to obtain new varieties through plant breeding. These varieties must:

- yield more than current varieties with the same inputs.
- be adapted to tropical and subtropical conditions,
- have some degree of resistance to major pests and diseases,
- be acceptable to consumers

Seed Systems. Seed tubers available to most developing-country farmers are costly and poor in quality. Improvements are needed in seed systems -- both in use of tuber seed and in true potato seed (TPS) to increase yields and reduce unit production costs.

New Approaches to Pest Control. Use of pheromones (attractants) and biological control techniques help improve the quantity and quality of output with presently used varieties and at reduced costs. Better pest control helps raise and stabilize yields in traditional areas and facilitates introduction of potatoes into non-traditional, warm environments.

Appropriate Post-Harvest Technology. Post-harvest losses reduce food supplies to consumers, reduce the quality of seed tubers and yields of subsequent crops, and inflate potato prices. Most northern hemisphere potato storage and processing technologies are of little use in developing countries because of differences in climate, scale of operation, availability and relative prices of labor, materials, and energy. Farmers and market agents quickly adopt post-harvest techniques which are more appropriate for their conditions.

Priority Area for Socioeconomic Research. Rapid progress in crop improvement requires not only technical but socioeconomic research. This is particularly true for potatoes because of the complexity and scarcity of information on potato growing, marketing, and use in developing countries. Improving the quality of seed

available to small farmers, for example, requires improved virus elimination techniques as well as new institutional models for seed programs. Most seed programs established with external funding in developing countries have failed. This is because they used the *wrong* technology rather than *poor* technology — it was inappropriate for solving local problems within the existing institutional setup (which differed from those "back home" in Europe or the United States).

Given the extremely small amount of literature on potatoes in the developing world, socioeconomic research is needed to understand where, how, and why potatoes are grown, marketed, and consumed. Information is also needed on trends in potato production and use, the major problems confronted by farmers, and the process of technological change.

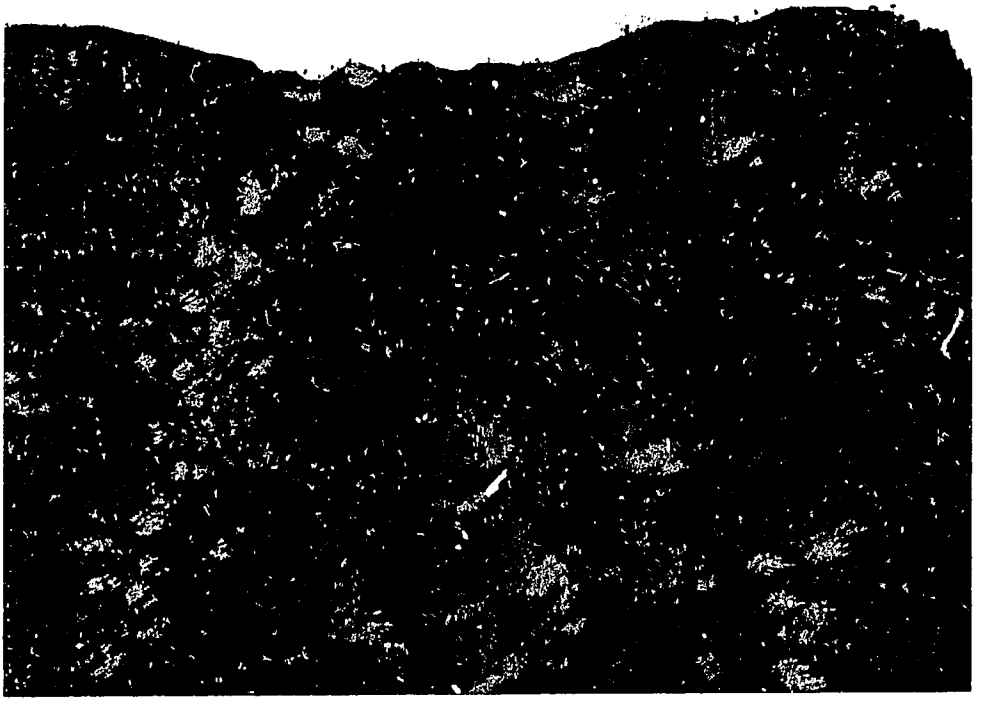
Social scientists can also contribute significantly on interdisciplinary teams working to solve specific technological problems, such as those identified in the preceding section. A model for interdisciplinary teamwork, involving biologists, social scientists, and farmers — known as "Farmer-Back-to-Farmer" — is briefly described in the next chapter and discussed at greater length in an illustrated study.

Findings of surveys . . . under auspices of CIP scientists in potato marketing and consumption . . . are serving as 'eye-openers' for future development work on potatoes.

— Pema Wangchhuk, Bhutan.

Below, interviewing in Peru.

Potato production area near Baguio, Philippines.



PART 3

The International Potato Center
CIP within the CGIAR

The CGIAR

The International Potato Center, known in Spanish as Centro Internacional de la Papa (CIP), is one of 13 International Agricultural Research Centers (IARC) sponsored by the Consultative Group on International Agricultural Research (CGIAR).

The CGIAR goal is to improve agricultural technology, increase food production, and better the welfare of poor people in developing countries. The system of internationally funded agricultural research centers originated with a joint crop-improvement program undertaken by the Rockefeller Foundation and the Mexican government in 1941, and the International Rice Research Institute (IRRI) established by the Ford and Rockefeller Foundations and the government of the Philippines in 1959.

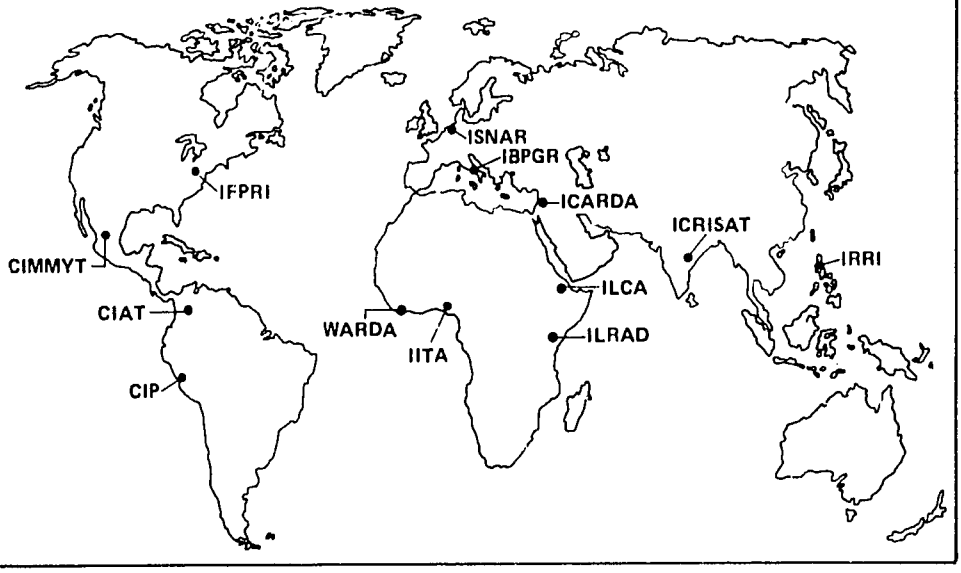
By the late 1960s, it was apparent the system must expand to cover other food crops, farming systems, and agroclimatic zones of the developing world. It was also evident that the Rockefeller and Ford Foundations would be unable to carry the financial burden of an expanded system.

The CGIAR was established in 1971 under the joint sponsorship of the World Bank, the United Nations Development Programme (UNDP), and the UN's Food and Agriculture Organization (FAO). The CGIAR is an informal association of governments, international and regional organizations, and private foundations. The World Bank provides the CGIAR chairman and secretariat; the FAO provides a separate secretariat for the group's Technical Advisory Committee (TAC). The TAC, consisting of agricultural and social scientists, regularly reviews scientific and technical aspects of each center's programs and advises the Consultative Group on research needs, opportunities, and priorities. The CGIAR meets once or twice yearly to consider program and budget proposals and policy issues. Decisions are reached by consensus.

Donations are on a voluntary, bilateral basis between individual members and the centers. While the CGIAR is active in coordinating and stimulating financial support for the system, it does not grant funds.

The 13 research centers in the CGIAR system employ nearly 600 senior scientists and have an annual budget of approximately US$180 million. Programs of 10 commodity-oriented centers cover a range of crops, 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.

Consultative Group on International Agricultural Research



CGIAR-Supported Centers

Centro Internacional de Agricultura Tropical (CIAT)
Cali, Colombia

Centro Internacional de la Papa (CIP)
Lima, Peru

Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT)
Mexico 6, D.F., Mexico

International Board for Plant Genetic Resources (IBPGR)
Rome, Italy

International Center for Agricultural Research in the Dry Areas (ICARDA)
Beirut, Lebanon

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
Andhra Pradesh, India

International Food Policy Research Institute (IFPRI)
Washington, D.C., U.S.A.

International Institute of Tropical Agriculture (IITA)
Ibadan, Nigeria

International Laboratory for Research on Animal Diseases (ILRAD)
Nairobi, Kenya

International Livestock Centre for Africa (ILCA)
Addis Ababa, Ethiopia

International Rice Research Institute (IRRI)
Manila, Philippines

International Service for National Agricultural Research (ISNAR)
The Hague, The Netherlands

West Africa Rice Development Association (WARDA)
Monrovia, Liberia

CIP is seen as a permanent source for consultation.

— **Carlos Crisci and Francisco Vilaro, Uruguay.**

The International Agricultural Research Center model is based on five basic principles:

(1) Increased food production and welfare betterment in developing countries require research, not merely "transfer of technology" directly from industrialized nations.

(2) Centers search for generalized solutions to agricultural production problems, not just location-specific solutions for a certain region or country within it.

(3) Centers are based in developing countries, but are independent, autonomous, and international in character, responsible to Boards of Trustees consisting of leading agricultural scientists and policy makers selected on a worldwide basis.

(4) Long-term funding permits stability of employment and pursuit of long-range research goals with minimal staffing and funding constraints and political pressures.

(5) Maintaining the practical mandate of the CGIAR, centers cut across traditional academic lines to form multi-disciplinary, problem-oriented research teams.

CIP Mandate

CIP's agreement with the host Peruvian Government is for research on root and tuber crops. As a member of the CGIAR system of centers, however, CIP is funded only for research on potatoes. CIP is a single-crop institute focusing on expanded use of the tuber-bearing species of *Solanum* in the developing world.

The base for CIP was established in the late 1960s with a potato program in Peru funded by USAID and run jointly by the Government of Peru and North Carolina State University. CIP was formally established in 1971 through agreement with the government of Peru. First funding was in 1972 when financing of CGIAR-sponsored Centers commenced. A joint Mexican Government-Rockefeller Foundation international potato program concentrating on late blight and associated with Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) became part of CIP in 1974.

CIP collaborates with research and development agencies throughout the world to achieve two basic objectives:

- Increase the potato's yielding ability, stability and efficiency of production in developing areas where it is now grown, and,
- Improve the potato's adaptability to grow more extensively and efficiently in cold, high regions, as well as in warm, low tropical regions.

CIP's program has as a focal point the exploitation of genetic resources still available in the potato's center of origin, and to use them for potato improvement worldwide.

CIP Program and Budget

Headquarters Research

CIP research develops technologies to solve major problems of potato production in developing countries. Results are further evaluated under a range of developing country conditions in collaboration with national research institutions. This enables both CIP and national program scientists to quickly determine if the technology is applicable to growing conditions in specific regions.

Research at CIP headquarters is organized into 7 Departments, 10 Thrusts, and 69 Projects. For administrative purposes, CIP scientists are assigned to Departments according to their discipline. The Departments of Taxonomy, Breeding and Genetics, Pathology, Entomology and Nematology, and Physiology are headed by a senior scientist responsible to the Director of Research. The Social Science and Training and Communications Departments are within the Regional Research and Training Program.

	Research Thrusts	No. of Projects
I	Maintenance and Utilization of Unexploited Genetic Resources	7
II	Production and Distribution of Advanced Breeding Material	10
III	Research on Bacterial and Fungal Diseases	6
IV	Potato Virus Research	8
V	Integrated Pest Management	9
VI	Warm Climate Potato Production	6
VII	Cool Climate Potato Production	4
VIII	Postharvest Technology	4
IX	Seed Research	10
X	Potatoes in Developing Country Food Systems	5
	Total number of research projects	69

Maximum interaction of teams of experts in various scientific disciplines is gained by grouping research projects into specific areas of research concentration (thrusts). Each thrust has a coor-

External Program Review. CIP was described as a tightly-run, cost-effective center of scientific excellence, with a dynamic and effective research program and a complex of linkages with developing and developed countries. CIP's innovative regional programs were praised, as were its use of core-funded research contracts with potato scientists in developing and developed countries, and its use of planning conferences to refine and adjust its programs. CIP's decentralized approach was seen to be a major strength, as was its emphasis on utilization of the world potato germplasm collection. CIP was praised for its good management, innovations in research planning, relations with national programs, cost effectiveness, and zero growth policy.

— Guy Camus, Technical Advisory Committee report, CGIAR.

dinator responsible for projects in that particular area of research concentration.

CIP scientists may work simultaneously on several projects within different thrusts as a leader or as a cooperator to provide essential interdisciplinary input. Project leaders are responsible for direction of a project and for annual progress reports. Funding for a project is an administrative activity managed by the project leader's department.

Before a project begins at CIP, several factors are considered. Advantage is taken of the built-in, two-way communication between national programs and Lima headquarters through regional offices to determine specific problems. Also considered is accumulated documentation on the problem and whether CIP has the expertise and facilities to do the necessary research and the amount of work expected from the scientists who would be involved.

A research project develops cooperatively through discussions involving a thrust coordinator, a department head, and scientists. The end result is a formal research Project Outline, which is submitted to the Director of Research for authorization. In the development of a project, a department head may sometimes have a dual role: to provide expert advice, and to administer project funding if he is head of the project leader's department.

This organization plan permits flexibility for changes in priorities without major shifts in staffing. Additional commodities — sweet potatoes, for example — or thrusts could be added without a major increase in funding for staff and facilities. Departments would remain the same.

Regional Programs

Regional research is guided by priorities developed through headquarters and regional scientists and their national counterparts. A workplan, developed at the annual internal review during detailed discussions with regional staff, is followed closely during

The government of Rwanda suggests that other commodity programmes follow the same training strategy as the CIP/PNAP team uses for technicians and farmers.

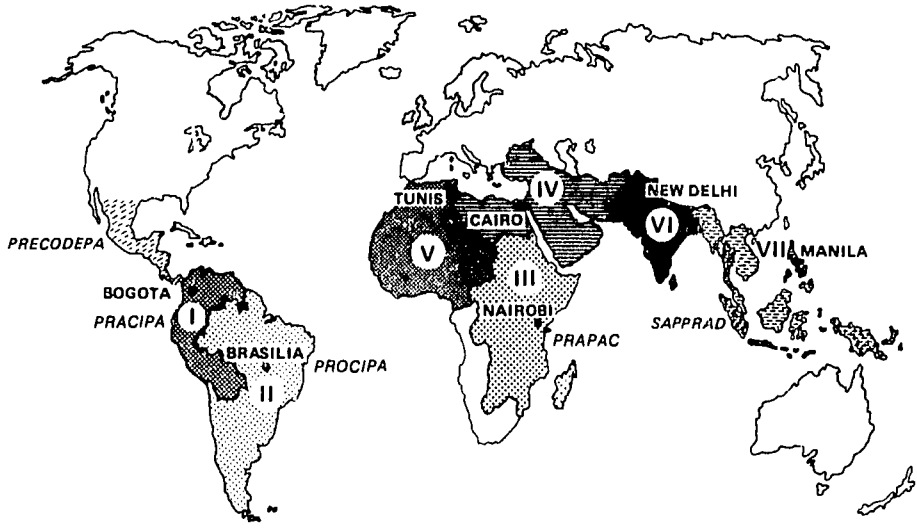
— M. Bicamumpaka, Rwanda.

Farmers attending training session (below). Africa.

the subsequent year. Reporting follows the same program lines as in headquarters research and results are compiled in Progress Reports. Priority areas for regional research are currently: regional germplasm evaluation, adaptation of potato to tropical conditions, strengthening national seed systems, developing technology for potato production from true seed, improving post-harvest technology, and agronomic management.

The Regional Research and Training Program works directly with national scientists to conduct production-oriented research and exploit technology available from CIP and elsewhere. Host countries and boundaries for CIP's seven regional programs shift occasionally in response to emerging national capabilities and political developments. Current regional organization is shown on the accompanying map.

Regional staff members collaborating with national scientists are responsible for identifying key production problems, testing and adaptive research, multiplication and distribution of genetic materials, training, and related activities that strengthen national potato research and extension programs. CIP has few physical



CIP REGIONS IN 1983

facilities at its regional stations and relies on a national institute or another center for office space and logistical support.

Short-term consultants are not a substitute for permanent personnel in regional programs. Effectiveness in a region depends on detailed knowledge of the individual countries, insights that can only be built up over time by regional scientists in the field. Short-term consultancies generally can be filled by headquarters scientists in routine travels. Consultants from Europe, North America, and Australia are sometimes used but local consultants are preferred.

CIP concentrates research and training efforts of regional teams in priority countries according to the following criteria:

- Capabilities of national potato program, human resources, research facilities, and transportation.
- Importance of potato and potential for improvement.
- Commitment of host government to improve potato production from national funds.
- Existence of national expertise for cooperative research projects related to priority research areas.
- Location of CIP regional research staff.

Socioeconomic Research

CIP is unique among the International Agricultural Research Centers in the manner and extent to which it involves social scientists in its program. As members of interdisciplinary teams, anthropologists, economists, and sociologists make several contributions to research:

- Through provision of data and insights on household decision making, farming systems and institutions, they help establish

research priorities which are in keeping with the needs and resources of developing countries.

- Through involvement in farm-level testing of potential new technologies, they help evaluate research progress and pinpoint areas for needed adaptations to local conditions.
- Through studies of farmer adoption, rejection, and adaptation of new practices, they contribute to the understanding of technological change and its consequences.

Social scientists also conduct specialized studies on world patterns and trends in potato production and use; farming systems in which potatoes are, or may be, grown; marketing problems; and potato consumption and nutritional contributions to the human diet.

Budget and Staffing

CIP operates under the smallest budget of the CGIAR-sponsored commodity research centers with global mandates. Yet, employing strategies described later in this publication, CIP's contacts with country programs and the delivery system for research and training are the most thorough of any Center's. From the initial planning grant of $50,000 in 1970, CIP's operating budget has grown to approximately $10 million in 1984.

The CGIAR system's 1984 total core operating budget (approximately $180 million) is smaller than the budget of some individual developing country agricultural research systems. This illustrates that International Agricultural Research Centers in general, and CIP in particular, constitute only a small, yet strategic, part of the global agricultural research system.

Of CIP's total budget, approximately 60% is allocated to research at headquarters and contract research at other institutions and 40% to Regional Research and Training.

A large portion of the budget has been for regional programs since CIP's inception. This has led to firsthand knowledge of developing country conditions and interaction with national program leaders to help CIP develop programs that respond directly to the priority needs of clients. Strengthening national programs and positive impacts on potato production and use began early in CIP's life — long before the first CIP crosses had resulted in new varieties used by farmers. Examples include assistance with planning for national programs, training, distribution of germplasm originating in other breeding programs and dissemination of new techniques for seed multiplication, storage, and agronomic management.

CIP employs a relatively small staff of biological and social scientists — currently 77 internationally-recruited staff members from 11 developing and 10 developed countries. Fifty-four of these scientists are based at CIP headquarters and 23 at regional sites, working in close collaboration with national programs. The research program is fortified by senior staff contribution through contracts and collaborative associations at a relatively low cost to CIP.

PART 4

Collaborative Research and Development Strategies

CIP's research and development philosophy is to involve as many other institutions and scientists as possible in research, training, and potato improvement while keeping its own program modest in scope. Part 4 briefly overviews strategies CIP employes in program planning and review, interdisciplinary team research, institutional linkages, and training. How these strategies are used is illustrated by examples in the latter part of the publication.

Program Planning and Review

CIP uses a wide range of external resources and inputs from its many regular contacts to provide continuous, active planning and review of its programs.

The Board of Trustees

CIP's Board of Trustees, consisting of 10 internationally known scientists and research managers, has been innovative in several respects. To date, 30 individuals from 16 nations have served as board members — 14 from developing and 16 from developed countries. The Board's 8-member Program Committee participates actively in CIP's annual Internal Review. The Executive-Finance Committee developes the program and budget document prior to final approval by the full board.

Individual trustees participate actively in CIP's research and training in areas related to their scientific discipline and research management experience — for example in planning conferences, workshops, and training activities.

Over the years, the Program Committee's report, circulated to all CIP scientists, has provided comments, questions, and suggestions that have substantially influenced work priorities. Specific "position papers" on key research areas are requested each year by the board and have stimulated re-thinking of research needs and strategies. A board request for an updated series of "country profiles" on potato production and use resulted in 75 documents for use as information sources for shaping CIP's research and training priorities in relation to specific country situations and needs.

> *I would like to see development of more and stronger linkage in the field of agricultural economics and social science research between BARC and CIP.*
>
> — Ekramul Ahsan, Bangladesh.

CIP was the first center to elect a woman as chairperson of its Board of Trustees. This individual — a sociologist from the Philippines — has provided invaluable guidance for the social science program.

Involvement of Social Scientists

Social scientists are well integrated into CIP's research planning and review.

When CIP was established, little was known about potato agriculture in developing countries. A team of social scientists — anthropologists, economists, and sociologists — assembled and analyzed needed information on key topics including production trends, technologies employed, marketing, and consumption. This information, much of which has been published in bibliographies, statistical handbooks, journal articles, and book-length monographs, is intensively used by CIP management, the Board of Trustees, regional scientists, review teams, and national program leaders.

Social science publications are distributed to a mailing list of nearly 700 individuals and institutions from 77 countries around the world.

Internal Reviews

A unique method for program evaluation and change is an annual week-long internal review in December. Scientists present 10- to 15-minute verbal reports on their research before the entire scientific staff, national program leaders, the Program Committee of the board, and contract research scientists. After presentations on each major area of research, transfer, and training, lively and constructively critical discussions ensue. Trustees participate as part of the CIP team and not as external reviewers. However, observations and recommendations of the Program Committee become an input into management decision-making.

While in Lima for the internal review, regional staff members meet with each headquarters-based thrust representative to plan regional research, travel, and training activities for the coming year.

Planning Conferences

Institutions and scientists from throughout the world participate in evaluating and planning for each of CIP's priority research areas

> *Both CIP and our contract scientists would benefit from more extensive interchange with the broad range of CIP staff.*
>
> — **Robert L. Plaisted, Cornell University.**

in periodic planning conferences. To date, 273 scientists from 41 countries have participated in 27 planning conferences. The conferences, which review progress and recommend future research, have three functions:

- Provide CIP with an objective external review and guidance by international experts.
- Establish informal networks of scientists which function for years after the conference, providing a useful mechanism for exchange of research information.
- Stimulate participating scientists to re-orient their own research to help solve key problems identified at the conference.

Distribution of Planning Conference proceedings helps familiarize scientists and policy makers in both developing and developed countries with CIP's principal research areas, progress to date, and future priorities.

Brain Picking as a Research Aid

Lima, Peru — Planning Conferences are a unique way used by the International Potato Center (CIP) to keep its research activities before the world's scientific community, and receive advice and suggestions from top scientists in specialized research areas.

Planning Conferences give professionals the opportunity to mingle over potatoes and exchange ideas. In addition to making recommendations for future research (a part of each conference agenda), every planning conference results in worthwhile spinoffs. For example, in a recent conference on integrated pest management two groups got together on possible manufacture of a sex pheromone for controlling the potato tuber moth.

Each conference is for a week with scientists presenting papers on current research activities. An attempt is made to have a Planning Conference on each of CIP's priority research areas about every 3 years.

The 273 scientists attending Planning Conferences over the last 11 years have been from these 41 countries: Argentina, Bangladesh, Brazil, Chile, Colombia, Costa Rica, Denmark, Ecuador, Egypt, England, France, Guatemala, Honduras, India, Ireland, Israel, Italy, Japan, Kenya, Korea, Mexico, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Panama, Philippines, Peru, Poland, Republic of China, Scotland, Sri Lanka, Sweden, Switzerland, Taiwan, Tunisia, Turkey, Trinidad, USA, and West Germany.

Long-Term Planning

In 1979, based on results of planning conferences and assessment of developing-country needs and CIP's comparative advantages, the first edition of CIP's "Profile 1972-2000" was issued. This long-term plan, the first developed by any center in the CGIAR system, is updated periodically to reflect research progress and changing circumstances. Time frames for completion of specific activities are identified, as well as shifts in research priorities. The Profile, widely distributed to policy makers and scientists in both developing and developed countries, is a benchmark to measure progress and determine funding and staffing needs.

Management

The management philosophy at CIP has been to spread decision making among a large number of senior staff who take responsibility and are given authority once the budget and funding has been

Potatoes and bananas and beans and kids. Rwanda.

established for a given year. Four essential points in CIP's management approach are:

1. An organizational structure permitting maximum involvement of scientists in decision making.
2. Executive management training for scientists moving into or occupying management positions.
3. A flexible management approach that permits routine problems to be resolved at the project level.
4. Senior management concentrated mainly on policy issues, relations with donors, and contracts and agreements with other institutions and national programs.

With two scientists attending concentrated executive management courses each year, management expertise has been established at CIP so that scientists feel comfortable performing financial and personnel management responsibilities along with their scientific duties. Hence, the transition from a scientific to a management role at CIP is smooth and without trauma.

Thrust requirements determine the manpower facilities and operational funds which must be built into departmental budgets. Departmental and Regional Research budgets result from discussions among thrust coordinators, department heads and regional leaders with the directors of Research, Regional Research and Training, and the Controller present. A final budget document goes first to the Executive-Finance Committee which includes the chairman of the Board, secretary of the Board, chairman of the Program Committee and Director General before going to the full board for approval.

Once the budget has been approved and funded, the authority and responsibility goes to thrust coordinators, department heads and regional leaders for follow-through with operational program details for a given year.

Institutional Linkages

Several strategies link CIP to other research, transfer, and training programs.

CIP regional staff members corresponded with scientists from 89 developing countries during 1983: 17 countries in Latin America, 19 in Central and East Africa, 30 in North and West Africa and the Middle East, and 23 in South and South East Asia. In the same year, CIP staff members visited 61 developing countries and scientists from 44 national programs visited CIP regional offices. Scientists and policymakers from 32 countries visited CIP headquarters in Peru.

CIP's 54 internationally recruited headquarters-based scientists spent 1,040 man-days in 1983 outside Peru in 179 visits to other developing countries. These visits were to familiarize CIP staff with local problems, interact with national leaders, and scientists, and participate in training courses and workshops.

I am highly impressed with this collaboration [with CIP] which has not only helped in building a strong potato program but has given national pride.

— Ayubur Rahman, Bangladesh.

Specific linkage strategies are described in this section and illustrated in greater detail in the illustrative studies later in this book:

- Special projects
- The "Third Dimension" approach
- Collaborative research networks
- Regional research projects
- Research contracts

Special Projects

CIP was the first Center to establish regional programs on core funding, thus ensuring continuity of relations with country programs and minimizing dependence on special project funding.

CIP has formal written memoranda of understanding with 44 institutions in 33 developing countries, but prefers to backstop national programs through collaborative research projects and contracts rather than directly manage and staff special country projects. The few special projects which CIP administers generally provide short-term funding for specific national or regional needs.

Special project funding allows CIP to post staff in countries to work full-time with local scientists in identifying production constraints and strengthening research and extension capacity. Currently, CIP has four special country projects in Bhutan, Burundi, Peru, and Rwanda. All involve seed improvement programs. Previously, special country projects were in Nepal and Tunisia. The Rwanda and Tunisia studies later in this publication document the high rates of return to investment in effective local seed improvement programs.

The "Third Dimension" Approach

When country leaders seek external funding for a potato program, CIP attempts to link the country program with a donor agency and a locally based international agency capable of administering the funds and implementing the project. In most cases, drawing on its extensive contacts with potato specialists around the world, CIP also helps identify qualified project staff. This strategy allows CIP to minimize the number of special projects. CIP backstops these potato projects managed by others. Their staff members are invited to participate in the annual Internal Review and are treated as CIP staff for all but payroll purposes.

Technology transfer alone is not sufficient to assure food security and increased food availability per capita. The LDCs need an effective network of regional, national, and international institutions and must be willing and able to revise their policies to encourage increases in food production.

— **Josette Murphy, U.S. Agency for International Development.**

Three Third Dimension projects presently active are in Bangladesh, Nepal, and Pakistan. A somewhat similar approach was taken with a bilateral project in Bolivia, discontinued in 1981 and expected to be re-activated in 1984.

Collaborative Research Networks

Many developing countries cannot afford a comprehensive potato research program. For this reason CIP fosters collaborative research networks in which country programs pool their resources to establish their own integrated research programs. CIP participates as a member in these networks but does not manage them. These are not be be confused with the "nursery networks" established by many international centers for evaluating germplasm.

In initial development of a collaborative network, country leaders assess capabilities of their own and other country research institutes for solving priority problems in the region. Projects are assigned within the network in accordance with each country's needs, interests, and facilities. This type of network builds national program capabilities and a spirit of confidence and cooperation for mutual benefit. This strategy is particularly useful in small countries with few scientists and limited research facilities.

This type of cooperation makes it unnecessary for each country to mount an extensive potato research program, particularly where the crop is of secondary importance. For CIP the advantage is that for each problem area, CIP scientists can concentrate support in the country which has been assigned a leadership role. Subsequent diffusion of information through training and consultancies is the responsibility of the countries themselves.

The Third Dimension approach of locating interested donor countries and needy recipient countries, matching their interests in formulating and implementing national potato development programs, is very productive. Recipient countries immediately benefit . . .

— **Pema Wangchhuk, Bhutan.**

Two factors are essential for success of this strategy:

1. **strong coordination, particularly through the formative years of the organization; and**
2. **additional external funding to start individual research projects and finance regional activities beyond the scope of national budgets.**

Five collaborative networks now functioning:

	Member Countries	External Donor	Initiated
PRECODEPA	Mexico, Dominican Republic, Guatemala, Costa Rica, Honduras, Panama, El Salvador, Cuba	Switzerland	1978
SAPPRAD	Philippines, PNG, Indonesia, Thailand, Sri Lanka	Australia	1982
PRACIPA	Venezuela, Colombia, Ecuador, Peru, Bolivia	Canada (IDRC)	1984
PROCIPA	Brazil, Uruguay, Argentina, Chile	CIP	1983
PRAPAC	Rwanda, Burundi, Zaire	U.S.A. (USAID)*	1982

PRECODEPA = Programa Regional Cooperativo de Papa
SAPPRAD = Southeast Asia Potato Program for Research and Development
PRACIPA = Programa Regional Andino Cooperativo de Papa
PROCIPA = Programa Cooperativo de Investigaciones en Papa
PRAPAC = Programme Regional d'Amelioration de la Pomme de Terre en Afrique Centrale

*Proposal in preparation.

Impressive performance of PRECODEPA, one regional network established in Central America in 1978, is illustrated in the final part of this publication.

Twenty-five persons from 13 different countries have been trained at Cornell University with CIP contract funds. We are enthusiastic about CIP's contract research philosophy. It allows CIP to tap ❝ *into existing programs and get a lot for its* ❞ *money . . . we are able to give students from developing countries thesis topics relevant to the needs of their countries.*

— Robert L. Plaisted, Cornell University.

Collaborative Research Projects

Just as research projects are the building blocks of CIP's headquarters research program, collaborative projects are the building blocks of Regional Research. Direct collaboration of CIP and national program scientists ensures that project objectives are in line with priorities of both institutions, and that results are immediately available to both. Each year project results are sent to CIP headquarters on a standardized project progress report form. In 1983 a total of 111 collaborative research projects were implemented in 30 developing countries, making a substantial contribution to research programs of both CIP and the national programs involved.

Quick Solution to a Storage Problem

Santo Domingo, Dominican Republic — PRECODEPA, the Regional Cooperative Program for Potato Development in Central America and the Caribbean, helped solve a potentially serious potato storage problem in the Dominican Republic.

Due to a rice deficit in 1983, the Government of the Dominican Republic promoted potato production through radio and television, offering credit, and guaranteeing purchase of the harvest by the Instituto de Estabilizacion de Precios (INESPRE). The result was almost too successful.

Potato growers responding to these incentives produced a surplus of more potatoes than INESPRE could store in existing facilities. Additional storage capacity was urgently needed.

Originally, INESPRE decided to construct costly sophisticated cold storages. But then, technical staff of the Dominican Republic's potato program were consulted by the executive director of INESPRE. Based on technical storage publications they had received from the International Potato Center (CIP), headquartered in Lima, Peru, and from Guatemala they convinced INESPRE's executive director to construct low-cost rustic storages instead.

Two technicians were immediately sent to Guatemala — the PRECODEPA organization's project leader for storage research — to learn about construction of simple storage. Upon returning to the Dominican Republic, they recommended designs and with INESPRE technicians selected construction sites for the stores. A total of five stores was built for consumer-potatoes, using local materials — sugar cane stalks and pine poles. Cost of each warehouse was around 2,500 pesos (US $2,500).

To ensure better storage of the potatoes, it was decided to use growth inhibitors. Technical assistance and training were sought from Panamanian scientists, based on their experience with consumer-potato storage in that country.

First of the 1,200 tons of surplus potatoes went into the rustic stores just 4 weeks after INESPRE and the national potato program learned of the problem — fast time any place. Results were highly successful: potatoes were stored for 6 months with less than 2% loss.

PRECODEPA is a network of eight Central American countries which have pooled their human and physical resources to provide potato research on "local" problems. The organization has operated since 1978 with these countries participating: Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Honduras, Mexico and Panama (Cuba and El Salvador joined in 1983).

> *The project [bilateral with CIP backstopping] is one of the successful and fruitful collaborations with the network of the international centres under the CGIAR system and could serve as a valuable model for other countries.*
>
> — M. M. Rahman, Bangladesh.

Research Contracts

Research contracts provide CIP with low-cost access to available scientific expertise and research facilities throughout the world. Contracts motivate researchers to work on priority problems of developing countries, and provide operating funds necessary to conduct needed research. Contracts allow CIP staff members to establish personal working relationships with leading scientists around the world, and permit flexibility for changing research priorities without incurring major changes in headquarters staff and facilities.

Research contracts provide operating funds for labor, expendable supplies, and travel but not for salaries for scientific staff.

In the early years, contracts with breeding programs in North America quickly gave CIP access to world class breeding programs and genetic material to distribute to developing countries. Over time, an increasing number of contracts are with developing country institutions. In 1983 CIP had 21 active research contracts with research institutions in nine developing countries and 14 contracts in seven developed countries.

Training and Communications

CIP's long-range plan calls for development of a global communications network to reach third world potato researchers, extensionists, and educators through national programs. Such a network depends on an effective training program supported by communications and library services.

CIP's training program is based on the philosophy that research and extension efforts conceived and executed collaboratively with national programs are more appropriate, effective, and longer lasting than those conceived and executed independently by CIP. A fundamental concept is that national programs have a comparative advantage to reach their producer/farmers more efficiently in addition to analyzing governmental policies, growing conditions, research, and training needs. CIP's role is to assure that all involved contribute their part to benefit a third world country where the potato can become a major factor in alleviating hunger.

CIP's training goal is to strengthen national capabilities to develop and transfer improved technology. Specifically, training activities seek to improve national abilities to:

- identify research needs and priorities for improving production;
- identify existing technology relevant to the country's needs;
- conduct research in the most important problem areas;
- adapt research results from other sources under home country production conditions;
- participate in transfer of appropriate technology within their countries and surrounding countries; and,
- train others to identify existing technology and research needs, conduct research, adapt results, and participate in the transfer process.

Plans for collaborative research and training emerge from continuing dialogue between CIP regional staff and national leaders. These plans address real-world problems and, more importantly, reflect the contribution of current national research and extension capabilities in the transfer process.

Essentially CIP is involved in two types of training: production-oriented and specialized.

Production-oriented training stresses general principles of potato production directed at researchers and extensionists, enabling them to better respond to farmer-level production situations. It is conducted away from headquarters in collaboration with national programs.

In production training, advanced national programs with greater technical and administrative expertise take more direct responsibility for training than less advanced programs where expertise is

Contracts for Specific Research

Lima, Peru — The International Potato Center (CIP) employs a strategy of "contract research" to augment its headquarters research base in a low-cost and flexible manner. The advantage is to use personnel and facilities of other institutions when needed and not available at CIP for special research projects.

CIP financed 35 research contracts with 26 different institutions worldwide in 1983. Of these, 21 were with universities and research institutes in developing countries, 14 were in developed countries.

Most research contracts were for breeding or evaluation of germplasm — 11 in developing countries, seven in developed countries. The average for the past 7 years has been 30 research contracts each year at an annual cost of $437,500.

Aspects of seed tuber production, including storage, virus detection, and tissue culture, involved eight contracts. Four contracts, all with developing country institutions, were for research on true potato seed.

Other research areas were refining electrophoresis techniques for clonal identification, statistics, fundamental research on bacterial pathogens of the potato, and training.

Contracts were with institutions in Argentina, Australia, Brazil, Canada, Chile, Colombia, Ecuador, Germany, Holland, Kenya, Korea, Peru, Scotland, Sri Lanka, Switzerland, and the U.S.A.

> *CIP has played a significant role in training technical manpower in Pakistan . . . during workshops 61 researchers, extension workers and farmers have been trained . . . prior to CIP collaborative activities there was a dearth of trained personnel.*
>
> — **Amir Muhammed, Pakistan.**

still in the development stage and where it is necessary for CIP to take more responsibility. CIP's involvement — providing trainers or financial resources — may not even be needed for advanced programs, such as Chile and Colombia.

Specialized training concentrates on areas of research for which CIP is the principal source of information and experience. It is directed at enabling researchers to conduct research.

Specialized training is similar to production-oriented training in that more advanced programs provide a greater input than the less advanced. However, where programs are non-existent, no direct CIP input is made until the countries have determined their research and training priorities and some advancement has been made. Personnel capable of producing potatoes must be available before training in specialized areas is advantageous. As programs improve, the need for CIP direct input diminishes. In advanced programs CIP continues to provide specialized training in areas where national expertise is not available and for new technologies.

Do-It-Themselves Training

Lima, Peru — Three international agricultural research centers in mid-1981 joined a unique training project funded by the United Nations Development Programme (UNDP).

Taking part were CIAT, Cali, Colombia; IITA, Ibadan, Nigeria; and CIP, the International Potato Center headquartered in Lima, Peru. CIP, for example, uses funds received under the program to train the trainers — to give national potato program scientists, extensionists, and educators experience to train others within Peru and from other countries.

It is called "horizontal" transfer of technology and has been a singular success. In 12 potato storage courses many of the 261 participants, for instance, found themselves actually constructing a rustic store to obtain basic knowledge before teaching that particular subject.

The idea went deeper, however. Participants did their own course planning and preparation and presentation. Often it was the first time they had the opportunity to "be on their own." They learned and practiced the fundamentals by doing. Successes were theirs, as were errors.

During CIP's 3½ years of UNDP-funded training a total of 473 national program personnel took part and they represented 45 different countries. The 18 courses were on seed production, storage, and on-farm research. Countries in which the courses were held included Colombia, Chile, Rwanda, Zambia, Tunisia, Sri Lanka, Bangladesh, the Philippines, and Peru.

Mid-Career Scientist Training

Simla, India — One of the first mid-career scientists to study at the International Potato Center (CIP) headquartered in Lima, Peru was a veteran of 27 years of agricultural research in India.

S. K. Bhattacharyya, a plant pathologist in the Central Potato Research Institute (CPRI), used CIP's World Potato Collection in research, mainly at Huancayo, Peru, to obtain plant material resistant to charcoal rot, caused by the fungus *Macrophomina phaseolina* (Tassi.) Goid.

Dr. Bhattacharyya returned to India in August of 1980 after screening thousands of clones in the World Collection and selecting 22 clones that were immune to charcoal rot, 11 that were resistant, and 44 that were moderately susceptible. Charcoal rot, a warm climate disease, may cause field and storage losses as high as 75% in some parts of India. Losses have also been reported in the Middle East and in Texas in the United States.

All of the 22 immune clones were from the breeding population that is also used in root knot nematode resistance research. He reported that all clones from the promising source of charcoal rot resistance — and root knot nematode resistance, too — possess a wild potato, *Solanum chacoense*, in their parentage, a fact confirming studies beginning nearly 20 years earlier. He also pointed out that the *andigena* clone OCH 6112 is of interest as it is also resistant to soft rot, another serious problem in the plains of India. The clone OCH 6112 was discovered in 1975 during one of CIP's plant exploration expeditions.

As a result of interaction with national programs across all regions a plan for all of CIP's training is prepared. The current plan looks ahead to the next 5 years. It is updated annually and reflects national needs as well as national involvement.

Training Accomplishments

Since 1978 CIP has trained or facilitated training for more than 2,500 national potato researchers and extensionists (Table 4). These potato workers from 102 developing countries received training in seven major areas of CIP's research: germplasm management, production of potatoes from true potato seed, potato production in warm climates, post harvest technology, on-farm

Table 4. Evolution of training activities:

Year	General Production Courses	Specialized training			Total
		Courses	Individualized	Research assistantships	
1978	145	107	5	37	294
1979	221	100	18	48	387
1980	117	65	27	43	252
1981	94	390	10	48	542
1982	146	246	19	48	459
1983	355	128	46	62	591
TOTAL	1,078	1,036	125	286	2,525

NOTE: Research assistantships, which often extend beyond one year, may be reported in two or three consecutive years.

research, seed production, and general production techniques (Table 5).

Table 5. Trainees by country of origin and course topic 1978-1983.

Country	Germ-plasm Mngemnt	Tropical Agronomy	Seed Prod.	TPS	Post-Harvest Tech.	On-Farm Research	General Prod.	Total
Algeria	1						24	25
Afghanistan		1			3			4
Argentina	3		21		2		17	43
Australia	1		1					2
Bahamas			2					2
Bangladesh		4	62	1	27	1	11	106
Benin					1	1		2
Bhutan	1		11		1		46	59
Bolivia	3		17		5	2		27
Brazil	5		62		6		19	92
Brunei		1	1					2
Burma		3	2		1	1		7
Burundi			2		17	6	16	41
Cameroon	2		2		2	2		8
Cape Verde					1	1		2
Chile	3		26	1	8	2	1	41
China	1		1					2
Colombia	6	1	40		28	1	3	79
Congo	1							1
Costa Rica	1		11	1	2	13	6	34
Cuba	2		1	2				5
Cyprus	2		1			1	3	7
Dominican Republic	1		7	2		2	5	17
Ecuador	4		15		5	2	10	36
Egypt	5		1	1	1	2	3	13
El Salvador				1	2	1		4
Ethiopia	2		4				7	13
Fiji		1	1					2
France						1		1
Ghana	1							1
Guam							1	1
Guatemala	1		2	1	5	1	2	12
Guinea							1	1
Haiti			2					2
Holland	2		2					4
Honduras			2		3	1	2	8
India	1	2	9	2	1			15
Indonesia	6	25	3	1	1	1		37
Iran	2						2	4
Iraq							4	4
Ivory Coast					1	1	1	3
Japan			1					1
Jordan	3						13	16

Country	Germ-plasm Mngem..t	Tropical Agronomy	Seed Prod.	TPS	Post-Harvest Tech.	On-Farm Research	General Prod.	Total
Kenya	2		15	2	9		22	50
Liberia	1		1					2
Libya							5	5
Madagascar						5	50	55
Malawi	1		4				1	6
Malaysia	2	3	2					7
Mauritania					1	1		2
Mauritius		1	1				15	17
Mexico	4		14	9	3	3	1	34
Morocco	2					1	27	30
Nepal	1	2	5		2		2	12
New Caledonia		1						1
Nicaragua			2					2
Nigeria	6		2					8
Pakistan	1		35		15	34	39	124
Panama			7			2	10	19
Papua New Guinea		1	1		1			3
Peru	24		116	22	51	25	5	243
Philippines	18	37	62	2	13	9	25	166
Poland			1					1
Rwanda	1		4	1	2	14	107	129
Senegal					1	1	3	5
Sierra Leone	1		2					3
South Korea	3	4	4	2	2	2		17
Spain	2							2
Sri Lanka	3	6	7	2	232		4	254
Sudan	1		2		1			4
Swaziland			2					2
Switzerland					1			1
Syria	3		1		1		2	7
Taiwan	1	2						3
Tanzania			4		2		2	8
Thailand	6	2	6	1	4	2		21
Togo	1				1	1	3	6
Tonga	1							1
Tunisia	4		4		5	7	44	64
Turkey	18		17		1	12	7	55
Uganda			2				2	4
United Kingdom		1						1
Upper Volta					1	1	1	3
Uruguay			2		1		2	5
USA	3							3
Vanuatu	2							2
Venezuela	5		32		4			41
Vietnam	6	3	1			1		11

Country	Germ-plasm Mngemnt	Tropical Agronomy	Seed Prod.	TPS	Post-Harvest Tech.	On-Farm Research	General Prod.	Total
West Germany			1					1
Yugoslavia	2							2
Zaire	2		5			5	42	54
Zambia			4		1		2	7
Zimbabwe	1		1				1	3
TOTAL	188	101	681	54	478	169	621	2,292

NOTE: Pest management and tissue culture are included in seed production.

Results of training are difficult to measure. In an ongoing study of former trainees, CIP uses these criteria for evaluation:

(1) The number and types of research projects started after the training.

(2) The extent to which former trainees are training others on topics covered during training.

(3) The extent to which trainees are interacting with farmers on topics related to the training received.

Based on 300 initial responses the following was found:

- The largest percentage (33%) indicated their profession was general agronomy.
- More than half (56%) the respondents indicated they had begun new research projects following training. A total of 344 new projects were listed. The major problem areas covered are: seed production, germplasm management, post harvest technology, and agronomy.
- Eighty percent of respondents indicated they had trained 25,500 others including 12,900 farmers; 6,100 researchers, extensionists, and technicians; 5,100 university students, and 1,500 potato workers from other countries. That is an average of 85 other persons trained by each of 225 respondents.

These findings also indicate that about half of CIP trainees have research responsibilities, but there is little research specialization in national programs. This is particularly evident in countries with recently established national programs.

As a result of training, more time is spent on potatoes and a large number of research projects have started. This new research is being focused on major problem areas limiting potato production in the third world.

The multiplier effect of training is impressive. Clearly, those trained are training others, not only farmers, but other researchers, extensionists and university students. This is further evidenced in CIP's training. In 1983, 109 of the 138 instructors in CIP-sponsored production courses were either national program staff or CIP technicians — only 29 were CIP scientists. Also, of the 122 instructors in specialized training, less than half (57) were CIP scientists.

> *The 'new' technologies generated by CIP — genetic materials, information, virus studies, training, and others — have been provided national programs soon after they were solicited.*
>
> — Carlos Crisci and Francisco Vilaro, Uruguay.

The fact that 300 respondents report having trained nearly 13,000 farmers indicates that information on new technologies is reaching large numbers of farmers.

Training Effects - Two Examples

Ecuador Seed Production Program. Since 1980, CIP has provided research funds to the Ecuadorian potato program through INIAP. The national leader reported the following regarding training on rapid multiplication techniques:

> "Although ours is a small country, we have been able to use these techniques and in 2½ years get tons of seed. In 1981 we received four test tubes of varieties free of virus from CIP. From what was in one of these tubes 3

Trainee concentration.

Multiplier Effect of a Single Publication

Quito, Ecuador — A single copy of a publication provided the impulse to help *campesinos* improve their seed potato storage in a remote region of Ecuador.

It started when a missionary agronomist of the Luke Society saw a booklet on potato storage published by the International Potato Center (CIP), Lima, Peru, and distributed through offices of a national potato program in Ecuador. The publication described small, rustic low-cost stores constructed of local materials using the known principle of diffused light as a way to prevent tubers from sprouting.

The missionary took suggestions from the publication and combined them into a project for the Quechua Christian Indian Association of Chimborazo Province in Eucador. It was an entirely new idea; previously local farmers stored their potato tuber seed in dark corners of their homes.

Eucalyptus lumber for sides and bins plus a corrugated metal roof were the basic materials for a storage of 120 quintales capacity. Bins inside the structures contain the potatoes. Some stores were screened to reduce insect damage.

Each store cost about US$120 to build with the communities paying $20 and the remainder paid from donated mission funds.

Says the missionary-agronomist:

"We have constructed 55 of these storage structures in 50 communities. Some communities are beginning to fill them for the second year. Three farmers built their own storages using some of ours as models.

"To build a storage, we would send an agricultural facilitator from our program to show the community how. But the community had to do the actual construction — we hoped in this way to leave behind something of the construction technology for others."

months ago, we harvested 22 metric tons of virus free basic seed. This is important as it has caught the attention of many people. Before we even harvested we were getting inquiries from seed producers. This means we will now be able to get some producers to multiply this seed under contract with us to ultimately make it available to commercial producers. This would be of incalculable value.

"None of this would have been possible without CIP's assistance. We received training from CIP on tissue culture methods, rapid multiplication techniques, and virus indexing, and each person who has received training has trained others. We work in the field and in the greenhouse. The clean germplasm, of course, has been the key, but we would not have been able to use it without the training."

(F. Muñoz, 1983)

Philippines Seed Production. In 1981 a Filipino technician working with the Philippine-German Potato Research and Seed Program, headquartered at the Bureau of Plant Industry in Baguio, received 4 months training on rapid multiplication techniques. During a later tissue culture and rapid multiplication techni-

Through on-farm trials a mutual cooperative atmosphere between researchers, extension workers, technical disseminators, and farmers was formed.

— **K. K. Kim, South Korea.**

ques course in Vietnam, this technician reported that in the Philippines they are currently using a combined system of four multiplication techniques. Present output is 2,000 plantlets for planting per week. These are multiplied at the Baguio Seed Farm on the Mountain Trail in the potato growing area of the highlands in Luzon. Sixteen hectares are designated for seed production at

Missing Elements in Training

Lima, Peru — Usually two key missing elements hinder international agricultural training and success is harder to attain. National agricultural program personnel in the third world usually have the ability to conduct training — at the national or even the regional level — but lack experience and funding to organize courses.

The United Nations Development Programme (UNDP) is helping to resolve one of these needs (funding) which almost automatically solves the other. It is done under a global project on technology transfer on root and tuber crops. CIAT, IITA, and CIP, three International Agricultural Research Centers, are project participants.

UNDP provided funding to the Potato Research Program of the Universidad Nacional Agraria (UNA) in La Molina, Lima, Peru for training courses in 1982, 1983, and 1984. The International Potato Center (CIP) sponsored the courses — and assumed a back-up role, when requested.

UNA's training program was entirely "on its own" for all phases of the courses — it took the kudos and the raps. UNA prepared course programs and budgets well in advance which included selection of candidates, preparation of lectures, laboratory and field work, organization of field trips, and logistics.

Each 4-week course provided 200 hours of supervised training on potatoes with special reference to seed programs. Differences in potato production systems were all studied in visits to Peru's three main ecological zones: coast, jungle, and highlands.

Results were entirely satisfactory, according to all concerned. A total of 48 professionals were trained, 32 for the host country and Ecuador (2), Venezuela (4), Bolivia (4), Chile (2), and one each from Brazil, Argentina, Costa Rica, and Colombia.

Follow-up of one course showed 90% of participants had applied their learning within their institutions or organizations, 60% reported attempts to modify farmer practices, 90% shared their new learning with technicians and farmers and through university classes, all surveyed said they had used training materials furnished (mainly publications) after the course.

UNDP support included round-trip transportation, lodging, and meals at CIP, pocket money, materials, in-country logistical support, honoraria to instructors and for back-up technicians.

> *. . . training material to national programs, bulletins, lecture notes, circulars, books, proceedings of workshops and planning conferences, and slide sets on different aspects . . . serves as a valuable source of information to the national potato scientists with inadequate libraries.*
>
> — **Kazi Badruddoza, Bangladesh.**

the farm. This seed is further multiplied by selected farmers under contract on a total of 80 hectares. There is now enough seed to produce consumption potatoes on 2,000 hectares. According to the technician all this was possible because of training she and others received from CIP.

Distribution of Publications. Communications support has always been an integral part of CIP's development strategy. This unit produces publications and visual aids in support of administrative and research tasks as well as providing major support of the training program.

CIP regularly sends publications, including Annual Reports, CIP Circulars, Technical Information Bulletins, and Social Science Reports, to individuals and institutions in 136 countries: 29 in Latin America, 39 in Africa, 42 in Asia, and Oceania, and 26 in Europe and North America.

Technical Information Bulletins (TIBs) are now in English, Spanish, Hindi (India), and Bengali. Translations into French and Fari (Iran) are in progress.

TIBs synthesize generally available information and CIP-generated technologies important to researchers and extensionists. They are written for intermediate level professionals so they can be readily adapted for use by constituents and clientele. TIBs can be used for individualized study, support information in lectures on potato production, and disseminating information to farmers.

Nineteen topics have been covered by TIBs. They have been distributed to more than 60 national programs.

The CIP library contains 4,600 items in its book collection and loans to CIP staff and training programs total more 5,000 annually. The exchange agreement includes 320 libraries in 68 countries.

Client-Oriented Research. The Farmer-Back-to-Farmer Model

Agricultural research conducted in isolation from its potential clients often produces results that meet professional scientific standards of excellence but the results are of little practical value for application by farmers. CIP avoids this common pitfall by using a client-oriented interdisciplinary team research approach which also assures that new information actually reaches the farmer.

Based on experiences in development and dissemination of seed storage technology in the Mantaro Valley of Peru and elsewhere, CIP's post-harvest team formulated the "Farmer-Back-to-Farmer" research model. This model is based on the assumption that, to be effective, agricultural research should begin and end with the farmer, and involve interdisciplinary teamwork in all phases of a continuous research/diffusion process.

The Farmer-Back-to-Farmer model is now being used by CIP in collaboration with national programs to solve problems related to potato storage, seed systems, pest management and true potato seed. See the final part of this publication for additional details on development and use of the model.

Exploring for wild potatoes to add to World Collection (below). Southern Peru.

PART 5

Research Program and Results

CIP's research aims to solve priority problems of potato production and use in developing countries. Headquarters and Regional Research Programs are integrated to ensure a flow of information on production problems from national programs to CIP headquarters, and evaluation of headquarters research results under developing country conditions. Local evaluations of technologies and extension are primary responsibilities of national programs.

This section briefly describes CIP's major research areas and accomplishments to date.

The World Potato Collection

Future increases in world agricultural production to feed a growing global population will require new plant varieties with resistances to diseases, pests and environmental stress. Breeding for such resistances depends on access to gene pools with sufficient variability to permit new recombinations of genes.

"Centers of diversity" are areas where wild crop ancestors have been first cultivated as native cultivars. Plant extinction is a threat in many diversity centers, including that of the potato — the Andean region of South America for tuber-bearing *Solanum*. This genetic erosion, or loss of genetic diversity, is of international concern.

Through its sponsorship of collecting expeditions and as a repository of donated collections from other sources, CIP has assembled the World Potato Collection, which includes 5,000 classified cultivated accessions and 1,500 wild accessions. CIP's reservoir of germplasm — the material used by scientists to breed new combinations of plants — is the most complete and diverse collection of primitive potato cultivars in existence. Older collections are in the Soviet Union, the United Kingdom, Germany, and the United States. Thirty-one developing countries also have potato collections.

There are about 160 wild tuber-bearing *Solanum* species. More than 90 living species have been collected by CIP expeditions since 1976 and represent the most diverse collection of wild species in any gene bank. About 35 of the wild potato species collected during the past 150 years existed only as dried herbarium specimens and were considered extinct. However, during the past 8 years, 20 of these wild "extinct" species have been rediscovered. For example,

in 1981 a CIP scientist rediscovered specimens of *Solanum buesii* and *Solanum amabile*, both previously believed to have been extinct. Additionally, explorations since 1976 have discovered more than 12 entirely new species for science.

This World Potato Collection is at the heart of CIP's breeding research. It is available on a worldwide basis for developing new genetic combinations. Only an estimated tenth of the total known genetic variability of the tuber-bearing *Solanum* species had been used in world potato breeding prior to CIP's establishment. In other words, potato varieties long grown in temperature zone developed countries have a narrow genetic background with limited disease and pest resistance. It was this narrow genetic background which permitted the rampant spread of disease in the Irish potato crop in 1846 with the ensuing famine.

Management and Evaluation of the Collection

Efficient use of the World Potato Collection as a genetic resource in breeding programs requires its proper maintenance, evaluation to know its genetic characteristics, and documentation. Several thousand clones are planted in the field each year to screen for disease and pest resistance and to identify duplicates (Table 6). Samples of seeds of duplicate accessions are sent to the USDA Seed Storage Laboratory in Fort Collins, Colorado to insure long-term specialized maintenance. Samples of seeds of wild species are sent to the IR-1 project at the Sturgeon Bay facility of the University of Wisconsin.

All available data related to the World Potato Collection are accessible through a computerized data management system. It facilitates data retrieval to meet the needs of scientists. Efficiency in computerized information retrieval is maintained through a standardized descriptor system developed through a conference sponsored by CIP.

This system, and especially the electrophoretic verification of duplicates which is unique among germplasm collections, has helped reduce number of accessions in the cultivated collection from the original 13,000 accessions. Reduction in *quantity* of accessions improves *quality* of the collection by facilitating evaluation for desirable attributes in a smaller but more representative germplasm collection. It also makes long-term in vitro maintenance of the collection more feasible by eliminating many phytosanitary problems which accumulate when the collection is planted in the field every year.

In the potato's center of diversity it is also likely that more aggressive strains of pathogens and pests of the potato will occur. This provides unique opportunities to more fully evaluate the breeding potential of these potato genetic resources. Accessions are systematically screened against important nematodes, insects, fungi, bacteria, and viruses as well as against some environmental stresses such as frost, heat, hail, drought. For most traits the frequency of genotypes with some resistance ranges from 2% to 10%.

The research programme aims to improve potato yields . . . from 5 tons/hectare to 35 tons/hectare through breeding, agronomy and new production technology. These broad goals are gradually being realized largely through our close cooperation with CIP.

— J. M. Liwenga, Tanzania.

That is, out of 5,000 different clones, only 10 to 50 *may* have *some* degree of a desired attribute.

Some accessions have multiple resistances to certain pests and/or pathogens. One CIP accession has five different resistance traits, seven accessions four, 71 accessions three, and 14 accessions two resistance traits.

Primitive Andean cultivars as well as wild species may also possess undesirable characteristics. To overcome the "genetic

Table 6. Evaluations conducted in accessions of the World Potato Collection.

Traits evaluated		No. of accessions evaluated
Fungi		
Phytophthora	Blight	964
Phytophthora	Pink Rot	2,968
Streptomyces	Scab	927
Synchytrium	Wart	1,622
Angiosorus	Smut	329
Macrophomina	Charcoal Rot	2,383
Bacteria		
Erwinia	Soft Rot	226
Pseudomonas	Wilt	28
Viruses		
PVX		697
PVY		601
PLRV		1,112
Nematodes		
Globodera pallida		5,264
Globodera rostochiensis		1,252
Meloidogyne incognita acrita		3,938
Insects		
Phthorimaea	Tuber Moth	2,871
Environmental Stress		
Frost		341
Hail		3,932
Other Desirable Traits		
2n pollen production		806
Nutritive quality		840
		31,101

Our major collaboration with CIP is utilization and adaptation of advanced genetic materials. Dependence of our potato research programme on CIP for such materials will continue.

— **Gebremariam Shekour, Ethiopia.**

distance" between primitive cultivars and advanced clones, CIP develops "back-up populations." These populations permit wider use of genetic resources by concentrating genes for desirable attributes and reducing the frequency of undesirable traits.

Use of the World Collection

In CIP's early years, the breeding program drew heavily on other collections. For example, all bacterial wilt resistant clones distributed by CIP in its first 10 years either originated from a University of Wisconsin breeding program, or Wisconsin clones were used as parents in CIP's own breeding program. Every breeding program at CIP has used genetic material from other germplasm sources. Genetic material has been used from 22 developed country programs to make advanced clones quickly available to developing countries. However, CIP's World Collection is the primary source of breeding populations to develop improved clones with resistance to the potato cyst nematode, frost tolerance, adaptation to the lowland tropics, and virus resistance.

Wild species in CIP's collection are used to develop populations with new sources of resistance to bacterial wilt, the potato tuber moth and root knot and cyst nematodes. A source of resistance to potato spindle tuber viroid (PSTV), a virus-like pathogen of special quarantine significance in the international export of potatoes, has also been identified. Several sources of resistance to potato leafroll and X viruses have also been detected in the wild species.

Future Plans

Continued maintenance, exploitation, and utilization of the world germplasm collection is one major area in CIP's long-term plan. Research involving the World Potato Collection has only begun with an estimated 90% of the available genetic diversity of the gene pool of tuber-bearing *Solanum* awaiting future evaluation.

During the past 5 years difficult crossability barriers have been broken between species within the germplasm collection through use of modern tissue culture techniques (such as embryo culture) in combination with traditional methods (such as use of bridging species). This research has made previously inaccessible parts of the wild potato species gene pool available to modern breeding programs.

Advanced Lines and New Varieties

Most sub-tropical countries of the developing world that cultivate potatoes have depended largely upon imported varieties and cer-

One aspect of plant breeding (below).

tified seed from Europe and North America. These countries had no potato breeding programs of their own to develop disease and pest resistant varieties specifically suited to their agricultural conditions. In accordance with its mandate, CIP selected a breeding strategy to meet the specific requirements of client farmers in developing countries around the world. This strategy also makes efficient use of the World Potato Collection, a major resource of its breeding program.

Recurrent Selection

Various aspects of basic and applied breeding research are handled through CIP's nine projects and six research contracts with scientific institutions in Europe, North and South America. By using all of these resources, CIP brings together genetic materials combined on a scale never before attempted.

Interbreeding produces a new array of genotypes. In initial screening for pest and disease resistances and agronomic characteristics, desirable genes are at a low frequency. Selected in-

dividuals are intermated again, creating a new gene pool with an increased frequency of genes controlling desirable attributes. This process of recurrent selection is repeated several times, the selection pressure increasing in each cycle leading to the development of advanced clones.

The Population Breeding Strategy

The cycles of intermating selected parents, testing progenies and selecting a new population with a higher frequency of desired genes is known as population breeding. CIP decided on this strategy to meet its obligations to developing countries. It ensures that a breeding population maintains wide genetic diversity to assure high yields and stability of performance and it increases the frequency of genes controlling adaptation, yield, and resistance or tolerance to biotic stresses.

Seventy developing country potato programs have received germplasm distributed through CIP for evaluation under their conditions. Thirty-six selected clones have been multiplied and released by 22 national programs to growers. Eighteen are designated by specific names, often colorful adaptations of botanical, local or

Which Cultivated Potatoes Do You Prefer?

Lima, Peru — Seven different species of potatoes have been cultivated in the Andes since primitive times.

One of these species, *Solanum tuberosum*, exists as two subspecies, *Solanum tuberosum* spp. *tuberosum* and *Solanum tuberosum* spp. *andigena*. The subspecies *Solanum tuberosum* spp. *tuberosum* is the potato of commerce in North America, Europe and Asia and, as such, is the fourth most important food crop grown in the temperature zones.

The subspecies *tuberosum* potato originated in the Chiloé archipelago off the coast of Chile at a latitude of approximately 43 degrees South. Daylength there varies from 15 to 9 hours on the longest day (December 22) to the shortest day (June 22). It is a "long day" plant growing near sea level, say scientists at the International Potato Center, an agricultural research organization headquartered at Lima, Peru.

In contrast, the subspecies *andigena* originated near Lake Titicaca in what is now Peru and Bolivia at a latitude of approximately 15 degrees South. There daylength varies from 13 to 11 hours. *Andigena* is a "short day" plant growing at an altitude of 3,000 to 4,000 meters, CIP scientists explain.

Andigena potatoes generally have highly fertile flowers producing many berries containing seed. In appearance this highland potato is an upright plant of variable growth habit producing tubers of irregular size with deep eyes.

Tuberosum potatoes normally flower less profusely, are less fertile, lower growing and more spread out in growth habit than *Andigena* plants. *Tuberosum* tuberizes under long days, producing more uniform shallow-eyed tubers that are closer together than those of its more northern relative around Lake Titicaca.

Thus in Dublin, the Irish dine on their favorite variety of *Solanum tuberosum* spp. *tuberosum* grown under long summer days, while in Lima, Peruvians love the *andigena* "papas" common to northern South America.

Make mine french fries.

> *The release of these varieties effects a saving in per acre input costs to farmers as under local conditions they do not require any fungicide spray during their growth.*
>
> — Director of Agriculture, Sri Lanka.

historical significance. CIP does not name varieties but encourages developing country programs to provide appropriate variety designations on material they evaluate and release.

Years of careful planning are represented in each of scores of advanced selections going to national programs for evaluation. A total of 88 countries are now testing nearly 340 clones in advanced selection and variety trials. These clones have resistance or tolerance to frost, cyst nematodes, leafroll and X and Y viruses, late blight, bacterial wilt and heat.

From the outset, CIP scientists have assessed developing country potato problems and determined yield restraints to better orient their breeding programs. Such orientation is not easy considering the potato is vulnerable to some 265 diseases and pests as well as climatic stresses and soil nutrient deficiencies and toxicities.

Results so far have confirmed CIP's breeding strategy. It normally takes 10 to 15 years from the first cross to get a variety into farmer's fields. Now, after 12 years, useful material is being distributed by CIP at an accelerated rate. New sources of pest and disease resistances from the World Potato Collection should be in a useable form within the next 3 years.

The gene pool of wild species is being evaluated to find new sources of resistances to biotic and abiotic stresses.

Germplasm Distribution and National Programs

Germplasm Distribution

CIP attempts to fit the genetic nature and potential of its improved germplasm to the needs of the countries requesting material. The form in which genetic material is exported must also match the management capability of the recipient country to assure its efficient use.

CIP's unique quarantine system and procedures are briefly described in the sections on viruses and tissue culture.

Regional Germplasm Redistribution Centers provide the basic system for testing, multiplying, and distributing selected genetic materials to national programs. Selected clones have a greater possibility of being well adapted to the environmental conditions of

Out of CIP's tropicalized germplasm some new varieties are going to be added to our recommended list soon. The basic seed potatoes have already reached the seed multiplication programme.

— **Kamal Uddin Ahmad, Bangladesh.**

neighboring countries than materials selected under completely different environmental conditions.

Two Regional Germplasm Redistribution Centers are now operational, one at the Quarantine Station of the Kenya Agricultural Research Institute (KARI), at Muguga, outside Nairobi, and the other at Santa Lucia, near Los Baños in the Philippines.

National programs capable of carrying out the various phases of germplasm management can also receive directly from CIP's breeding program larger samples of segregating populations and advanced clones for testing and selection. A Regional Redistribution Center also sends clones selected in the regions to CIP headquarters for use in breeding subpopulations with greater adaptation to the environments in which they were selected.

To increase efficiency of this system, CIP offers intensive training courses in germplasm management to scientists from national potato programs. A total of 187 scientists has been trained in germplasm management.

CIP yearly distributes large amounts of improved germplasm produced under stringent export quarantine conditions. In 1983, for example, germplasm was sent to 53 developing and 17 developed countries. Before distribution, these materials are constantly checked for viruses and a viroid which might be the result of accidental contamination. Indicator plants, serology, electrophoresis, and electron microscopy are used to check for viruses and the potato spindle tuber viroid (PSTV).

Two principal types of genetic materials are distributed by CIP's breeding program:

1. Heterogeneous advanced populations as true seed or as tuber families. They are genetically variable and segregate for environmental adaptation, pest, disease and stress resistances or tolerance, earliness, and tuber quality factors. Tuber families are produced from hybrid true potato seed and in most instances are prescreened in early stages of their production for resistance factors.
2. Clones selected for specific adaptation to certain stresses or for their disease or pest resistance as pathogen-tested tuber samples or as in vitro plantlets.

CIP has a collection of 150 pathogen-tested selected varieties and advanced clones which originated either from CIP's breeding program or are introductions from other breeding programs subject to

CIP's scheme for seed production, testing and distribution. Some have resistance or tolerance to two or more biotic or abiotic stresses. Of the 150 selected clones, 16 carry combined resistance to late blight and bacterial wilt, 81 are late blight resistant, and 11 are heat tolerant and early maturing.

National Programs

Seventy developing and 18 developed countries are using CIP's improved germplasm, evaluating its performance in advanced clone and variety trials or using it as parental stocks for their own breeding programs. In 1983, a total of 43,000 tubers of clones and tuber families and 379,000 true potato seeds were airfreighted to 70 countries (Table 7).

Eighteen developing countries now have potato breeding programs capable of making their own crosses. More than 30 countries have identified promising clones and 22 have released new varieties from material received from CIP. Initially most of these originated from other breeding programs linked to CIP through research contracts. Increasingly, however, they originate from CIP's breeding program. Principal characteristics of these new varieties are resistance to late blight and bacterial wilt, adaptation to warm environments, and earliness (Table 8).

Late Blight Resistance

Late blight, caused by the fungus *Phytophthora infestans*, is the most damaging disease of the potato worldwide. Its control with chemicals is possible but costly. Several developing countries can plant potatoes only during the dry season or in colder climates

Table 7. Germplasm distribution 1983

	Countries in CIP regions					
	Latin Amer.	Africa	Asia	Sub-Total	Other Count.	Total
Countries receiving germplasm from CIP	15	16	22	53	17	70
Clones distributed						
Tubers	404	373	248	1,025	32	1,057
In vitro clones	9	18	50	77	167	244
Tuber families distributed						
Number	382	366	160	908	42	950
Genotypes (000)	18	9	10	36	6	42
True seed distributed (a)						
Samples	170	0	27	197	60	257
Genotypes (000)	17	0	15	32	7	39
True seed progenies distributed (b)						
Samples	13	10	35	58	10	68
No. seeds (000)	42	34	280	356	23	379

a. True seed for selection of potential varieties.
b. True seed for agronomic and adaptation studies.

> *The biggest arm of CIP is perhaps the regional research and training programme which appears to be extremely important for activities of the national level.*
>
> — **Kamal Uddin Ahmad, Bangladesh.**

because of late blight. Prior to CIP, breeding for resistance to late blight was mainly in developed countries in collaboration with a Mexican screening program. *Solanum demissum* was the principal source of resistance but unfortunately includes resistance genes liable to be overcome by mutants of the pathogens.

CIP is developing new clones based on late blight resistance from

Table 8. CIP germplasm introductions and source of clones released or named by 22 developing countries to 1984.

Countries	Clones released or named*	Major characteristics
Latin America		
Bolivia	Mariva (Peru)	CQ
Colombia	ICA Sirena (7.10, Wisconsin)	LB
Costa Rica	BR 63.65 (Wisconsin)	LB,BW,PLRV
	B-71-240.2 (Argentina)	LB,PLRV
Ecuador	INIAP-Bastidas (377520:1, CIP)	LB
El Salvador	India 830 (India)	LB
Peru	Molinera (BR 63.65, Wisconsin)	LB,BW,PLRV
	Caxamarca (BR 63.74, Wisconsin)	LB,BW,PLRV
	Amapola (BR ?, Wisconsin)	LB,BW
	Perricholi (P-3, CIP)	LB
Africa		
Burundi	Sangema (Mexico)	LB
	Kinigi (378699.2, CIP)	LB
Ethiopia	Anita (Mexico)	LB
Malagasy	Mariva (Peru)	CQ
	CFK-69.1 (Mexico)	LB
	BR 63.76 (Wisconsin)	LB,BW
Malawi	Rosita (Mexico)	LB
	CFK-69.1 (Mexico)	LB
	BR 63.76 (Wisconsin)	LB,BW
Mozambique	DTO-28 (Wisconsin)	HT,Early
Nigeria	BR 63.76 (Wisconsin)	LB,BW
Kenya	BR 63.76 (Wisconsin)	LB,BW,PVY
	I-1035 (India)	LB
	CGN-69.1 (Sweden)	LB
	ASN-69.1 (Mexico)	LB
	America (MS ?, Wisconsin)	LB,BW
	Mariva (Peru)	CQ

Solanum phureja and *Solanum andigena* that is expected to be durable. Because late blight is universal, resistance is incorporated into all breeding populations. Screening for long lasting resistance requires that seedlings be exposed to a wide variation of fungus strains. Thus, thousands of seedlings produced at CIP in Peru are screened initially under quarantine at CIP's highland facility. Selections are then sent to Rionegro, Colombia, where a CIP scientist in collaboration with Instituto Colombiano Agropecuario scientists subjects clones to field selection pressures. The best clones are then sent to Mexico for final screening.

Thirty-six varieties have already been selected by national programs for blight resistance (Table 8). For example, in Peru, Caxamarca, Molinera and Amapola are now widely grown in an area where severe late blight has been a limiting factor. As a result potatoes are now displacing other crops, pasture and forest, and for the first time what was essentially a subsistence farming region

Countries	Clones released or named*	Major characteristics
Rwanda	Gahinda (Murca, Mexico)	LB
	Kinigi (378699.2, CIP)	LB
	Nseko (65-ZA-5, Mexico)	LB
	Gasore (Graso-28, Belgium)	LB
	Montsama (Mexico)	LB,Early
	Sangema, Mexico	LB
Senegal	Naataange (DTO-33, Wisconsin)	HT,Early
Tanzania	CGN-69.1 (Sweden)	LB
	Mariva (Peru)	CQ
	BR 63.76 (Wisconsin)	LB,BW
Zaire	Sangema (Mexico)	LB
	Montsama (Mexico)	LB,Early
	Kinigi (378699.2, CIP)	LB
	Atzimba (Mexico)	LB
	Nseko (65-ZA-5, Mexico)	LB
	BR 63.76 (Wisc.)	LB,BW
Asia		
Fiji	Domoni (BR 69.84, Wisconsin)	LB,BW,PLRV
Nepal	CFJ-69.1 (Mexico)	LB,Wart
	CFM-69.1 (Mexico)	LB,Wart
	NPI-106 (Germany)	LB,Wart,PLRV,PVY
	NPI-108 (Germany)	LB,Wart,PLRV,PVY
Sri Lanka	Sita (I-1085, India)	LB,HT
	Krushi (I-822, India)	LB,HT
Turkey	Zeybek (378702.3, CIP)	PLRV,PVY
	Yayla Kizi (380543.2, CIP)	PLRV,PVY
Vietnam	Dalat 004 (CFK-69.1, Mexico)	LB
	Dalat 006 (B-71-240.1, Argentina)	LB,PLRV
	Dalat 012 (Atzimba, Mexico)	LB

Abbreviations: CQ = cooking quality. LB = late blight resistance. BW = bacterial wilt resistance. PLRV = resistance to potato leaf roll virus. PVY = resistance to potato virus Y. HT = heat tolerance. Wart = resistant to wart.

*Only 36 of the 54 clones listed are different.

> *. . . support in the study of nematodes is considerable in that this is one of the main pests encountered in potatoes in all of the mountainous area of the country.*
>
> — **Eduardo Ortega, Venezuela.**

is now supplying the cities of coastal Peru. The highly late blight resistant variety Perricholi recently released outyields other varieties.

In Rwanda, the blight resistant varieties permit earlier potato planting during the rainy season, thus increasing yields. Fiji has selected Domoni while Sri Lanka has named Krushi and Sita. Three more clones are being considered for release in Peru, one in Kenya and several in Rwanda.

Bacterial Wilt Resistance

Bacterial wilt caused by *Pseudomonas solanacearum* is the second most important limiting factor to potato production in the world's tropical belt. No chemical control is available. The first breeding program started at the University of Wisconsin, with which CIP early became associated.

Resistance to bacterial wilt is influenced by a complex pathogen-host-environment interaction, so CIP's breeding populations include wide variation which must be tested for final selection in each region or country. The initial source of resistance, *Solanum phureja,* performs well in cooler climates such as the tropical highlands. Additional sources of resistance for higher temperature conditions combined with resistance to root knot nematodes are under development.

Bacterial wilt prevented potato cultivation in Fiji until the release in 1983 of the dual resistant variety Domoni permitting reestablishment of this agricultural activity. In Huanuco, Peru, CIP clone 800942 developed for wilt resistance has also shown heat tolerance and leafroll virus resistance, thus permitting expansion of potato production into a new area. CIP clones have also shown resistance to bacterial wilt in Sri Lanka, Nigeria, Nepal, Indonesia, Kenya, Egypt, and Brazil.

Resistance to Cyst Nematode

Yield loss due to cyst nematode is correlated with levels of infestation. Two tons of potatoes are lost for every additional 10 larvae/gram of soil above a threshold of 10 larvae per gram at planting time. When field equilibrium is reached yields are minimal. In general more frequent potato cultivation means greater loss from cyst nematode.

Plant-host resistance is one of the most effective and economic means to control cyst nematode.

> *Cornell got into this area of research [root-knot nematode resistance] solely because of CIP contract and interest in adapting the potato for lowland tropics.*
>
> — **Robert L. Plaisted, Cornell University.**

Breeding for cyst nematode *(Globodera rostochiensis)* resistance in Europe began after discovery of resistance in *Solanum tuberosum* spp. *andigena* and *Solanum vernei*. Breeding programs are now in Europe, U.K., Russia, and the U.S. However, resistance incorporated into varieties in Europe is ineffective in the Andean region. Unfortunately, no third world country has a breeding program for nematode resistance.

One of the first programs CIP established was to search for sources of resistance to the species and race spectrum of cyst nematodes in the Andes where *Globodera pallida* predominates, and for which there were no resistant varieties. A second important cyst nematode species is *Globodera rostochiensis*, especially its common European race which occurs in countries where European potatoes were subsequently introduced — Chile, Venezuela, Panama, Japan, India, the Philippines, Morocco, and South Africa.

CIP is optimistic that with new resistance sources now identified in wild species and with the breeding procedures in place, the use of resistant varieties will dramatically raise yields.

Resistance to Virus and Viroid Diseases

Virus diseases have been documented to cause up to 80% loss in yield. Virus breeding at CIP seeks resistance to viruses that are most damaging to potato crops in developing countries. Because potatoes are propagated vegetatively, seed tuber production usually cannot be isolated from consumer production areas and the control of virus transmission is lacking or erratic.

The most important viruses are potato leafroll virus (PLRV) and potato viruses X and Y (PVX, PVY). PLRV and PVY, which generally occur together, are the most serious, being transmitted easily by aphids even with low aphid populations.

It has been possible to select PLRV resistant materials that are also immune to PVY by graft test. Many clones are also immune to PVX. An increasing emphasis is being placed on early maturity. In addition, at three field sites in Peru — coastal desert, temperate alpine, and high jungle — several clones have shown good adaptation over all sites. These are of special interest for exportation to national programs.

Clones showing good agronomic performance as well as verified virus resistance are submitted to the pathogen tested clone program where they are passed through shoot-tip culture and multiplied in a pathogen-free state for export to national programs.

Since 1977 segregating progenies have been sent to the Turkish National Potato Program for exposure to virus and subsequent selection. A number of clones have reached the stage of Turkish regional testing where several clones yielded significantly more than the standard test cultivar Isola. In Eastern Turkey, near Erzurum, an *andigena* x *tuberosum* hybrid has been the highest performer. The Turkish National Potato Program has named two varieties from CIP's virus resistance breeding program. Virus resistance selection programs are active in 10 other countries.

A collection of PVY immune clones has been assembled by CIP. These are highly variable in genetic background and show a range of maturities and adaptations. In certain cases other resistances have been combined with PVY immunity.

Evaluation of selected clones for PLRV resistance has led to an increase of mean resistance from 30% to 64%, an increase of 114%. New stronger types of resistance to PLRV have been discovered in *Solanum acaule* and *Solanum etuberosum*.

Resistance to the potato spindle tuber viroid from *Solanum acaule* has been incorporated into synthetic hexaploids that are fertile and crossable with cultivated *tuberosum*.

Breeding Potatoes for Warm Environments

From its beginning, the International Potato Center recognized the potential of the world's warm tropical areas to increase potato production. A breeding program to develop genetic material

National Program "Matures" in 7 Years

Izmir, Turkey — How long does it take for a national potato program of an international agricultural research center to become fully operational?

There is no set schedule but in the case of the Turkish national potato program it was less than 7 years.

The program began in collaboration with the International Potato Center (CIP) in 1975 when a Regional office was established with a resident CIP scientist at Turkey's Menemen Experimental Station near Izmir on the Mediterrean seacoast.

Turkey, the region's largest producer of potatoes was considered logical headquarters for the Middle East and North Africa. Potato disease and stress problems there were similar to those elsewhere in the region.

Selection of Turkey as the germplasm prescreening center for the region made it necessary to rapidly build up capabilities of national program personnel. This was done after 1975 through graduate degree programs, extended training at potato research institutes in developed countries, short courses abroad, and hundreds participating in in-country courses.

The first regional germplasm course in 1982 was attended by 10 Turkish agronomists along with 10 participants from other countries. By this time CIP's regional staff had increased to four. Germplasm was being introduced on an annual basis as tuber families and clones, and a large germplasm evaluation program had emerged, covering a total of about 5 hectares at two experiment stations.

National program personnel plac-

adapted to warm tropical conditions started early at CIP with about 6,000 commercial varieties and breeding lines from throughout the world tested at the mid-elevation experimental site in San Ramon. Only 34 of those were selected as tolerant and were taken to CIP's Yurimaguas experimental site in the warm tropics of the Amazon.

In Yurimaguas only four clones survived the test: the only character they had been selected for was adaptation to warm and humid conditions. These four genotypes, however, were not resistant to bacterial wilt and other important diseases common in Yurimaguas.

The next steps were to increase the frequency of clones adaptated to warm conditions and combine them with resistance to important diseases of that zone.

Experience accumulated from this breeding program indicates that selection for warm climates must be combined with selection for the following attributes:

- **Earliness: 60- to 75-day growing period.**
- **High yield: This must be considered in relation to earliness of the material; stability of performance is sought.**
- **Resistance to bacterial wilt, root knot nematode, PVY, and PVX. Experience has shown that resistance to late blight, originally of high priority, is not a problem in warm climates. Selection for resistance to potato tuber moth has now been added to the breeding program.**
- **Acceptable tuber quality, especially dry matter content, which is lowered by heat and excess humidity.**

ed highest breeding priority on selection of new varieties resistant to two of the potato's most damaging diseases: potato virus "Y" (PVY) and potato leaf roll virus (PLRV). They started an aggressive screening program under heavy infection pressure which led to rapid reductions in numbers of genotypes left over. A small amount of material continued to be healthy and yield well after several infection trials.

When it was decided in 1982 to move CIP's regional office from Menemen, Turkey to Cairo, Egypt, the Turkish national potato program had a system in place with trained people to introduce germplasm and select new varieties. In 1983 the Turkish National Potato Program sent a scientist for training in crossing techniques at CIP headquarters. Upon his return, crossing was successfully begun at the Eskisihir Station.

An indication of progress: yields of two new virus resistant Turkish varieties selected from CIP tuber families surpass those of Isola and Resy, two popular local cultivars from Germany and the Netherlands grown in western Turkey. One new variety, named Yoyla Kizi, yielded 65 tons per hectare compared with Isola's 47 tons and Resy's 25 tons. In another trial in 1983, the new Zeybek variety yielded 60 tons per hectare, Isola 37 tons, and Resy 24 tons.

The relationship between CIP and the Turkish National potato program has changed since 1982. Now CIP contracts the Turkish program to evaluate germplasm for the region. This research contract includes the use of shoot tip culture and pathogen eradication techniques to provide pathogen-free stocks of promising clones that can be accepted by quarantine services of other countries in the region.

Vender in a local market. (Nepal)

Maintenance of a wide genetic base was probably the major factor in obtaining populations adapted to warm climates. Sufficient genetic variability in a wide genetic base led to improvement of earliness, a highly desirable character for growing potatoes under stress conditions, especially heat.

The current stage of the breeding program for adaptation to warm conditions is a measure of rapid progress, with hundreds of adapted genotypes ready for testing plus large populations now being evaluated in several national programs.

Frost Resistance

Low freezing temperatures are primary factors controlling distribution and productivity of plants. In Colombia, Ecuador, Peru, Venezuela, and Bolivia approximately 308,000 of 563,000

hectares of potatoes are grown at altitudes higher than 3,000 meters where freezing temperatures occur frequently. Countries other than the Andean zone where frost may be critical during a growing season, particularly in high elevations or because of early or late planting, include southern Brazil, Turkey, Bhutan, Pakistan, Nepal, and Papua New Guinea.

Generally, potatoes do not survive temperatures lower than −1°C for several hours. If cultivars can be obtained to survive temperatures of −3° C to −4° C during 2 to 3 hours, losses to frost can be greatly minimized. Two breeding populations are being developed. One, for the Andean highland tropics, has resistance to major diseases and frost stress. A subpopulation meets needs of non-Andean highland tropics and sub-tropical cool environments where tuberosum-type potatoes have caused the adoption of crop standards different from those of Andean countries.

Teamwork in potato transport. Sri Lanka.

> *Efforts to cultivate potato locally earlier were not successful due to bacterial wilt . . . commercial cultivation of potato ceased several years ago. With wilt resistant/tolerant varieties from CIP, research has been revived . . .*
>
> — **N. P. Patel, Fiji.**

For the Andean highland tropics an advanced breeding population has been developed with frost resistance, good ability to thrive under low temperatures, and tolerance to hail.

Since 1980, non-Andean tropical highlands and sub-tropical cool environment areas have been studied for early maturity and frost resistance. A frost-resistant sub-population was screened for potential earliness and adaptation to longer daylength (15 hours) by a rapid leaf-node cutting technique. Long day segregants tuberized under long day conditions in the greenhouse while short day segregants formed shoots and roots. Field tests at Osorno, Chile (latitude 40° south) confirmed the efficiency of the screening method. Selected high-yielding clones of good agronomic type are undergoing further regional testing in Chile. Similar frost and blight resistant material has been sent to Turkey (latitude 35° north) for additional testing.

National programs of four Andean countries — Peru, Bolivia, Ecuador and Colombia — are involved in testing frost resistant genetic material as segregating tuber families for final on-site selection. Other non-Andean countries such as Bhutan, Nepal, Kenya, Pakistan, Papua New Guinea have also received frost resistant material from CIP during the past 8 years. The Peruvian Potato Program, at its request, is relying on CIP for breeding material developed for the highlands with resistance to frost and specific disease. The final testing for frost resistance is performed in collaboration with Peru's National Program at a farm station at 3,900 meters altitude. Selection of frost resistant clones is followed by national regional network trials. Selected frost resistant clones are entered into a new recombination cycle by CIP.

Agronomy for Warmer Climates

Highland zones have fragile ecologies and limited areas suitable for crop production. Consequently, policy makers in many developing countries hope to expand potato production rapidly in warmer lowland areas where approximately half the world's population lives. This requires not only adapted varieties but appropriate agronomy.

Local production has been limited mainly due to lack of varieties adapted to heat stress, resistance to bacterial wilt, and guidance on how to cultivate the crop. Because the areas were not typical for potato production, agricultural extension services and individual farmers lacked knowledge on the production of potatoes. In 1979

The influence of CIP in providing new methods of virus detection has been important for Argentina.

— **Americo Mendiburu, Argentina.**

CIP's tropical agronomy program began with the major objective to generate practical agronomic information as quickly as possible. Experiments were set up at three of CIP's experiment stations in Peru typifying distinct low and mid-elevation tropical climates.

An important factor for satisfactory yields in any warm climate in which research has been conducted is use of high quality seed tubers in the correct physiological state that permit vigorous emergence and early ground cover. Tuber yield may be reduced by up to 30% when lowland seed is used instead of highland seed. Good seed quality ensures a satisfactory number of stems at emergence, quick emergence of leaves and branches and a rapid cover over the soil by the foliage. Adequate ground cover reduces radiation reaching the soil surface to heat the soil and allows the plant to intercept all incoming radiation for conversion to dry matter.

Emergence and crop cover is improved by correct planting depth and shading by intercrops such as maize. Closer than traditional spacing hastens crop cover over the soil surface. Mulch effects on tuber yield are beneficial especially during dry seasons. Mulching improves efficiency of conversion of radiant energy to dry matter, an important consideration in warm climates. Intercropping studies have generated information on controlling insect damage. Certain rotations with pasture grasses reduced the incidence of bacterial wilt as also does non-hilling.

In developing country programs much of what has been researched at CIP is now being evaluated, initially in areas free of bacterial wilt. Results generally confirm those from Peru. Close contact with trainees in national programs help in quick information exchange on effectiveness of genotypes and agronomic techniques suitable for local conditions.

Virus and Viroid Detection and Elimination

At least one viroid and 25 different virus diseases have been identified on potatoes. Undoubtedly, potato leafroll virus (PLRV) and potato virus Y (PVY) cause the greatest yield losses and are the most widespread of all viruses. The potato spindle tuber viroid (PSTV) is primarily of quarantine significance, although in some locations it may become epidemic.

Control of virus and viroid diseases is based on exclusion and prevention rather than cure, necessitating sensitive and reliable methods for detection. Elimination of viruses from infected

CIP virus detection methods . . . have permitted us to rapidly check a large amount of samples and permits us to confidently preserve health of material CIP has sent to us.

— **Eduardo Ortega, Venezuela.**

cultivars provides the means of starting healthy nuclear seed stocks. Incorporation of resistance genes reduces or prevents infection. Any successful virus-elimination program depends on sensitive diagnostic tests.

The Latex test.

A serological method that uses antibody-sensitized latex particles was modified at CIP to better suit the test to routine virus detec-

Low-Cost Virus Testing Kit

Lima, Peru — Scientists have developed a truly mobile virus testing laboratory, small enough to be carried in one hand, and costing only $250.

The "ELISA Kit," named for enzyme-linked immunosorbent assay, is effective in detection of potato leaf roll virus (PLRV) and potato virus "Y" (PVY), which cause severe losses in potato yields in most producing areas. Viruses are disease agents so small they can be seen only with the aid of an electron microscope.

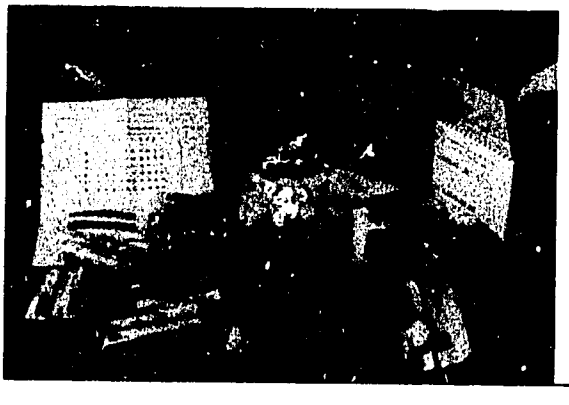
The kit was developed by virologists at the International Potato Center (CIP). The kits are not for sale commercially, being available only through the Lima, Peru-based agricultural research organization or its regional offices worldwide.

So far 39 ELISA Kits have been distributed to 13 developing countries requesting them: Venezuela, Brazil, Uruguay, Argentina, Burundi, Egypt, Tunisia, Bangladesh, India, Philippines, Mexico, Cuba, and China.

The minilaboratory — designed for use almost any place a small table can be set up — allows for accurate virus detection even where sophisticated laboratory facilities are not available.

Virus detection is necessary in seed potato programs being set up in developing countries attempting to enhance food supplies. CIP's ELISA kit was designed to help these programs succeed.

National programs in some instances are "cleaning" up old seed supplies by various methods learned through collaborative research with CIP. In most cases they want to multiply virus-free potato tubers of



The value of these virus detecting methods . . . is that in four local cultivars preferred by consumers because of small size and other attributes, viruses have been eliminated . . .

— **Kazi Badruddoza, Bangladesh.**

tion. The test is at least 1,000 times more sensitive than microprecipitation tests, is easier to apply and does not require a microscope.

Enzyme-linked immunosorbent assay (ELISA)

Development of ELISA to detect plant viruses was first described in 1977, the same year it was applied at CIP. In comparative studies with other serological tests ELISA supersedes the sen-

ELISA kit and mailing carton (facing page). Most items are color coded. Microtiter plate (below) placed over numbered sheet to help identify samples.

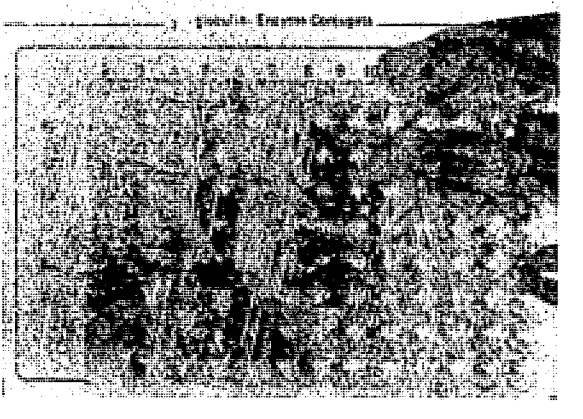
new, adapted varieties. Having a low-cost "laboratory" available to detect viruses and then to apply methods to eliminate diseased plants enables national potato programs to make positive, more rapid advances in potato seed improvement.

The small laboratory or kit took about a year of research and development. Of the more than 60 individual experiments it took, some were to find out effects of water type, incubation at room temperature, capability of withstanding delayed transport, and adverse storage conditions. In other words, the kit was designed to stand up in less-than-ideal conditions frequently encountered in developing countries. Of major importance was to make the kit simple to use, because only in the past 5 years has virology training been readily available at CIP for developing country scientists.

The most expensive single item in the kit is the plastic microtiter plate containing small "wells" into which drops of chemicals and ground-up plant parts are placed. The cost of this item has been reduced to rock bottom, and to make its use even more economical, a system to wash and re-use the plate has been developed.

Every item needed for virus testing is supplied with the kit from color-coded glass pipettes, to plastic bags over which an ordinary pencil is rolled to mash plant parts, to small bottles containing chemicals.

The instructions contemplate use of the kit under a wide range of conditions. For example, they note, "If distilled, de-ionized, or rain water is not available, tap or well water can be used." Then certain precautions are listed.



> *. . . international organizations and commercial firms have a particular role to play in setting and maintaining exacting health standards of the type now enforced by the International Centre for potato research when distributing breeding stocks around the world.*
>
> — J. M. Thresh, *Applied Biology*, 1980.

sitivity of other methods. ELISA detects viruses in tuber tissues, is a quantitative test readily automated and can be used for field detection of viruses. ELISA "kits" for use in developing countries have been designed at CIP headquarters.

Electrophoresis.

Lack of a protein coat on viroids such as PSTV precludes the use of serology. However, because PSTV is a small nucleic acid, it can be detected by electrophoresis. The most important recent development by CIP is use of a silver-based color staining of nucleic acid bands in gels following electrophoresis. This procedure increases sensitivity of detection of PSTV by electrophoresis by 32-fold.

Nucleic Acid Spot Hybridization Test.

The test required development of DNA complementary to the potato spindle tuber viroid (PSTV) sequence. The technique is highly sensitive and allows detection of PSTV at levels of one trillionth of a gram.

Such a sophisticated test is not directly applicable for developing country use, but it is essential for CIP to ensure the pathogen-free status of its material for international export. For this, CIP provides a Phytosanitary Statement with all export material assuring sanitation standards exceeding those required for commercial quarantine acceptance by an importing country. CIP's Quarantine Statement is unique among international agricultural research centers.

Importance of Undescribed Viruses

Eight novel viruses have been identified at CIP. Because their effects on the potato outside the Andean region is uncertain, elimination of these viruses from material for export is important. Elimination would have been impossible without identification of these previously unknown viruses.

At CIP the development of improved methodologies for virus and viroid detection and elimination has increased reliability of the health status allowing more rapid production of materials in the pathogen tested seed program. Production of an antiserum specific for routine diagnosis of the bacterial wilt organism, *Pseudomonas solanacearum*, has also been made possible through expertise developed in virology.

Simplified serological techniques permit developing countries to make use of ultrasensitive methods for virus and viroid detection

The policy of CIP to stimulate improvement of potato production in developing countries [and] also influencing activities in industrialized countries where potato research and training is important, has proved to be very successful.

— D. E. van der Zaag and Henk Beukema, The Netherlands.

with a consequent improvement in health of their crops. For example, Brazil, Colombia and Tunisia are now producing their antisera with CIP help. In Peru national potato program scientists produce their own antisera using CIP facilities, technology and supervision. Supplying antisera and direct training of scientists and technicians from developing countries on methods for virus detection and elimination has been conducted by CIP since 1972. Through seven virus training courses at least one member from each developing potato program has been trained in techniques for virus detection and elimination. The wide applicability of CIP's virus technology is indicated by requests for training scientists and technicians working with other crops.

During the past 5 years CIP has supplied developing countries with sufficient antisera for more than a half million virus tests (Table 9).

European countries, Canada, and the U.S. have requested antisera samples from CIP for use in quarantine services for several viruses including APLV, APMV, PBRV, and PVT. The training of scientists from developed countries in techniques for viroid detection reflects international recognition. Through improved technology for virus and viroid detection and elimination, acceptance of CIP germplasm by quarantine units with no or little virus testing is de facto recognition of high sanitation standards. The value of this germplasm for improvement of potato cultivars is evident. The application of CIP's technology for eradicating PSTV

Table 9. Distribution and antibody sensitized latex for virus detection tests in developing countries.

Year	No. Countries	No. tests x 1000				
		PVX	PVY	PVS	APLV	APVM*
1979	15	6.3	6.8	5.5	3.0	3.0
1980	16	12.2	12.2	12.2	4.3	4.3
1981	14	20.3	19.8	19.3	2.0	1.5
1982	22	99.0	92.1	92.0	10.6	10.6
1983	16	46.2	43.1	47.6	8.5	11.4
TOTAL		184.0	174.0	176.6	28.4	30.8

*PVX, PVY, PVS = Potato viruses X, Y, and S, respectively; APLV = Andean potato latent virus; APMV = Andean potato mottle virus.

from infected materials is now being attempted in other countries. Its applicability to eliminate viroid diseases in other crops is also being explored.

Safe, Effective Insect and Nematode Control

Insect Control

Pest damage to potatoes in field and in storage is a major constraint for potato production in the developing world. Pesticides are a costly input and overuse contaminates the environment.

Control of potato pests at CIP emphasizes resistant varieties and management techniques that improve control while reducing insecticide use. CIP's regional research, consultants, and national potato programs form a network of information exchange for insect identification, control, and for establishing research priorities.

Potato tuber moth (PTM) currently receives major attention from CIP because of its heavy damage worldwide in field and in storage. Potato tuber moth *(Phthorimaea operculella)* several years ago was a pest mainly in warm environments but severe infestations have now been reported in cooler areas, such as in highland Peru, Colombia, Kenya, and Nepal. PTM is now found in every developing country where potatoes are grown. Detailed reports on the pest's biological and damage potential come from every CIP region. The insect has high reproductive potential, insecticides often fail to directly prevent tuber infestation, it shows increased resistance to insecticides, and commercially-grown cultivars are highly susceptible.

Although barely 5 years old, CIP research on potato insects, particularly potato tuber moth, has established creditability in building an effective pest management program. A total of 22 primitive and 21 wild resistant potato accessions, has been selected after screening thousands of clones in CIP's World Potato Collection and from a U.S. university. They are now used in breeding resistance to prevent both tuber damage and successful pupation of the pest.

As part of an integrated control program CIP has developed a simple laboratory procedure to impregnate small rubber caps with potato tuber moth sex pheromone. The rubber caps are used with either funnel, water or sticky traps to monitor and detect first occurrence of potato tuber moth, facilitate proper use of insecticides if necessary, and in direct control. Tuber damage by potato tuber moth is significantly reduced in both field and storage by pheromone traps. Two CIP experimental stations regularly use sex pheromones to monitor and mass trap potato tuber moth to reduce insecticide use and obtain better pest control.

In collaboration with Peru's national potato program and the Peruvian National Agrarian University, CIP has identified two potential potato tuber moth parasites. Populations of one parasite collected in Peru, are being reared for testing in other countries. Cyprus and Zambia are two countries reporting good results in biological control use of *Copidosoma koehleri*, collected in South

Sex pheromones (attractants) of the potato tuber moth are impregnated on small rubber caps (right) which are attached to traps. (Photo below) a "sticky" type trap used for capturing as well as monitoring insects.

America. Mixed cropping has consistently reduced potato tuber moth damage when compared with monoculture. Onion and maize are suitable for growing with potatoes.

Covering tubers with chopped dry foliage of certain locally available weedy material provides a physical barrier and repellent action against potato tuber moth in stores. Weeds offering such protection are *Lantana* sp., often used in decorative hedges in tropical countries; *Eucalyptus* sp., found in many tropical countries, and Muña (*Minthostachys* sp.), a weed of the high Andes. A

> *Biological control of nematodes has enormous potential in Burundi where* Meloidogyne *spp. are ubiquitous but chemical products are unavailable, beyond the financial reach of farmers and use up scarce foreign exchange. Other crops would also benefit: sweet potato, beans, peas, and maize.*
>
> — **Mr. Kafurera, Burundi.**

single pre-storage application of a bacterial-based insecticide dust *(Bacillus thuringiensis)* also controls PTM in storage.

Inputs of national programs, usually through CIP-trained personnel, are already evident in potato insect control. Methods

Moth Traps with Sex Appeal

Lima, Peru — Developing country national potato programs collaborating in research with the International Potato Center (CIP) are interested in using sex pheromones (attractants) as components of low-cost, integrated pest management programs.

Female sex pheromones appropriately placed in a growing crop or storage structure attract male potato tuber moths. Suitable low-cost, easy-to-make traps placed nearby capture males by the hundreds, helping to reduce both current and future populations. It also helps pinpoint where and when flights of the insect are occurring so that other control methods can be used more effectively.

Potato tuber moths cause damage worldwide to potatoes in storage and in field. Four species are involved. One is especially damaging in South America and other locations in the world, another is a major pest in Central America, and the remaining two are mainly in South America.

Sex pheromones that can be synthesized and manufactured cheaply in relatively large amounts are being tested in Chile, Colombia, Peru, Mexico, Costa Rica, Guatemala, India, Nepal, Sri Lanka, Thailand, Kenya, Rwanda, Tunisia, and Egypt in collaboration with CIP research.

A CIP trainee in Mexico produces synthetic tuber moth pheromones in a rustic laboratory and then impregnates them on special rubber caps for use in traps on farms — at a considerable saving in cost. Farmers in Costa Rica, Mexico, and Guatemala have participated in his field tests.

Peruvian scientists are preparing to synthesize pheromones that would meet anticipated demand by farmers learning of integrated insect control methods through personnel of the national program.

The "different" tuber moth in Costa Rica *(Scrobipalpopsis solanivora* Polovny) has caused more than $2 million in damage in only a small potato growing area. Sex pheromones for the species have been identified, tested and are being used by farmers in several countries of PRECODEPA, the Central American network of cooperating countries.

An aggregation pheromone — one that attracts both sexes — of the Andean potato weevil needs to be identified and a firm in London has expressed interest in cooperating with CIP in this research. Entomologists say the Andean weevil is especially destructive in Colombia where annually more than $22 million is spent on insecticides for control.

> *. . . with discovery of effectiveness of* Paecilomyces lilacinus *against nematodes, our biological control studies seem to be paying dividends . . .*
>
> — R. Davide, Philippines.

developed at CIP for control of tuber moth are now being evaluated on experimental stations in 23 countries and in farm-level trials in nine.

In collaboration with a private company in the U.K. a microencapsulated spray has been formulated with a potato tuber moth pheromone for use in mating disruption for controlling potato tuber moth. This type of formulation can be readily prepared on a large scale and easily applied with conventional ground equipment. Success in developing insect controls lies in low cost methods environmentally acceptable, and within reach of the small farmer served by national potato programs.

Biological Control of Nematodes

Dependable biological control as an alternative to chemical control of nematodes is a long-sought goal. It would help reduce danger of using toxic nematicides, provide a control during lengthy development of resistant cultivars, ease pressure on land use when attempting control by rotation and other cultural methods.

CIP first discovered a fungus, *Paecilomyces lilacinus*, infecting eggs of the root-knot nematode, *Meloidogyne incognita*, in a potato field in the highlands of Peru. Early studies showed the potential of the fungus as a consistent and efficient biological control agent of root-knot nematodes, a cosmopolitan pest of many important food and fiber crops.

Once in contact with the egg masses, the fungus grows rapidly and eventually parasitizes all eggs in early embryonic development stages. A simple method, requiring minimal equipment, was developed for culturing and multiplying the fungus. Additionally, a simple procedure was devised for inoculation and evaluation to provide uniformity in the type of data collected.

CIP collaborates with the International Meloidogyne Project (IMP) which includes more than 100 workers in nematology in 70 countries. IMP helped distribute *Paecilomyces lilacinus* to nematologists in 46 countries for evaluation: 21 countries in Latin and North America, 8 in Africa, 12 in Asia, and 5 in Europe. So far, six countries reporting from Asia, Central and South America have all said the fungus is effective.

Following intensive greenhouse studies, field tests showed significantly lower root galling of potatoes in fungus-treated than in nematicide-treated plots. Seven on-farm trials gave consistent results further indicating the potential of *Paecilomyces lilacinus* as

> *During studies of biological control of nematodes in Panama a fungus was found that was more effective than the one discovered in Peru.*
>
> — **Franklin Atencio, Panama.**

an alternative control measure to that of nematicides. Yield of marketable potatoes was significantly higher in fungus-treated plots than in either control or nematicide-treated plots.

Three consecutive years of field experiments showed consistent reduction of *Meloidogyne incognita* populations as expressed by tuber galling. The fungus spread rapidly within experimental plots, a desirable characteristic of a successful and competitive biological control agent. In the field where this fungus was originally isolated, after 3 years of cropping of *Meloidogyne incognita*-susceptible hosts, no nematode could be found infecting the root system.

In an experiment with corn as a rotation crop, nematodes were reduced and tuber quality improved in fungus-treated plots while the corn doubled in yield compared with control plots. Potato yields were highest in fungus-treated plots.

In on-farm trials the fungus is being tested against other nematode species in potato and other crops in different countries. In Panama, for example, root-knot nematodes were controlled better with the fungus and yields were higher than with a nematicide in a large-scale trial with tomatoes. Similar results were obtained in another Panama trial to control potato cyst nematodes, *Globodera rostochiensis*. In other trials in Peru about half of *Globodera pallida* eggs were either infected or damaged by *Paecilomyces lilacinus* during two experimental periods. In an orange grove infested with citrus root nematode *(Tylenchulus semipenetrans)* fruit diameter was significantly greater from trees in soil that had been inoculated with the fungus.

In the Philippines the fungus grew abundantly in sterilized mashed potato, chopped water hyacinthe plants, ipil ipil *(Leucaena* sp.) leaves, and corn grits. With these readily-available substrates the University of the Philippines is recommending their use for introducing the fungus into soil for nematode control.

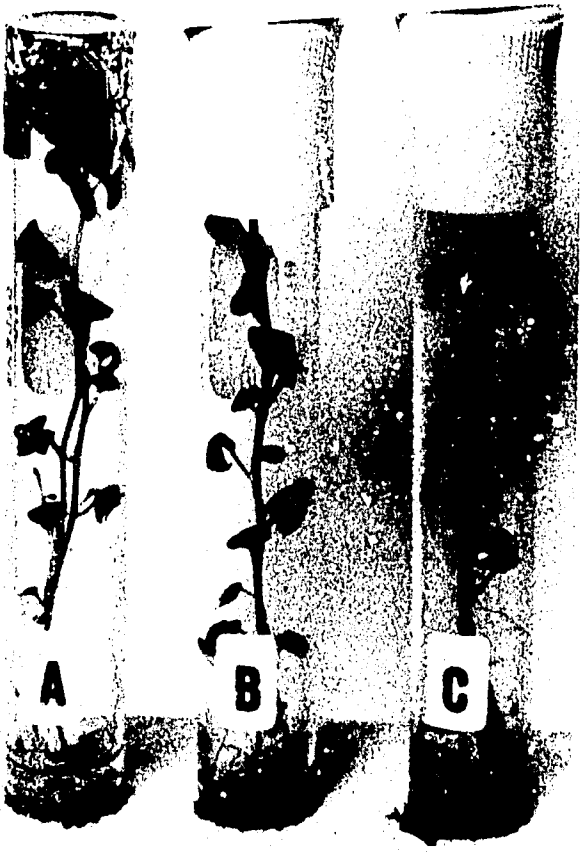
Reduction of tuber root galling in fungus-treated plots in farmer fields has been the first evidence of a practical biological agent for controlling nematodes. Farmers who have participated in the study are eager to use biological control against nematodes in crops other than potato including tomatoes, beans, and cotton. In the United States studies are underway to improve mass production and field application of the fungus.

Figure 5.
Tubers (below) in test tubes (in vitro) for export. Styrofoam shipping boxes are used for protection.

Tissue Culture

CIP is the first institution to use tissue culture methods on a large scale for potato crop development. From modest beginnings, tissue culture at CIP has developed into a unit responsible for basic and applied research plus training tissue culture specialists from national potato programs. In addition to these responsibilities, the unit is in charge of the disease-free maintenance and distribution of in vitro (in glass) potato germplasm.

A new tissue culture laboratory will be primarily dedicated to conservation of the World Potato Collection by tissue culture methods. Construction of this laboratory was made possible by a grant from the government of Japan.



. . . direct involvement particularly in research — basic seed production, tropicalized germplasm and TPS — was initiated only after the collaboration that took place between CIP and Bangladesh.

— **Kamal Uddin Ahmad, Bangladesh.**

Application of Tissue Culture Techniques

"Meristem (tip) culture" has become a routine procedure for obtaining pathogen-free material from a long list of ornamental and crop plants, including the potato. Meristem culture is a routine method at CIP to free valuable genetic material from viruses. This is essential for CIP's own work, and is also a useful service for national programs wishing to "clean up" their own materials.

The rapid, in vitro propagation of clonal material is another area where tissue culture techniques have become routine. Advantages of in vitro propagation:

- **Newly selected hybrid plants with specific characteristics can be increased in number in a short time.**
- **A constant flow of pathogen-free plants can be obtained by going back to the original in vitro stock that was started from a pathogen free source.**
- **Propagation can be year-round and specifically scheduled when manpower is available.**

Several methods of in vitro propagation have been developed of which two — accelerated formation of axillary buds and production of adventitious buds — are already widely used. A third method, somatic embryogenesis, is showing excellent potential for in vitro propagation.

Long Term, Pathogen-Free Storage. Potato germplasm stored in vitro represents a constant and valuable source of pathogen-free material for propagation; and, if properly handled, will remain free from contamination by microorganisms. Germplasm stored in vitro, however, must be transferred to a fresh culture medium when the plantlets reach a certain stage of development. CIP scientists, in collaboration with other investigators, have found methods to prolong the transfer intervals enabling cultures to be stored for 16 to 24 months without transfer.

In Vitro Tuber Production and Distribution. CIP has transferred about 250 clones to in vitro conditions. These clones are in demand by many national potato programs and are ready for export to meet the strictest quarantine standards around the world.

As a result of training in recent years, a rapidly growing number of national programs — 16 in 1983 — in developing countries are now able to apply tissue culture techniques and receive in vitro genetic materials from abroad. CIP is the major source of training as well as in vitro potato germplasm for developing countries.

With assistance of CIP, a sound base for basic seed production has been established.

— Pema Wangchhuk, Bhutan.

Twice a year, in vitro shipments of plantlets are prepared and dispatched. In 1983, 244 in vitro clones were distributed by CIP worldwide. These shipments, however, can be handled only by institutions that have adequate facilities and trained personnel for transferring plantlets from the test tube to the field. This process is much more complex than handling tubers.

In vitro tuber production has these advantages: tubers can be produced in large quantities regardless of season, they need not be transferred to fresh media, they can be stored for several months for local use or for export, and national programs can handle them more easily than in vitro plantlets.

Trial shipments were first sent to the Plant Quarantine Station in Nairobi, Kenya, where CIP has a collaborative Regional Germplasm Center for Africa. Samples arrived in good condition for further in vitro propagation. Another important advantage is that national programs receiving in vitro tubers can now receive CIP germplasm any time and it can be stored until the growing season in their countries.

Embryo and Endosperm Culture. Tissue culture methods have, in unexpected ways, become useful methods in plant breeding. Potato breeders at CIP are resorting more and more to wild species for resistance and tolerance to biotic and abiotic stresses. It has been possible to use embryo culture to overcome crossability barriers — a new application of a known technique. Another unexpected benefit of this technique was a significant shortening of time intervals between the various generations of hybridizations. Also, it has been possible to culture endosperm on an artificial medium. The endosperm is also a hybrid tissue like the embryo, but its ploidy level is different from that of the embryo. This fact might become important when breeders try to overcome crossability barriers in wide crosses.

Protoplast Fusion. The fusion of protoplasts of *Solanum* species that are so distantly related that a conventional type cross will not succeed, is another possibility for use of tissue culture. Scientists are already investigating incorporating genes or pieces of foreign chromosomes into the potato genome. Potato genotypes with completely new and economically useful characteristics could be obtained through this type of genetic engineering, which may lead to potato varieties that combine new characteristics.

Research on use of tissue culture as an efficient method for obtaining haploid plants from anthers is already in progress at CIP.

> *Research shows sprout cutting (rapid multiplication) works best in Rwanda. The technique is routine in increasing seed stocks of varieties about to be named.*
>
> — **M. Bicamumpaka, Rwanda.**

Modern potato breeding programs depend increasingly on the use of haploid genotypes, obtained from tetraploid clones, for hybridization at the diploid level. The tissue culture ability of anthers, however, has been found to be strongly genotype-dependent. Research at CIP is concentrating on transferring this ability from one genotype to another.

Rapid Multiplication

Over the years, techniques, such as single node and sprout cuttings, stem cuttings and leaf bud cuttings have been developed for use in screening germplasm, disease elimination, and seed programs. These techniques have been adapted for rapid production, using local materials available in developing countries in need of innovative techniques to shorten the multiplication cycle.

At present, rapid multiplication techniques are being used routinely by more than 20 national seed programs. Some prominent examples follow:

Colombia. Long-time use of stem cuttings is presently producing the quantity of "basic seed" necessary for the ICA program. ICA produces about 30 tons of basic seed each year multiplied from stem cuttings; stem cuttings are also used to increase some potential new varieties.

Ecuador. In vitro plantlets to produce stem cuttings are now in massive use. The combined methods enable Ecuador to produce slightly more certified seed in four generations than was being produced in the clonal selection program in seven multiplications. The resulting certified seed is reported to be giving growers up to 25% yield increases.

Peru. Following extensive training of personnel, the INIPA-CIP-COTESU program is producing large numbers of cuttings of many varieties. Smaller units are also beginning to produce high quality pre-basic seed. Peru's program is the largest in the developing world using rapid multiplication techniques.

Chile. Rapid multiplication techniques are used to increase genetic materials on a limited basis.

Brazil. In vitro derived mother plants are used to produce tubers directly and tuberlets from leaf-bud cuttings. A 200% increase in first generation material was measured with less problems with virus. Full scale use is pending an increase in personnel to handle the expanding program.

> *Rapid multiplication techniques introduced through CIP are being used to speed up production of advanced germplasm material.*
>
> — **Mr. Kafurera, Burundi.**

Rwanda. Sprout and stem cuttings are used routinely to increase new genetic material. In Burundi cuttings are being used to increase new introductions to levels sufficient for variety testing.

Philippines. The German/Philippine seed program is using an integrated rapid multiplication program. It combines use of sprout, single-node and stem cuttings to produce large numbers of cuttings transplanted to the field for further multiplication. Practically all

Molinera — Earliness and Multiple Resistance

Cajamarca, Peru — The values of interinstitutional collaboration and breeding for multiple traits are illustrated by the rapid development and farmer adoption of a new potato variety in Peru.

The variety is "Molinera." After its release in 1977 by the Peruvian national potato program it was readily accepted by farmers. Since its release it has become the most widely-grown variety in Cajamarca, a department in northern Peru. No formal seed program was operating in the area — spread of Molinera was spontaneous, from farmer to farmer as they saw its favorable attributes.

A 1984 field study in Cajamarca province indicated that Molinera now covers about 40% of the area seeded to potatoes. More than 80% of farmers surveyed said they cultivated Molinera mainly because of its earliness. Other reasons were its resistance to late blight, good yield, and short period of dormancy in storage. Earliness and short dormancy are valuable traits in this area where climate permits year-round cultivation of potatoes and other crops. Blight resistance is essential for potato cultivation in the rainy, winter months. Farmers noted that Molinera did have one main drawback: susceptibility to "hollow heart."

Molinera is the product of dedicated scientists working in many institutions — in Peru, Colombia, and the U.S.A.

Peruvian scientists, observing late blight and bacterial wilt in Cajamarca, and aware of the need for a fast-maturing (early) variety to fit into the area's cropping system, requested that the North Carolina State University Mission to Peru introduce early genetic material resistant to bacterial wilt and late blight from the University of Wisconsin. The Wisconsin materials were the result of a breeding program, partially funded by the Rockefeller Foundation, which used *Solanum phureja* a wild species from Colombia's Central Potato Collection.

The National Program, backstopped by the NCSU Mission and later by CIP, evaluated 950 clones under field conditions. From these, two clones which were early and showed field resistance to bacterial wilt and late blight were released by the National Program as new varieties in 1976 and 1977: Caxamarca and Molinera.

A few farmers have accepted the TPS technology and have raised successful crops on their lands.
— Director of Agriculture, Sri Lanka.

Philippine certified seed is now derived from cuttings. All work is done by CIP-trained scientists.

The CIP Regional Germplasm and Redistribution Center in the Philippines uses combinations of rapid multiplication techniques with emphasis on combined in vitro, single-node cuttings pioneered in Dalat, Vietnam.

In Mindanao, the CIP associate expert is producing creditable amounts of pre-basic material using sprout and single-node cuttings. Yields are double normal and farmers are beginning to adopt the technology.

Vietnam. The Dalat area in southern Vietnam has made important and innovative use of rapid multiplication techniques. Five hundred hectares are planted with material derived from in vitro single-node cuttings of CIP-introduced varieties. The impact on plant health and improved varieties has resulted in doubled yield. The system involves farmer production of large numbers of transplants giving an increase of several thousand to one. The lessons CIP and national programs are learning from the Vietnam experience are detailed in a study in the last part of this book.

Korea. In vitro derived mother plants are producing 50,000 stem cuttings which are transplanted to 22 screenhouses and yield about 22 tons of basic seed for further field multiplication.

Sri Lanka. Two large screenhouses are being constructed for rapid multiplication use.

Panama. New decree by Government to decrease seed importation has given new demand and need to use rapid multiplication in a new seed program.

True Potato Seed

Research on true potato seed which started at CIP in 1977 has since increased through research both at CIP and with cooperating institutions. Use of true potato seed could offer developing-country farmers several advantages:

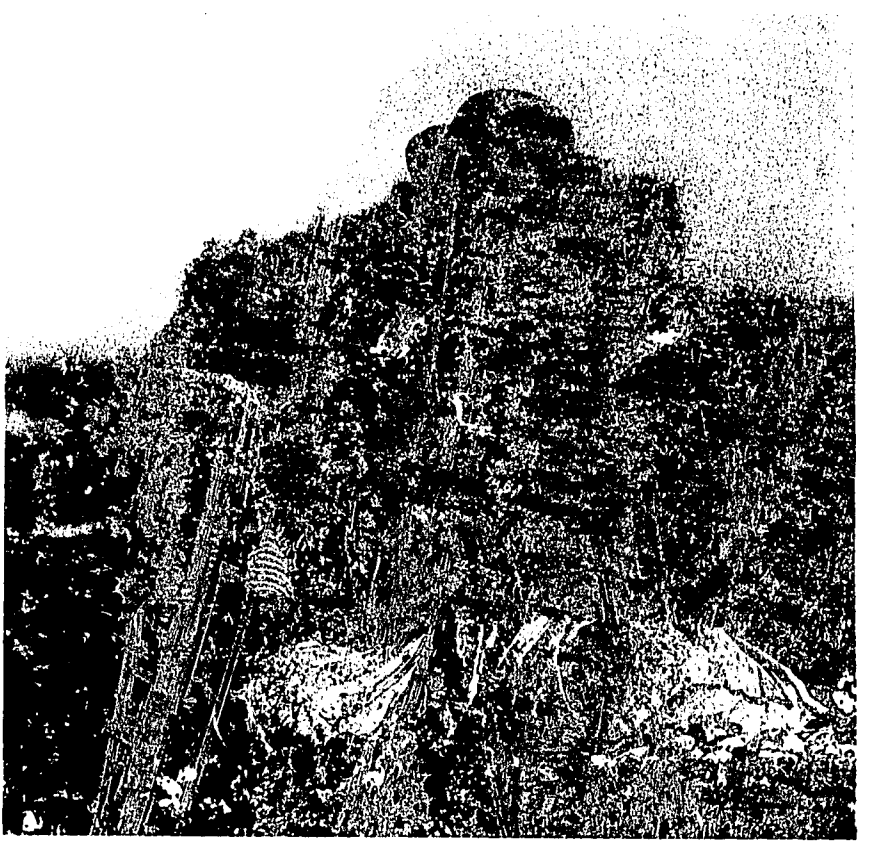
- Cost of planting material could be reduced sharply. A handful of it can replace up to 2 tons of perishable, bulky, and costly seed tubers required to plant one hectare.
- The amount of edible potatoes used for seed could be reduced. An estimated 11 million tons of potato seed tubers are required annually in developing countries, equivalent to nearly twice the

> *TPS technology will . . . revitalize the potato programme in this country. Even if it does not completely replace the cultivation of potato with seed tubers, it will offer a cheap source of seed tubers for the entire programme.*
>
> — Director of Agriculture, Sri Lanka.

total yearly production of potatoes in Africa. Use of true potato seed instead of seed tubers would make these potatoes available for human consumption.

- Spread of tuber-transmitted diseases could be minimized. Only PVT and PSTV are known to be transmitted by true seed. For subsistence growers in tropical areas who do not have access to good quality seed, true potato seed could be a low-cost source of high quality planting material.
- True potato seed is much easier to store than seed tubers. Hence, farmers using true potato seed could have it available for planting any time. This would allow them to fit potatoes in-

Desprouting potatoes. Peru.



True potato seeds are obtained from berries (below) that grow on the top portion of the plant.

to cropping systems where seed tubers of correct "physiological age" are not available. Problems of tuber seed storage are discussed later in this part of the book. The Sri Lanka study, in the next part, illustrates how seed storage problems affect cropping systems.

True potato seed research at CIP is directed to development of a viable alternative to vegetative propagation of potatoes. A breeding program selects genetic materials to ensure tuber uniformity, earliness and ability to grow and yield well under diverse environments.

Breeding for TPS

Evaluations of progenies from CIP's breeding program show that hybrids have a higher potential than open and self-pollinated progenies. Highest yields extrapolated from experimental plots are

> *This project (rustic seed storage) is considered an example of rapid transfer of technology from experiment stations to the farmer — it only began in 1981 and within 2 years more than 60 small growers had constructed storages.*
>
> — Fernando Gomez Moncayo, Colombia.

84 and 41 tons per hectare for hybrid and open-pollinated true potato seed progenies, respectively. Yields of up to 2.0 kg per plant are common in experimental fields.

Agronomy for TPS

True potato seed is obtained from berries growing on the top portion of the plant. Thirty or forty berries may be produced on a single plant while a single berry may contain up to several hundred seeds. Seed is, as a rule, dormant immediately after extraction from the fruit, depending on genotype and conditions of seed production. If seed is dried to about 5% moisture content it can be stored for years with little loss in ability to germinate.

Transplanting potato seedlings from nursery to field is a convenient method of potato production from TPS, particularly under warm tropical conditions. Advantages over direct sowing of true potato seed is that in nurseries careful management helps to produce vigorous seedlings for transplanting. In addition, seedling transplants are commonly used by small farmers in the tropics for many vegetable crops. Yields are comparable to production from potato tuber seed in a range of tropical environments.

Seed tuber production by true potato seed seedlings can provide potato growers with a simple method of producing healthy seed tubers in their own environment. One method is to produce seedling tubers in nursery beds densely sown with true potato seed (100 plants per square meter). Production of seed tubers from true potato seed in proximity to consumer potato production areas overcomes problems related to transport of seed tubers. Prolonged seed tuber storage is avoided when seed tubers from true potato seed are produced off-season.

Use of TPS in Developing Countries

In parts of China, true potato seed technology substitutes for basic seed tubers. After the first generation, conventional tuber multiplication is used. Since use of true seed began in China in 1972, there has been a significant increase in production of potatoes originating from true seed. It is estimated that an area of 15,000 to 20,000 hectares is annually planted with seed tubers produced from true potato seed.

Sri Lanka has been designated lead country for true potato seed research in Southeast Asia. True potato seed research concentrates on breeding and evaluation of improved true potato seed materials, seed production techniques, and development of

management practices. Farmers in Sri Lanka are interested in true potato seed partly because of increasing scarcity and cost of seed tubers. The true potato seed program in Sri Lanka is receiving substantial governmental support.

Increasing scarcity of seed tubers — importing has been prohibited — is also motivating the commercial use of true potato seed in West Samoa. In the Philippines, true potato seed has become a useful production alternative in Mindanao, where potato yields are quite low due to poor seed tuber quality. Transplanting and use of seed tubers produced from true potato seed are now employed for commercial production in Mindanao.

Production of potatoes for both consumption, using seedlings transplanted to the field, and for seed tubers from hybrid and open-pollinated true potato seed has been evaluated in Rwanda. Yields either from true potato seed transplants or seedling tubers doubled those using farmers' seed tubers.

In India, with best true potato seed management practices highest yield has been about 30 tons per hectare compared to 15 tons per hectare by using seed tubers. Similarly, in Korea, the yield of a locally produced true potato seed hybrid was 50 tons per hectare while the local variety yielded 37 tons per hectare under experimental conditions. True potato seed is thought to have applicability in specific production areas of Korea where a three-month season is available for growing the crop. An early progeny could be transplanted to the field and fit into existing rice cropping system.

Peruvian scientists are conducting true potato seed research in several locations. In Tacna testing in farmers' fields for different alternative uses of true potato seed started in 1983. In the early season in the coastal area, true potato seed produced a net benefit considerably higher than the conventional potato growing method.

The number of developing countries involved in true potato seed research has increased rapidly to a total of 36. This is mainly due to high potential for application, great flexibility to suit different agroeconomic conditions, and to recent progress by CIP breeders in production of improved true potato seed materials. On-farm research with true potato seed is underway in seven countries and true potato seed has reached commercial use in four countries. True potato seed research is being conducted by universities, research institutes or private companies in several developed countries, including the United States, Japan, England, Holland, and New Zealand.

Post-Harvest Technology

Seed Tuber Storage

Problems associated with storage of seed tubers include excessive sprouting, high storage losses, and lack of tuber vigor and field performance following traditional farm storage, often merely in the darkened corner of an all-purpose storage room. These problems result in economic losses as well as the time lost in sorting and desprouting seed tubers prior to planting.

The impact of diffused light storage and TPS technology [is] tremendous.

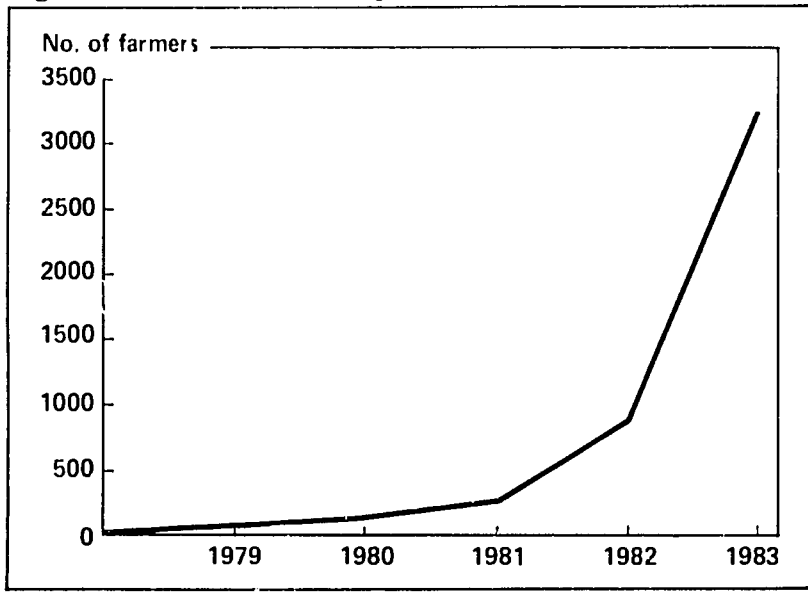
— S.P.R. Weerasinghe, Sri Lanka.

Within 3 years of experiment station and on-farm trials in the Peruvian highlands the effectiveness of natural diffused light was demonstrated in reducing sprout elongation, increasing sprout number, reducing total storage losses, and increasing total yields because of improved seed vigor. The average yield increase from use of natural diffused light in storage was 17% on the experiment station and 20% in on-farm trials.

In comparisons between cold-stored and diffused light-stored seed tubers, the former yielded significantly more than the latter in only one of 10 comparisons at 12 degrees (C) ambient temperature and in only three out of 18 comparisons at 24 degrees.

CIP's post-harvest team and their national program colleagues developed an effective approach for applied research, known as the "Farmer-Back-to-Farmer Model." This model provides the framework for storage courses. Researchers and extensionists from 34 developing countries have participated in these courses. As a result, diffused light technology for storing seed potato tubers is now being evaluated on experiment stations in 42 developing countries and in farm-level trials in 21 countries. Seed programs in 23 developing countries now use diffused light storage, and adoption by farmers has been reported in 16 countries (Figure 6).

Figure 6. Known farmer adopters of diffused light seed storage.



... advances really encouraging... in the mountain areas rustic storages were constructed at the farmer level and experiment station level as a result of the program which has now been consolidated in a low-cost seed program under PRACIPA.

— **Eduardo Ortega, Venezuela.**

Development of the Farmer-Back-to-Farmer model and the introduction and spread of diffused light storage in Sri Lanka are documented in illustrative cases in the final part of this book.

Actual design of stores varies from country to country, ranging from simple modifications of existing buildings to more elaborate purpose-built structures. All use locally available materials and rely on the natural diffused light principle to avoid high-cost temperature control systems. Capacities vary from 200 kilograms to 100 tons.

Pest and Disease Problems in Stores

Aphid infestation of stored seed tuber sprouts showed that total number of aphids increased equally in light and darkness. Where aphid infestation of sprouts was not controlled, increase in incidence of both PLRV and PVY was highly significant in the subsequent crop. If attention is not paid to aphid dissemination of viruses during storage, several years seed multiplication may be lost.

Damage from potato tuber moth, a major pest of stored tubers particularly in warm climates, is increasingly prevalent in cooler highland areas. CIP has concentrated on component control measures such as use of repellent weeds, synthetic sex pheromones, biological insecticides, and water barriers which have shown good potential when tested in natural diffused light stores under high natural infestation pressures. These components are now available for testing in integrated pest management systems under farmer conditions.

Tuber greening resulting from storage of seed tubers in natural diffused light slightly increases resistance to tuber infection and spread caused by *Erwinia* spp. Anaerobic conditions conducive to tuber rotting and spread of soft rot do not normally develop in natural diffused light stores where tubers are placed in shallow layers which also aids in ventilation.

Work at CIP on storage and TPS has had a positive effect on research in these fields and has “ *influenced advisory work on these subjects in* ” *developing countries.*

— **D. E. van der Zaag and Henk Beukema, The Netherlands.**

This technology [diffused light seed storage]... in the program... highly appreciated by growers and is being followed by the farmers.

— R. B. Rana, Bhutan.

Fast, Easy Food Mix

Huancayo, Peru — A dry food mix, consisting of potatoes, cereals, and a legume, is being tried experimentally as a meal component in Peruvian schools. The experimental mix was developed by the International Potato Center (CIP) at its Lima, Peru headquarters.

The mix, known as "M-6," contains 30% potato, 14% rice, 14% bean, 14% oat, 14% barley, 12% maize, and 2% salt. It can be modified according to consumer tastes, costs, and availability of ingredients. Other native crops may be incorporated in it — *quinua* and lupins, for example, in the case of Peru.

Processing the potato consists of peeling, cooking, and mashing. The other ingredients are premilled and thoroughly mixed into the wet, mashed potatoes. This mixture is dried with either solar or artificial energy. Sequence and process details vary to accommodate local conditions.

The cost is about 2 cents (U.S.) per serving, based on Peruvian ingredient costs. One serving consists of 20 grams of dry mix with 250 milliliters of water, making about a cup of porridge. It is prepared by cooking 80 grams of mix in one liter of water for 20 minutes and served either hot or cold after mixing in additional savory ingredients according to local food preferences. In CIP experiments, costs were 60% for ingredients, 14% for processing with solar energy, and 26% remaining costs including a small profit margin.

M-6 is one of several potato products being developed in the CIP processing project supported by the Irish government. Financial assistance is also from Canada's International Development Research Center (IDRC) and involves technical cooperation with the Instituto Nacional de Desarrollo Agroindustrial (INDA) of Peru.

Consumer research during 1983 indicated high product acceptance. Peru's Ministry of Health is interested in possible large-scale use of M-6. Six tons of the mix are being used over a 6-months period in a major school feeding test program. This represents 1% of a potential 600-ton market for the mix in this region.

Three areas have been selected in Peru's highland Mantaro Valley for evaluating potential production and household use of the mix. An advantage would be converting part of the perishable harvest into dehydrated form to help stabilize food supplies throughout the year.

Possibilities of production and use of M-6 at a community level are being evaluated in Puno, one of Peru's highest, poorest, and most potato-dependent areas near Lake Titicaca, in the south. Consumption is also being monitored in *comedor popular* eating establishments in Lima's low-income suburbs. Daily use during a 9-month period in one such *comedor* feeding about 100 children daily has given encouraging confirmation of M-6 acceptance.

Storage of Consumer Potatoes

Improving systems for storing consumer potatoes is considerably more complex than seed potato tuber storage. At CIP's highland station several naturally-ventilated structures, ranging from temporary field units to purpose-built 35-ton stores, when coupled with adequate pre-storage selection of tubers and use of chemical sprout suppressants, successfully kept potatoes for at least 6 months with total storage losses less than 2% per month. In India and Bangladesh, where problems of *Erwinia* soft rotting may not be severe, the use of simple passive evaporative cooling combined with chemical sprout suppressants appears promising.

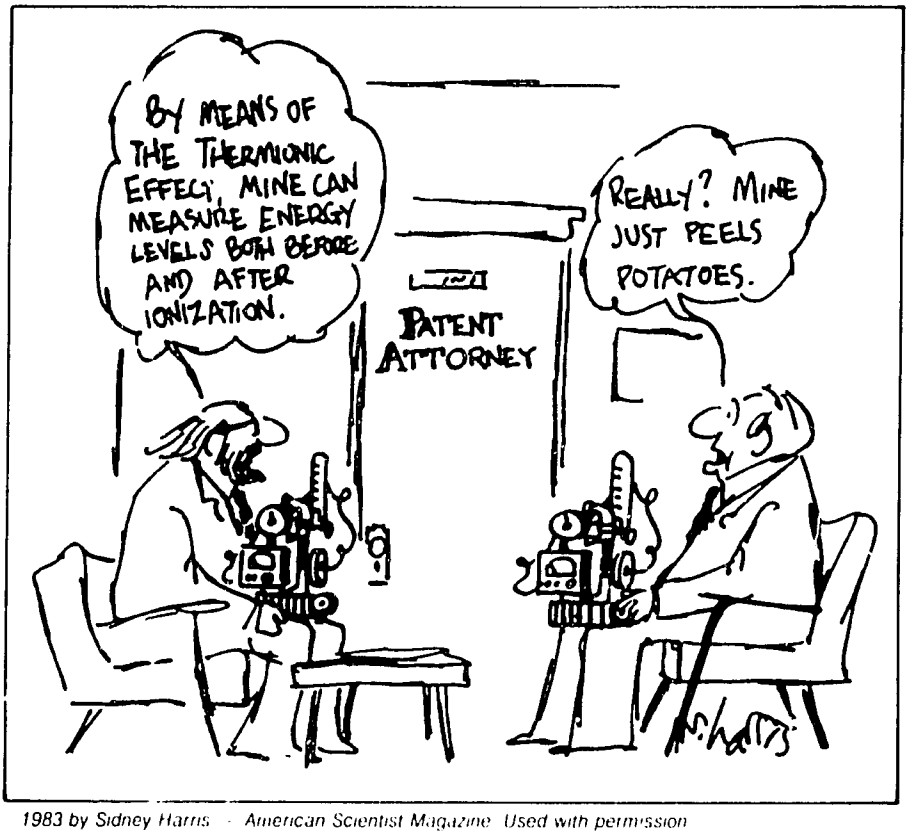
Improved consumer potato storage methods are being evaluated in 16 developing countries and have been adopted by farmers in six countries.

Simple Potato Processing

A study of needs and problems of traditional processors of sun dried potatoes in the highlands of Peru concluded that chief concern was about labor-intensive operations of peeling and cutting. Although a complete low-cost pilot plant was established at CIP/Huancayo for production of dried potatoes and potato starch, little adoption of the total plant concept occurred.

As a consequence, and using Peru as the initial test area in 1983, product development research based on the concept of "potato extension" through mixes was started in an attempt to keep the cost of final products competitive with others available to low-income consumers. In addition to significant cost advantages, mixtures often enhance nutritional value over individual components. Potatoes mixed with dried cereals and legumes produce acceptable food products and numerous mixes using locally available and indigenous crops have been produced and evaluated for all-around consumer acceptability.

CIP's processing research is aimed not at producing scholarly papers for scientific archives but practical solutions to the problems of developing countries.



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PART 6

Illustrative Studies

Introduction

Instead of attempting to quantify the production impact of CIP-generated technologies at the farm level, we have chosen another method: depict collaborative efforts with seven brief studies illustrating how CIP and national programs work together to solve problems of potato production and use. They tell how various types of benefits have been generated, ranging from training and institution building to yield increases, to development of an effective model for interdisciplinary problem solving.

The first illustration describes CIP's relation with its host country, Peru, emphasizing the reciprocal nature of the relationship and resulting mutual benefits.

Four specific areas are highlighted: institutional support, (including graduate-level training in Peruvian universities), breeding and farmer use of new varieties, development of a new seed program, and on-farm research.

The second illustrative case describes how, through trial and error, a team of post-harvest technologists and anthropologists developed an interdisciplinary model which now helps researchers both at CIP and in national programs focus their work on farmers' problems and solve them in the shortest possible time.

The third case, from Vietnam, illustrates how an international agricultural research center can learn from a developing country's innovations, incorporate this knowledge into its own research and training programs, and help other countries benefit from the country's experiences.

The fourth example, from Tunisia, shows how high the economic returns can be in a successful seed multiplication program.

The fifth illustrated case documents how quickly an effective commodity research and extension program was established, practically from scratch, in one of the world's poorest countries — Rwanda.

The sixth example, from Sri Lanka, illustrates how innovations in one key element of the potato production system — seed storage — can occur rapidly and have far-reaching benefits in several areas: alterations in planting time, yield increases, intensification

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of cropping systems, expansion of the potato crop, savings in foreign exchange, and reduction in potato prices.

The seventh and last illustrative case describes operation of a regional collaborative research network in Central America (PRECODEPA), and how the network has worked to strengthen the potato programs of each country, improve the "horizontal" flow of information between the countries, and increase the region's ability to benefit from CIP's research and training resources.

"The impact of agricultural research on food production is ultimately decided not by researchers but by the farmers themselves, who decide on their farming practices for each crop season."

— Josette Murphy, USAID.

Relations with Host Country: Peru

CIP collaborates with Peruvian institutions in many ways. This brief report highlights germplasm evaluation, design and implementation of a new seed program, on-farm research and training. These activities are of value both to Peru and to CIP. For example, evaluation of germplasm provided by CIP has led to release of several new Peruvian varieties resistant to late blight and bacterial wilt. One of these — "Molinera" — is now the leading variety in Peru's northern Cajamarca Department. Based on Peruvian evaluations, CIP sent the same clone to other countries, where it is also showing promise as a new variety.

CIP has helped Peru obtain funding and has provided technical assistance for a new seed program. At the same time, CIP and other countries are learning many lessons from Peru's experience in implementing the program.

Thesis research projects supervised by CIP scientists contribute to the formation of human capital needed for Peru's agricultural research. This also contributes substantially to CIP's headquarters research program, and at low cost.

Similarly, results of on-farm research in Peru are of direct value both to Peru's and CIP's research and technology transfer activities. Moreover, lessons learned in Peru about on-farm research — both methodological and substantive — have proven to be valid in other countries.

The Peruvian National Potato Program is one of five commodity programs of Peru's National Agricultural Research and Promotion Institute (Instituto Nacional de Investigacion y Promocion Agropecuaria: INIPA).

The potato is the most important food crop in Peru, grown on 204,000 hectares, about 90% in the highlands, 2,000 meters or more above sea level. The national average yield is about 7.9 tons per hectare and annual production is about 1.6 million tons.

CIP emerged from the North Carolina State University (NCSU) mission to Peru in 1971. NCSU had established a well-organized potato program. Many improved varieties were developed that today are used on about a third of the area planted to potatoes.

Seed production, fertilizer use, and pest control were intensively studied in the 1960s, resulting in a substantial body of research results. After Peru's land reform began in 1969, conditions were unfavorable for agricultural research for the next decade, and insufficient funding made it difficult to continue previous work. Nevertheless, from 1973 to 1982 yields per unit area of

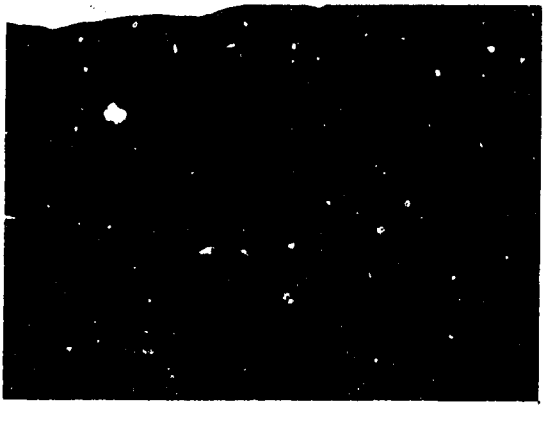
Highlands potato harvest (below). Peru.

potatoes were increased, and higher yields compensated for reduction in planted area.

Rapid urbanization lowered the percentage of rural population from 50% to 40% during this period, and today the capital city, Lima, has about a third of the country's population. The need to supply food to its urban population has made Peru highly dependent on imported wheat, rice, corn, and other foodstuffs. About 90% of the wheat consumed in Peru is imported and imports of rice and maize increase each year. Peru is self sufficient in potatoes and only under abnormal weather conditions do shortages occur.

Importation of potatoes, even in small amounts, has not been successful because of consumer preferences and lack of infrastructure to handle a product as highly perishable as fresh potatoes.

With present technology, potato yields could be significantly increased in a short time. However, for this to occur, greater investment is required in applied research and extension. Modification of price policies to favor domestically produced crops over subsidized imports would also stimulate input use, yield increases and expansion of potato production.



Institutional Support

Since 1981 INIPA has been intensifying research and extension in the country. Close collaboration with CIP has permitted the national potato program to launch a seed program and to organize a network for better use of CIP-generated potential varieties.

The flow of technology from researchers to farmers requires a well organized and aggressive national program. INIPA is receiving support from CIP to strengthen its national potato program through training, equipment, research contracts, and technical assistance.

Several contracts for bilateral cooperation between international institutions or governments and INIPA for potato development have been arranged by CIP. Vehicles and equipment have been donated to INIPA for use in the national potato program. CIP scientists are always available for consultation. Even under present austerity conditions, the Peruvian potato program is able to operate with assistance from CIP by means of a diversity of supporting research contracts with INIPA and several universities.

Training

Hosting CIP has given Peruvian national scientists easy access to training. Long- and short-term training at CIP headquarters or at the regional level has been provided

True potato seed research (below) Peruvian coast.

in the most diverse areas of research and extension related to potato development. Nearly 200 national scientists have attended short courses sponsored by CIP.

CIP scientists have guided many Peruvian students in their research at the master's level. Fields of research agree with national priorities and approval of national program leaders. To date, 116 have been completed with CIP supervision and partial financing. Of these, 42 have been in breeding and genetics, 22 in entomology and nematology, 21 in pathology, 15 in physiology, 12 in social sciences, and 4 in taxonomy.

A program for on-the-job training was proposed by CIP to INIPA by which a team of CIP scientists will be exchanged temporarily for an equivalent team of INIPA scientists. CIP scientists frequently participate in national training activities programmed by INIPA and often offer consultancy in specialized subjects as requested.

International level courses on potato production are taught yearly at the National Agrarian University (La Molina). CIP provides logistic support for organizing and teaching these courses along with national scientists. Other courses in subjects related to agronomic management of the crop are offered to extension personnel to update them with most recent technological developments.

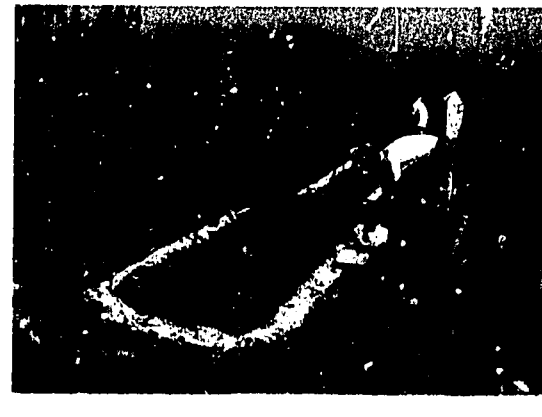
New Varieties

The national program has identified three major constraints to highland potato production:

- late blight,
- frost, and
- nematodes.

CIP and INIPA collaboration has resulted in substantial progress in solving these problems. The national potato program organizes trials throughout the country to test advanced selections from CIP's breeding program. Varieties Molinera, Amapola, and Caxamarca have been selected and named by the national program for their earliness and resistance to late blight and bacterial wilt. Perricholi was selected and released in 1982 for its high yield and late blight resistance.

Six advanced selections resistant to late blight and frost have entered the process of low virus seed production for release to farmers. Breeding for cyst nematode resistance has resulted in advanced clones showing resistance in field trials. The national program is selecting clones to be multiplied for demonstration plots with farmers before official release.



The International Potato Center (CIP) has played a major facilitating role in providing a mechanism for accessing the resources (human and otherwise) of the other international centers and other international resources in support of the . . . program . . . in addition to the excellent work . . . in the NPP for potatoes.

— USAID, Peru.

Seed Program

A basic seed production system is essential to a national potato program. CIP in 1982 identified a donor for a cooperative program involving INIPA, CIP, and the Swiss Technical Cooperation (COTESU), which is laying the ground work for a seed program appropriate for the country's needs and resources. A technical support unit formed by seed specialists, agronomists, and economists is providing necessary technical expertise to INIPA.

Several previous attempts to establish a national seed program in Peru were unsuccessful. This new attempt offers much greater promise than earlier ones for two reasons.

First, the project benefits from lessons learned in CIP's intensive studies of economics of seed systems in Andean countries. As a result, economists are directly involved in project design, implementation, and periodic review. This is leading to a practical approach that is technically sound and is appropriate for the needs and capacities of INIPA and farmers in Peru.

Second, the new seed program uses the latest available techniques for rapid multiplication of disease-free material, including those developed in Vietnam (see later illustrative report).

Diffused light storage of seed potatoes has been widely adopted by Peruvian farmers as well as by the seed program. Farmers rapidly accept the principle and adapt storage designs to suit their particular needs. The national program promotes such stores through the extension service.

True potato seed research has attracted the interest of Peruvian scientists, who feel it could help solve seed tuber shortages in areas affected by adverse climate. The potential value of true potato seed was highlighted by Peru's severe drought of 1982 which led to a drastic reduction in potato production in the altiplano of Peru and Bolivia and caught farmers and public officials unprepared. Farmers were left without seed for the next planting season, and it was impossible to purchase, transport, and distribute seed to farmers in remote areas during the short period between planting seasons. Even if tuber seed had been available, hard-pressed farmers could not have paid the high prices during a shortage year. Under such conditions, true potato seed could have been extremely useful because it is low in cost and easily transported.

True potato seed has been tested in several Peruvian locations, and initial results augur well for the economic viability of using it for production of seed tubers or consumer potatoes in areas where seed tubers are scarce.

On-Farm Research

Beginning with the Mantaro Valley Project in 1977, CIP has engaged in numerous studies of traditional farming practices and performance of potential new technologies under farmers' conditions. The initial work focused on seed systems, post-harvest

The technological packages being prepared by the researchers and specialists [in the National Potato Program] are the most complete. Extension agents and para-professionals are being trained using research work both on and off the experiment station. Technological packages are further being modified by extension specialists and agents to fit individual areas as needed.

— USAID, Peru.

technology, and general agronomic practices. Early results indicated that "technological packages" had serious defects. Yields of "improved seed" available at that time were not sufficient to compensate most highland farmers for its higher cost over common farmer seed. In contrast, measures to improve seed storage and control insects were successful in farm-level trials and were adopted by farmers. These results stimulated researchers, both in the National Program and in CIP, to concentrate efforts on sharper identification of farmers' problems, and to evaluate technologies more carefully in farm-level trials.

On-farm research continues for seed (both conventional and TPS) and post-harvest technology and is now beginning with insect control.

This report is based on a presentation of Fernando Ezeta of the Peruvian National Program, given at CIP on April 24, 1984.

Highland potatoes to market by llama-back. Peru.

Farmer-Back-to-Farmer Model

This is an example of a successful interdisciplinary experience that resulted in a model and guiding principles for teams working toward solving technological problems. The discussion includes the philosophy as well as some nuts-and-bolts aspects of how to conduct interdisciplinary team research involving social and biological scientists.

Some of the eyeball-to-eyeball confrontations it took to thrash out details that all could live with are not recorded here. But the results that are recorded should be of use to scientists, policy makers, and their ultimate clients, producers and consumers.

Although emphasis is on agricultural technology, the derived model should be of value in interdisciplinary research dealing with appropriate technology and development in other fields.

Diagnosing and Understanding Farmer Problems

The contribution and role of each discipline of CIP's post-harvest team is best understood by studying the team member interaction over time.

Initially, the anthropologist studied post-harvest activities and storage problems facing highland potato farmers in the Mantaro Valley of Peru's central Andes.

Biological scientists at first restricted their activities to research with both consumer and seed potato storage on the experiment station in the same region.

Soon the social scientist and technologists found themselves in an intra-team debate over concept of "storage losses." This was a critical point because potato as a vegetable tuber is a highly perishable item. Storage specialists were logically concerned with designing a system to reduce both pathological and physiological losses since these are major technological problems.

The anthropologist, based on a 2-months village-level survey, argued that central Andean farmers did not necessarily perceive small, shriveled or spoiled potatoes as "losses" or "waste" — all potatoes were used by farm families in some form. Potatoes not sold, used for seed or immediate home consumption were fed to animals, mainly pigs, or processed into dehydrated potatoes *(chuño, papa seca)* storable for as long as 3 years. In addition, some wives said the shriveled, partly spoiled potatoes were sometimes preferred for certain dishes.

These observations, as one biological scientist later put it, were "the beginning of understanding that we scientists often perceive technical problems through different eyes than farmers. Potato losses as we saw them were not necessarily losses to farmers."

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One team technologist in reflecting on the experience explained:

> "I was not totally convinced of the anthropologist's argument, although he certainly made me think about what I was doing. We biological scientists hadn't even really talked to a farmer about the problems we were working on. We were doing research from a distance, not research to solve a problem. When I finally went with him to visit farmers I could see he was right, but only partially."

Defining the Problem: Seed Storage

It turned out that "real losses" in storage were indeed perceived by many farmers. Since small producers in the study area stored most of their potatoes (whether for consumption, sale, or seed) in dark rooms, they did not automatically offer information to the anthropologist on different activities related to potatoes destined for different purposes. Through consultations with the biological scientists on technical aspects of storage, the anthropologist was able to sharpen his questions to farmers.

Seed potatoes stored in darkness produce long sprouts that are generally removed before planting. Asked specifically about this activity, farmers complained of cost in time and labor loss associated with desprouting. Thus, farmer "losses" were not merely physiological problems, but social and economic ones as well. The team now appeared on common ground with the farmer. By drawing knowledge from farmers and both disciplines, a commonly agreed upon problem was defined: seed potato storage with specific emphasis on reducing sprout length and improving seed tuber quality.

Team Research: Seeking a Solution

With the problem more narrowly defined, the team faced the research task of solving the technological challenge in a way acceptable to farmers. The anthropologist continued field research on seed storage, constantly feeding his findings to the technical scientists who had intensified on-station experiments with seed potato storage using a known principle: sprout growth is much less and seed quality generally improves when potatoes are stored in natural diffused light. This principle was thought by CIP scientists to have a practical application in developing countries but exactly how and under what circumstances was not clear until on-station experiments involving stored seed proved successful in terms of reduced sprout elongation. Design of experimental seed stores was still from the biological scientists' point of view, however.

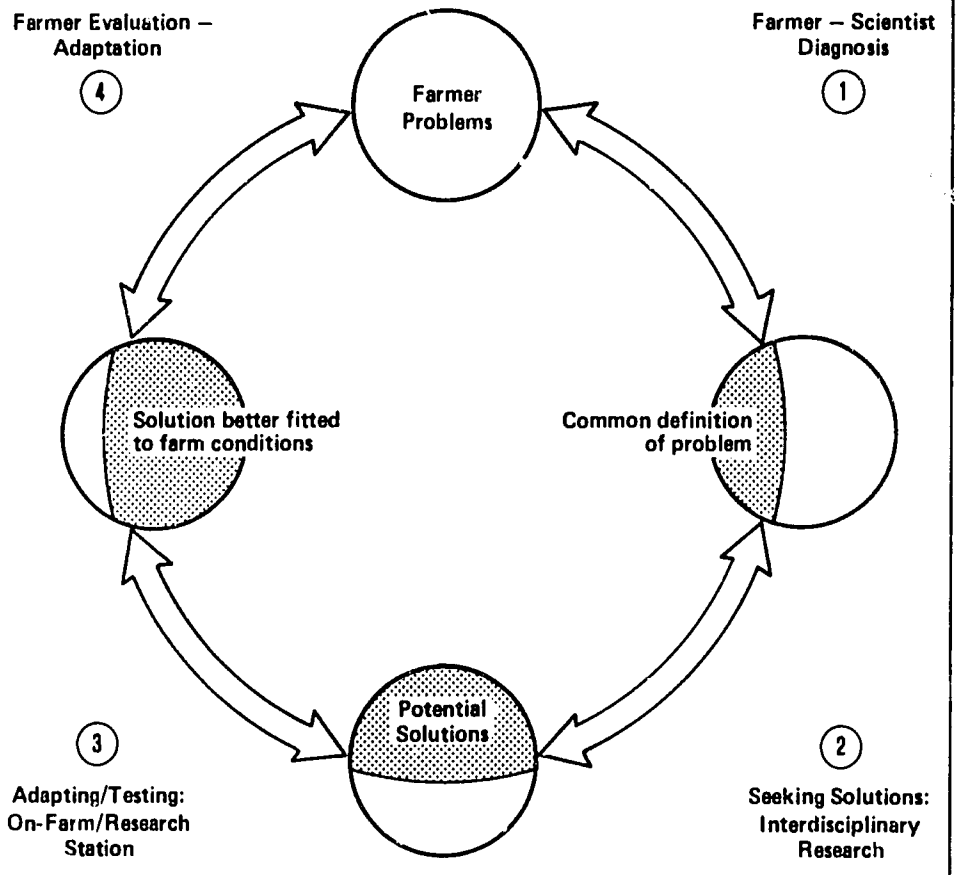
The anthropologist was concerned if the design related to farmers' conditions. Was it acceptable? His knowledge of architecture and uses of farm houses and buildings in Andean villages prompted a concern with how seed stores might be adapted to local conditions. It appeared impossible to introduce diffused light into dark, traditional multipurpose store rooms. For one thing diffused light results in "greening" of potato tubers, making them inedible and unmarketable.

Thus, only potatoes destined to be used for seed could be stored in indirect light. Also, due to security and convenience needs, any physical storage changes must blend into existing farm compounds.

Testing, Adapting Proposed Technology

The anthropologist, anxious to begin on-farm trials, inspected farm buildings with his technical colleagues and talked with potential farmer cooperators. They noted that the inner courtyard of many

FARMER–BACK–TO–FARMER



The farmer-back-to-farmer model begins and ends with the farmer. It involves four major activities each with a goal. The hatched areas in the circles indicate an increasing understanding of the technological problem area as research progresses. Note that research may constantly recycle.

	Activities	Goals
1	Diagnosis	Common definition of problem by farmers and scientists
2	Interdisciplinary team research	Identify and develop a potential solution to the problem
3	On-farm testing and adaptation	Better adapt the proposed solution to farmer's conditions
4	Farmer evaluation/adaptation	Modify technology to fit local conditions; understand farmer response

Andean houses has a roofed veranda that permits entrance of indirect light.

With farmer cooperation, the team set up experiments under the veranda using conventional seed trays taken from the experiment station stores. In other words, no new store structures were built. Rather, the wooden trays in which the seed had been stored on the experiment station were stacked under the veranda in such a way to allow indirect light to reach the seed.

These on-farm trials yielded positive results similar to those obtained in the on-station experiments. Farmers expressed interest in the new storage technology — but were concerned over unavailability and cost of seed trays.

As a result of this feedback from farmers, the technologists designed simple collapsible shelves constructed from locally available, roughhewn lumber. These were used in a second series of on-farm trials.

Again, results in terms of improved seed tuber quality and increased yields were similar to those obtained on the experiment station. Due to lower cost and familiarity with materials and rustic design, farmers could relate more closely to the diffused light stores. The technology now appeared ready and thus entered the final phase of farmer use, adaptation, and diffusion.

Farmer Evaluation: The Last Judgement

But would the farmers test and use the technology at their own expense and time. Thus, a follow-up evaluation was necessary, not only to validate or negate preceeding research phases, but to seek new directions in improving the technology. Central to this evaluation was need to obtain information on farmers' behavior as they began to experiment and use the technology on their own.

The job of understanding the farmer's evaluation was by *both* social and biological scientists. It is clear, however, that just as the biological scientists took the lead in the physical design of rustic stores, the social scientist assumed more responsibility in the farmer evaluation.

Interestingly, the first opportunity for farmer evaluation came not in Peru but in the Philippines. In 1978, a CIP post-harvest technologist worked closely with national potato program workers to diagnose storage problems in the Philippines main potato producing region. At that time, the technologist served as his own social scientist by drawing on the Andean experience with anthropologists.

A series of farmer meetings and informal interviewing led to the suggestion that diffused light storage might be relevant to the region. As a consequence, farmers in a small community decided to erect a small demonstration seed store using municipal funds. This was followed by five more demonstration stores built in a Philippine Potato Program-CIP joint effort at strategic points on the national road leading through the potato production area.

The post-harvest team, working with national potato program workers, discovered at least 40 farmers in the area had made alterations in their seed storage practices, mainly by allowing for diffused light. By 1983, the number of adopters increased to more than 700 and the innovation continued to spread.

The opportunity for farmer evaluation in Peru came a year later, after the national research began establishing demonstration stores. Follow-up studies showed that farmers on the coast and in the highlands had started making changes in their storage practices. The Peruvian patterns of adoption

and adaptation were strikingly similar to those in the Philippines.

Initially, farmers took a cautious, wait-and-see attitude toward the technology. They often experimented, jointly or singly, with small amounts of seed before making large-scale changes. To gain flexibility, some used the diffused light principle for part of their seed but continued to follow traditional practices for the remainder. A positive propensity to adopt was found in close-knit communities or with voluntary farmer associations, often involved in active seed improvement programs.

Investigations of farmer response revealed that in both countries, the new technology was continuously being refined and altered by farmers. In other words, adaptive research — but this time almost exclusively through the initiative of farmers. It continued well after the scientific team had finished its major adaptation and testing activities. Farmers rarely copied exactly the prototype store designs. They blended the new ideas with local architecture and, if a new store was constructed, made changes to suit their own concepts of space and design. Farmers were proud of these changes, and the CIP post-harvest team is convinced farmers will be more likely to accept changes if they actively participate in this final research process.

Farmer-Back-to-Farmer Model

With the rustic seed storage technology in a refinement and transfer stage, the post-harvest team took a new look at the general problem of consumer potato storage. As a result a model called "Farmer-Back-to-Farmer" was formulated. Although not entirely novel to agricultural research, the model (see accompanying figure) offers a rarely followed but viable alternative to traditional applied agricultural research and extension.

The basic philosophy upon which the model is based holds that successful agricultural research and development must *begin* and *end* with *farmer* participation. In practice, this means obtaining information about, and achieving an understanding of, the farmer's perception of the problem and finally to consider the farmer's evaluation of the solution. Thus, research must strive to close the circle, from proper identification of the problem to farmers' acceptance or rejection.

Technology should not simply be designed, introduced and abandoned by applied scientists. Information must be collected on the technology's acceptance or rejection by farmers, the final judges as to the appropriateness of a proposed technology. Until this point, all scientific evaluations remain at the level of hypothesis. Unless the circle can be completed, unless research results reach the farmer, prior efforts may have been fruitless and research findings are shelved in science archives.

This brief account is drawn from Rhoades, R., and R. Booth (1982). Farmer-Back-to-Farmer: a model for generating acceptable agricultural technology. *Agricultural Administration 11*, 127-137.

Learning from a Developing Country: Tissue Culture and Rapid Multiplication in Vietnam

CIP and national programs in many developing countries can benefit from studying experiences of researchers and farmers in the Dalat area of Vietnam. This is the first known case where farmers are applying tissue culture techniques on a commercial basis to generate planting material for seed and table potato crops.

Tissue culture methods are being successfully used by farmers with a minimum of facilities and training. Previously a laboratory operating under sophisticated conditions was believed to be necessary.

Vietnamese farmers in the Dalat area are now rooting tiny in vitro cuttings in a subsoil-manure substrate to produce mother plants from which apical cuttings are taken. Some 10 to 12 harvests of apical cuttings (one harvest a week) are obtained over a 3-month period from these mother plants which are kept in a juvenile stage (producing apical portions with no more than four to five simple leaves).

The potato was introduced into Vietnam by French missionaries in the late 1800s. The first published reports on potato production appeared around the beginning of the 20th century. Less than 5,000 hectares of potatoes were grown in Vietnam before 1970, primarily in areas surrounding the larger cities of Haiphong and Hanoi in the north, and the central highlands around Dalat, 300 kilometers north of Ho Chi Minh City, in the south. Since then, potato production has expanded at a rapid pace. At present 743,000 tons are grown on 75,000 hectares. This is one of the most rapid rates of increase of any crop in any developing country.

In Vietnam's northern provinces, new potato varieties and clean seed were imported from France up to 1956. During the next two decades, most European varieties degenerated and disappeared, except for Thuong Tin — identified later as the variety Akersegen, originally released in Germany in 1929 — which persisted and is still being grown. In the south, no new seed was imported after 1975, and varieties like Greta, Désirée, and Cosima gradually degenerated but were still commercially grown in the Dalat area until 1981.

In the late 1960s introduction of early maturing rice varieties caused a dramatic change in the traditional rice monocultural system of the Red River Delta in the north. As a result farmers could grow two rice crops a year — one from June to October and the other from February to May. This left a 3-month, dry winter period from about mid-

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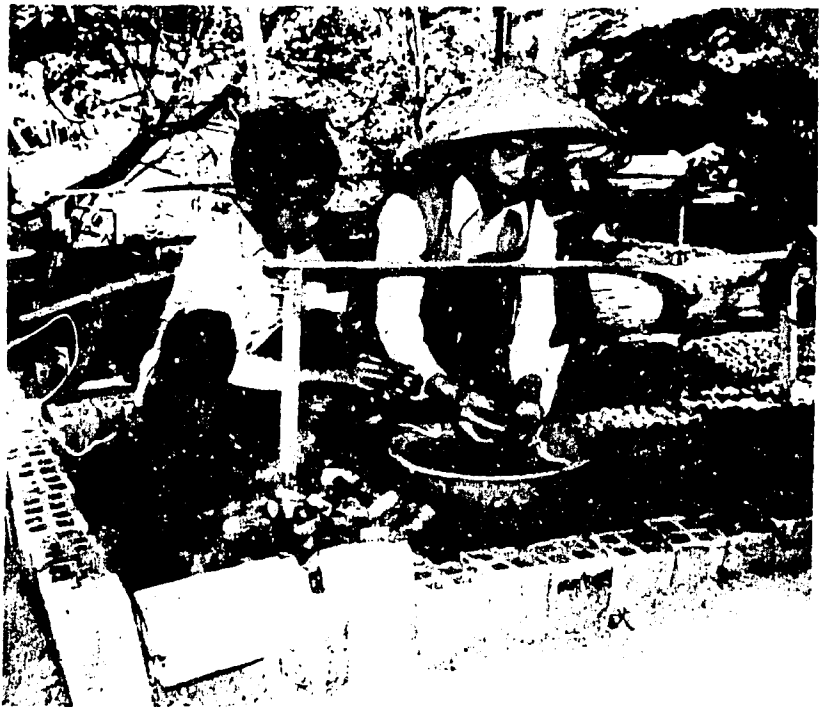
Apical cuttings are rooted in rolled banana leaves (below) and later sold to other Vietnamese farmers for planting directly into the field.

October to mid-February during which another crop could be grown.

In 1973, a high Vietnamese official visited the Laboratory of Plant Morphogenesis at Orsay University in France. There he was introduced to the ideas that:

- Potato plants established in tissue culture return to a juvenile stage characterized by rapid rooting and leaf development and vigorous growth.
- The juvenile stage of a plant is a baseline for multiplication to produce an infinite number of "copies."
- If started from a well-organized structure (meristem), variation is minimal, probably equal to variation in normal asexual reproduction.
- Under low light and low nutrient conditions, the juvenile stage can be maintained for long periods.

Upon returning to Vietnam, the official requested that the National Center for Scientific Research in Hanoi send a scientist to France to learn these techniques. Nguyen Van Uyen was chosen to go, and on his return a tissue culture laboratory was established at the research station in Dalat, part of the Center for Experimental Biology. By late 1977



Some Vietnamese farmers use homebuilt units to replace sophisticated and expensive laboratory equipment (below).

experiments were being conducted using these techniques.

In less than a year, technicians using the predominant variety, Thuong Tin, found that a single in vitro nodal cutting could produce at least four cuttings in less than a month. With subsequent in vitro multiplications, this, theoretically, meant that 12 to 16 million plantlets could be produced from a single in vitro plantlet in a year. It was also found that each in vitro plantlet transplanted directly to the field would produce several small tubers.

These findings, coupled with strong farmer demand for better planting material, encouraged the research station to develop a multiplication system to meet four requirements:

- **Have a disease-free environment.**
- **Be simple and inexpensive.**
- **Have a rapid multiplication rate.**
- **Fit into the climate of Dalat where potatoes can be grown year-round.**

Tissue culture fulfills the first requirement, because plantlets in test tubes can be maintained in a disease-free environment. The plant part used for multiplication must be as young as possible and small enough to minimize space and material requirements. However, it

was necessary to find substitutes for large numbers of expensive and often unavailable test tubes.

Instead of large numbers of test tubes, use of cuttings derived from plantlets in test tubes was explored. Through trial-and-error, including the use of washed sand in beds, it was discovered that in vitro cuttings could be multiplied in non-sterile conditions of subsoil mixed with manure. Under these conditions the growth substances, sugar and agar, were not used — they represented a large percentage of total operational costs — and the multiplication rate was the same as for sterile conditions.

The potential for a rapid multiplication system was known, so rooting nodal cuttings was tried in sandbeds and transplanting to rice paddys. Vigorous plants were obtained.

A climate that permitted continuous planting was the fourth requirement. By working year-round even with minimum facilities, the local demand could be met more easily than by working a short time using sophisticated facilities.

A turning point for tissue culture and rapid multiplication work in Dalat was reached in 1979, when Van Uyen took part in a CIP-sponsored course in the Philippines where he learned about rapid multiplication techniques and, additionally, that improved germplasm could be obtained from CIP. The research station at Dalat received 17 in vitro cultivars from CIP during 1979 and 1980. They were adapted to the short-day growing season and could also be grown year-round in Dalat; some had better resistance to late blight than the European varieties.

With experience, researchers extended the lifetime of the in vitro-derived mother plants and the number of apical cuttings harvested from each one. To avoid a high mortality rate during the dry season, apical cuttings were rooted in pots where they could be cared for and protected from sun and wind.

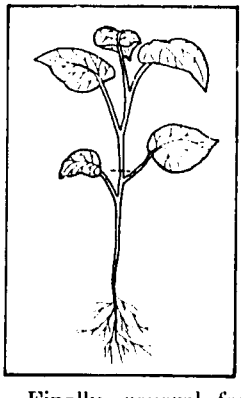
Several types of pots were tried, but farmers selected banana leaf pots, which are inexpensive, easy to make, and hold soil moisture well. The original idea was to plant rooted cuttings in high densities and produce large amounts of small seed tubers in easy-to-control areas. The farmers, however, rejected this idea and transplanted the rooted apical cuttings at normal field densities to produce large tubers for immediate sale.

From more than 60 cultivars obtained from CIP, three have been selected and released: Dalat 006 (late blight and potato leafroll virus resistance originally from Argentina), and Dalat 012 and 004 (late blight resistant from Mexico). Two others, both with late blight resistance, are being tested in farmers' fields and look promising: N-503-31, a neotuberosum from the United States: and P-3, a CIP clone named and released in Peru as Perricholi.

The potato crop harvested in 1981 by both farmers and the research station caused considerable interest in Dalat. Farmers got high yields and had almost no late blight infection in the three varieties selected.

For the 1981 harvest, these varieties averaged more than a kilogram of tubers per plant from transplanted cuttings.

Farmers in the Dalat area, impressed that a tiny cutting could produce a good harvest, began to buy rooted cuttings in small numbers from the research station. Almost all gave high yields. Soon, as demand exceeded supply, several farmers began to root cuttings purchased from the research station — they followed the steps they had observed at the station. To avoid purchase of large numbers of cuttings, some farmers set up soil beds and began to use the apical cuttings as mother plants in their homes.



Apical cutting. Growing tip plus three expanded lateral leaves.

Finally, several farmers took a more sophisticated step and began to multiply plantlets in vitro. After several attempts, the most successful farmers developed family-sized laboratories in their homes as well as rooting areas for rapid multiplication adjacent to the house. Equipment and instruments, mostly homemade, were kept inside. These farmers recovered their total investments within a few months.

The rapid multiplication technique used in the Dalat area remains essentially the same, except for minor modifications and improvements. Twelve farmers, called "satellites," in 1983 produced and sold nearly 3 million rooted plantlets to cooperatives for transplanting directly to the field. Cooperatives sell or multiply tubers from these plantlets in the traditional manner for seed or table potatoes. New cultivars from CIP have replaced all old varieties planted in the 400 hectares in the Dalat area and yields average 18 tons per hectare.

The tissue culture techniques used for potato production in the Dalat area are profitable because:

- Germplasm is maintained inexpensively without virus infection.
- New, healthy planting material is obtainable when needed without the expense of foreign exchange.
- Farmers' yields are increased. (In Dalat, yields have more than doubled with the new varieties selected from CIP materials).

This account of tissue culture and rapid multiplication is adapted from a speech given by Dr. Nguyen Van Uyen, director, Research Center for Experimental Biology, Ho Chi Minh City, Vietnam. He spoke during a workshop on tissue culture and rapid multiplication techniques February 16-24, 1984 conducted in Vietnam by the International Potato Center and attended by 15 participants from eight Southeast Asian countries.

A Small, Effective Seed Multiplication Program: Tunisia

Tunisia demonstrates a small, but effective, seed program. It was established with partial external funding and technological assistance, but is now fully institutionalized in the country's research-extension system and financed entirely with local funds.

The program's impact on potato production and its economic benefits are great. The program's net internal rate of return is now estimated to be at least 40% and is projected to be over 100% by the end of the decade. These returns are considerably higher than those offered by most other Tunisian development projects.

Three keys to the success of the Tunisian program are:

1. While CIDA (Canada) provided funds and CIP provided technical assistance, the seed program was established within the existing framework of national institutions and was perceived, from the outset, as a Tunisian program.

2. The program focused on solving an apparently simple, but important problem: seed in poor physiological condition.

3. As the seed program expanded, high quality standards have been maintained.

Through CIP's regional programs, other countries are learning from experience of the Tunisian program.

Since independence in 1956 the Tunisian government has promoted cultivation of potatoes and other high-value vegetable crops in newly irrigated areas, known as "irrigated perimeters." As a consequence, potato production has tripled since the early 1960s, and now totals 140,000 tons produced on 12,000 hectares. Potato production is expanding much faster than total food production in Tunisia.

Potatoes are grown in three distinct seasons (Table 1). The early

Table 1. Characteristics of three potato seasons in Tunisia.

Season	Main seed source	Area (000 ha)	Yield (t/ha)	Production (000 t)	Use of output
Early	Imported	1.9	12	22.2	Local market and export
Main	Imported	7.4	14	103.7	Local market
Late	Local	3.1	10	30.9	Local market and export

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> *The contribution of CIP scientists comes frequently in short-term consultancies with objectives well defined by the host country. This method avoids problems based on massive input of 'experts.'*
>
> — **Mustapha Yasram, Tunisia.**

crop is in frost-free northern coastal regions, while the main and late crops are grown both in the coastal regions and in irrigated areas throughout the country. Yields are higher in coastal regions than in the newer irrigated perimeters, and higher in the main season than in early and late seasons.

Tunisian farmers depend upon imported European seed for planting the early and main crops. The late crop is planted with tubers harvested in the preceding early season.

The National Potato Program

The Tunisian National Potato Program was established in 1976 through agreement between the Government of Tunisia and CIP. Under this agreement a 5-year cooperative program began, with funding from the Canadian International Development Agency (CIDA) and the Tunisian government. CIP provided a full-time potato specialist as well as technical and administrative backstopping.

Under terms of the agreement, a "Technical Committee" was created within the Ministry of Agriculture to coordinate implementation of national policy regarding the potato crop. This approach differed from that of many other development projects which bypassed local politics by setting up their own, autonomous administrative structures.

Planners and executors of the Potato Program, instead, worked to strengthen existing institutions and facilitate coordination of their actions through the Technical Committee.

Five Tunisian institutions were most directly involved in the program:

GIL: Groupement Interprofessionnel des Légumes, responsible for seed multiplication.

CPRA de SAIDA: Centre de Perfectionnement et Recyclage Agricole, responsible for training.

INRAT: Institut National de Recherche Agronomique de Tunisie, responsible for research.

INAT: Institut National Agronomique de Tunis, Agricultural School.

D.P.V.: Direction de la Production Végétale responsible for extension.

In 1976 the new Tunisian potato program team and consultants from CIP concluded that simple seed multiplication for the late season should have top priority for potato research, extension and training.

The Tunisian-CIP team observed many single-stemmed plants in both early and late season potato fields indicating that seed tubers were physiologically "too young" at planting time.

Because potato crop yields are highly correlated with the number of mainstems per plant, the team hypothesized that yields could be increased by seed management practices, such as choice of physiologically mature seed harvested as early as possible in the preceding early season, better

CIP's working method differs from that of similar international institutions . . . execution of cooperative programs [is] the responsibility of the national scientists and technicians.

— **Mustapha Yasram, Tunisia.**

storage, and breaking off of apical sprouts before planting. These measures would increase the number of vigorous sprouts and stems produced by each seed piece, and hence increase yields.

Seed multiplication specialists from GIL began testing this hypothesis in on-farm trials and exploiting the research results in the seed multiplication system. Soon, CPRA and INAT began incorporating findings into extension and training messages for farmers.

On-farm trials showed that yields in the late crop could be nearly doubled through improvements in seed physiology resulting from:

- desprouting imported seed and earliest possible planting of the seed crop in the early season,
- early harvesting of the seed crop and elimination of unhealthy tubers before storage, and
- desprouting locally produced seed tubers before planting in the late season.

Program Costs and Benefits

Few seed programs established in developing countries with foreign technical assistance have produced a significant proportion of the total seed requirement. In fact, most have collapsed after a few years. The Tunisian program is an exception.

Beginning with 64 tons in 1977, improved seed production for the late season rose to about 900 tons per year in 1981-83. This is about 20% of the late season's total seed requirement.

After a brief initial period, the program's annual benefits have exceeded costs (Table 2). For 1976-83 discounted benefits exceeded costs by a wide margin, and the project's

Table 2. Estimated costs of seed program 1976-83 (000$).

	Program budget		Increased cost of seed	Total costs	Benefits
	CIDA + CIP	GIL			
1976	90	24	0	114	0
1977	90	24	7	121	36
1978	90	30	13	133	90
1979	90	30	26	146	182
1980	90	36	59	185	385
1981	35	42	85	162	544
1982	20	42	71	133	419
1983	0	54	66	120	502

Sources: Project proposal and progress reports, CIP Accounting Department, and annual reports and personal communications with staff members of Tunisia's Groupement Interprofessionnel des Légumes (responsible for seed multiplication).

> *The third specificity of CIP [after working method and national program] and not of lesser importance, is the training program.*
>
> — **Mustapha Yasram, Tunisia.**

internal rate of return was about 40% — much higher than the returns of most other development projects implemented in Tunisia during the same period.

Tunisia's seed program is well established, and since 1982 all its operational costs have been locally funded. Plans are to continue seed multiplication for the late season at about the present volume, and also hold future program costs at present levels. Thus, the anticipated internal rate of return for the seed program over the entire period 1976-1990 is a minimum of 50%.

In 1983 the Tunisian program began to produce seed for the early season, to substitute for imported seed which generally reaches Tunisia soon after harvest in Europe and is still dormant and low yielding. On-farm trials indicate that cold-stored seed from one year's early season harvest (May-June) until planting time the next early season (November-December) outyields imported seed, despite its higher levels of virus infection.

A new cold store for the seed program has been built, and in 1984 seed is being cold stored for the first time for large-scale planting in the early season.

"Spillover" Effects

The economic rates of returns noted above are on the conservative side, since calculations considered all program costs but only the direct benefits resulting from use of improved seed, distributed by the program. In fact, the seed program has had many "spillover effects," both national and international.

Many Tunisian farmers have learned — from training courses, field days and observing their neighbors' fields — how to improve their own seed stocks. Hence, total benefits generated by the Tunisian Potato Program far exceed the value of yield increases resulting from use of improved seed distributed by GIL.

Benefits have also crossed national boundaries. More than 100 scientists and extension agents

Table 3. Participants in international training courses held in Tunisia 1977-83.

North Africa		**Central Africa**	
Algeria	15	Burundi	9
Morocco	12	Rwanda	8
Tunisia	32	Zaire	1
West Africa		**Other Countries**	
Guinea	1	Cyprus	2
Ivory Coast	1	Jordan	1
Mauritius	1	Madagascar	8
Senegal	3	Syria	2
Togo	3	Turkey	9
Upper Volta	1		
		TOTAL	109

have been trained in International Francophone Production Courses held annually in Tunisia and in specialized courses (Table 3).

Beneficial horizontal transfer of technology among countries was formalized in 1982 when CIP established a regional program for North and West Africa, based in Tunisia.

This discussion is briefed from Horton, D. and A. Monares (1984). A small, effective seed multiplication program: Tunisia. *Social Science Department Working Paper 1984–2*. International Potato Center, Lima.

Building An Effective Country Program: Rwanda

PNAP in Rwanda illustrates how a simple, yet highly effective, potato improvement program can be established in a short time.

PNAP is considered by many Rwandan authorities and foreign observers to be the country's most successful agricultural development program and it is being used as a model in Rwanda and in neighboring countries.

Four keys to PNAP's success:

First, since the beginning, PNAP has had strong support from the Ministry of Agriculture. This commitment is illustrated by the Rwandan government's financial support which now amounts to more than 75% of PNAP's local operating budget.

Second, since its inception PNAP has introduced farmers' needs and points of view into research planning, implementation, and technology transfer. Through its on-farm research PNAP focuses research and extension on the solution of farmers' production problems. As a result, potato research is relevant and makes a valuable contribution to Rwanda's agricultural development.

Third, PNAP focuses on a few priority lines of action which respond to farmers' most pressing needs and do not require sophisticated research facilities or complex institutional arrangements.

Fourth, dissemination of improved varieties has been rapid because PNAP's well functioning seed program is linked to a national seed service and development projects which distribute seed throughout the country.

PNAP's success is spreading to neighboring countries through the regional networking of PRAPAC (Programme Régional D'Amélioration de la Pomme de Terre en Afrique Centrale).

Situated in south central Africa, Rwanda is small and densely populated. Its land is hilly with high average altitude. The country is landlocked, has few natural resources, and has underdeveloped physical and institutional infrastructure. Foremost among Rwanda's problems is its rapidly growing population, currently estimated at 5.2 million, or 722 persons per square kilometer of agricultural land — among the highest in continental Africa. The rate of population growth, 3.4% per year, is one of the highest in the world.

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The growth in potato production stemming from PNAP's activities, reflected both in farmers' diet and income, has been dramatic. Potatoes are now the most important crop in the Project area by weight and by value. Maize is second.

— **Rwanda-IFAD Maize Project Report, World Bank/IFC.**

Potatoes in Rwanda's Agriculture

The potato is one of Rwanda's most important and fastest growing foodcrops. In the last 20 years the area under potatoes grew from about 18,000 hectares to 35,000 hectares. Total potato production is now more than 225,000 tons a year and annual per capita consumption is about 34 kilograms. The annual growth rate of potato production is double that of population growth. Hence, over time potatoes play an increasingly significant role in Rwanda's diet.

Only about a third of Rwanda's total foodcrop production is sold in the market place. But the marketed share is increasing, particularly in the case of potatoes. Growing food demand in urban centers has stimulated significant increases in potato prices. As a result, potatoes generate higher returns per hectare than most other food crops, and they are displacing both traditional and cash crops.

Members of women's cooperative grow potatoes for cash income.

. . . diffusion of PNAP improvements is occurring with, for instance, small-farmer [multipliers] spontaneously taking up seed potato multiplication and sales . . .

— **Rwanda-IFAD Maize Project Report, World Bank/IFC.**

Potatoes are grown mainly between 2,000 and 2,400 meters altitude on the Zaire-Nile Divide. Potato cultivation is most intensive on Rwanda's northern volcanic slopes, where temperatures vary little from the 17 degrees (C) average; and annual rainfall is about 1,500 millimeters. Here, potatoes are grown nearly year around.

Approximately 60% of the total potato crop is destined for home consumption on small farms with an average size of one-half hectare. In most areas, potatoes are grown in mixed cropping with maize, sorghum, beans, and peas. However, monocropping of potatoes is increasing.

The main inputs in potato production are seed tubers and labor. Use of purchased inputs, such as chemical fertilizers, pesticides and machinery, is extremely limited. The average production cost using traditional technology is less than $500 per hectare; seed tubers account for a third and labor the remainder.

Principal factors limiting potato production in Rwanda are late blight *(Phytophthora infestans)* and bacterial wilt *(Pseudomonas solanacearum)*. Secondary constraints include lack of fungicides and fertilizers, seed degeneration caused by viruses, and poor storage.

Many of some 20 varieties of potato now grown in Rwanda were introduced years ago and have been maintained by farmers with no formal seed program. The six most popular varieties — Sangema, Montsama, Muhabura, Gashara, Bufumbira, and Condea — are cultivated by more than 80% of Rwanda's 100,000 potato farmers. Farmers prefer the first two (introduced from Mexico), over other varieties because of their resistance to late blight and relatively high market price.

The degeneration rate for seed potatoes is low in most potato producing areas, permitting farmers to replant tubers harvested from their own fields for several years before virus infection substantially reduces yields. For this reason, only about a third of the farmers buy seed each season, and some old varieties introduced in the country 40 years ago are still cultivated.

The National Program

During the colonial period Rwandan agricultural research was by the National Institute for Agronomic Studies in the Belgian Congo (INEAC). After independence, 1962, the Rwandan Institute for Agricultural Sciences (ISAR: Institut des Sciences Agronomiques du Rwanda) was established. Development of ISAR's research program was severely constrained by lack of trained manpower. Belgium provided ISAR with technical assistance staff until 1982. By that time only one ISAR scientist had obtained a Ph.D. in agricultural science, one a degree in veterinary science, 13 had agronomy engineer (Ingénieur Agronome) degrees, and two had bachelor of science-level degrees. Four foreign experts continued within ISAR, two working on potatoes and two in forestry.

> *CIP's regional office in Nairobi has several times flown in materials. Thanks also due to our neighbors in Rwanda who, with their CIP colleagues, have provided basic seed, thus speeding up the seed multiplication programme.*
>
> — **Mr. Kafurera, Burundi.**

In 1979 the National Potato Improvement Program (PNAP) was established in cooperation with CIP. It was financed by Belgian Technical Cooperation, the Rwandan government, CIP, and PNAP itself (from seed potato sales).

Prior to PNAP, potato research was limited to some variety trials and seed multiplication in cooperation with farmers. However, effective research and seed potato production were limited because of lack of trained personnel and scarcity of physical facilities.

PNAP now has a 4-hectare research station and a 45-hectare seed farm in northern Rwanda. It employs five Rwandan scientists, two expatriate CIP scientists, 10 technical and clerical staff, and about 80 field hands.

PNAP's Rwandan director makes all program implementation decisions. CIP personnel share responsibility for technical development with Rwandan colleagues in the program. The position of research coordinator is held by a CIP scientist.

PNAP strives for simplicity and practical application of research information. A key element of PNAP's philosophy is that research should respond to farmers' needs.

To overcome problems limiting potato production, the national program focuses on:

- Selection of varieties resistant to late blight and bacterial wilt.
- Operation of a seed multiplication system.
- On-farm research.
- Training national researchers and extensionists.

Germplasm Evaluation

From its inception, PNAP's breeding program focused on identifying varieties resistant to late blight and bacterial wilt. Since 1979, PNAP introduced and tested more than 18,000 different genotypes; most were from CIP, others were from Belgium and Uganda.

Table 1. Potato clones released and named as varieties by PNAP in 1982.

Name	Clone number	Characteristics	Yield (t/ha)
Gahinga	Uganda-11 Rukoko Petero Murca	Late blight, high yield	15-25
Kinigi	378699-2	Late blight, high yield	20-25
Nseko	65 ZA 5	Late blight	20
Gasore	Grasso-28	Earliness (75 days)	10-12

Source: PNAP technical reports, 1984.

Politically the potato takes the first place in Rwanda through the approach by CIP/PNAP team to develop the crop. It became a model for other commodities. Government of Rwanda attached more personnel to PNAP due to CIP presence in the country, than it would have done otherwise.

— **M. Bicamumpaka, Rwanda.**

PNAP selected and named in 1982 four late blight resistant varieties with yields in the general range of 20 tons per hectare: Gahinga, Kinigi, Nseko, and Gasore (Table 1). Gahinga, Gasore and Kinigi are presently being multiplied by PNAP, the Selected Seed Service (SSS: Service des Semences Sélectionées), special projects and selected farmers. Gasore is early, and can be cultivated two seasons each year, especially in the lower and drier areas. Nseko, which is susceptible to bacterial wilt, will probably be dropped from the multiplication program.

Key factors to the rapid selection of varieties in Rwanda are:

- weather conditions in the volcanic region permit two crops for selection each year,
- PNAP's scientists use rapid multiplication techniques (mainly sprout cuttings) to increase basic seed stocks,
- on-farm trials are used for screening and evaluating advanced clones under farmer conditions.

Seed production and distribution.

Rather than attempting to establish a sophisticated seed certification program, PNAP uses simple techniques to supply farmers with improved quality seed. The rationale for this approach is based on two key considerations: First, virus degeneration of seed is slow. Second, the country cannot afford sophisticated research facilities such as a virology laboratory.

Rwanda's seed production system is based on mass selection. Without post-harvest virus testing facilities, the system depends primarily on field observation of plant vigor and the proportions of healthy and diseased plants.

The seed program now produces about 250 tons of seed per year of which about 200 tons are distributed to seed multiplication projects throughout the country. PNAP does not multiply the older local varieties. About 50% of the seed produced and distributed is of new Rwandan varieties selected from genetic material introduced by CIP.

The result is an increasing number of Rwandan farmers with access to improved seed which gradually replaces old, degenerated varieties. Farmers are eager to replace their old varieties with new, late blight resistant varieties. Production of improved seed is still significantly lower than current

A significant contribution is already being made by PNAP which since 1979 has been screening potato varieties, breeding new varieties for improved performance under local conditions, and releasing seed potatoes of improved varieties to projects, cooperatives and the like for bulking up and distribution to farmers.

— **Rwanda-IFAD Maize Project Report, World Bank/IFC.**

farmer demand for seed. Yet, reports from seed projects and preliminary surveys indicate that about 7,000 hectares, representing 18% of the total potato area, are now planted with seed originating from the national seed program. The average yield increase on farms due to use of improved seed is estimated to be about 3 tons per hectare — a 40% increase over traditional seed. Newly selected varieties often yield twice as much as common farmer seed in on-farm trials (Table 2).

An economic analysis indicates that, after a short start-up period, the seed multiplication program's benefits have far exceeded its costs (Table 3). As of 1985 the program's internal rate of return is projected to be 40% — more than twice the return offered by most development projects in the country. Since the program is expected to continue operating at the same scale, the future rate of return is expected to be much higher. This is because costs will remain at about the same level while benefits increase significantly as cultivation of new varieties spreads. Given the slow virus degeneration rate, the multiplier effect of a small stock of clean seed is great.

On-farm Research

PNAP combines experimentation and technology transfer in on-farm

Table 3. Benefits and costs of PNAP seed program in current and discounted values (000 US$) and internal rate of return.

Year	Current values Benefits	Costs
1978	0	27
1979	0	188
1980	0	310
1981	23	362
1982	173	352
1983	706	360
1984*	1,526	358
1985*	3,207	358
Internal rate of return = 40%		

*Benefits and costs for 1984 and 1985 are estimated.

Table 2. Yield increase over farmer seed of three sources of improved potato seed multiplied by PNAP.

	No. of on-farm trials	Yield (t/ha)	% increment
Farmer seed	7	12.5	—
Improved local varieties (Muhabura, Bufumbira)	8	15.3	23
Improved introduced varieties (Montsama, Sangema)	72	17.5	40
Locally selected and named varieties (Gahinga, Kinigi)	64	25.8	100

Source: PNAP Technical Reports, 1984.

trials. Every PNAP scientist conducts on-farm trials in two communes in either Ruhengeri or Gisenyi prefectures. One scientist devotes full time to the planning, coordination, and follow-up of these trials. Staff members conduct more than 80 on-farm trials each year. The resulting close contact between researchers and farmers is a main reason for PNAP's success in rapidly identifying production problems and providing farmers with appropriate solutions.

During the first years of PNAP's operation, on-farm trials helped determine the main constraints to potato production. Later they were used to evaluate new technologies at the farm level. Currently, all technologies developed by PNAP research are screened and tested in farm-level trials.

On-farm trials use two adjacent plots: one for the farmer's common practice and the other for the proposed alternative technology. Evaluations consider both yield and economic returns and results are discussed with farmers. If considered successful in a large number of cases, the new technology is then demonstrated in field days and recommended to farmers.

During 1982-83 PNAP conducted on-farm trials to evaluate four new technologies: late blight control with either fungicides or resistant varieties, use of compost, and diffused light stores.

Late blight control, with either fungicides or resistant varieties, increased yields considerably. Since fungicides are expensive and not generally available it was concluded that resistant varieties are the most appropriate means of controlling late blight. Results of trials using compost varied widely and were inconclusive. Diffused light seed stores proved to be less appropriate than traditional stores because Rwandan farmers plant twice a year and need their seed to sprout immediately after harvesting. Storage in diffused light delays sprouting and hence is most useful where there is a longer period between one season's harvest and the next planting.

A survey of farmers after the trials led to these conclusions:

- Farmers are more interested in new varieties than in any other technology tested.
- Adoption of new technologies radiated out from the sites of on-farm trials.
- Technologies which required costly inputs or substantial changes in the farming system were not widely adopted. (An example is compost.)

Training Activities.

Establishment of a potato program in any developing country requires training. This was especially true in Rwanda, because of the country's extreme scarcity of research and extension personnel. CIP has provided Rwanda with significant financial and technical support for training national personnel to conduct an effective potato program.

With CIP's help and through external funding, intensive training has included in-service training, short courses in both Rwanda and abroad (Tunisia, Kenya, Peru,

Netherlands), and advanced degree training abroad.

Twenty-three Rwandan scientists and technicians have participated in specialized courses and workshops from 1978 to 1983 (Table 4). In addition, two scientists obtained higher degrees abroad. CIP also partially financed training for four technicians in the Netherlands. Annually, PNAP has averaged two in-country courses and a number of individualized and pre-professional programs which have trained more than 200 local extensionists, students from agricultural schools and farm managers. These training activities were in French and Rwanda's local language.

This discussion is based on Monares, A. (1984). Building an effective country program: Rwanda. *Social Science Department Working Paper 1984—3*. International Potato Center, Lima.

Table 4. Rwandese personnel trained through CIP collaborative courses and workshops (1978-83).

Year	Subject	Country	Duration	No. of participants
1978	Potato production	Tunisia	4 weeks	2
1979	Seed production	Kenya	4 weeks	1
1980	Seed storage	Kenya	2 weeks	1
1981	Agroeconomic methodologies	Rwanda	2 weeks	9
	Tissue culture	Nigeria	3 weeks	1
	Potato production	Tunisia	4 weeks	2
	Germplasm management	Peru	4 weeks	1
1982	Potato development	Ethiopia/ Kenya	1 week	1
1983	On-farm research	Rwanda	1 week	3
	Potato production	Tunisia	4 weeks	1
	On-farm research	Tunisia	3 weeks	1
			TOTAL	23

Source: CIP files.

Changing a Post-Harvest System: The Case of Diffused Light Potato Stores in Sri Lanka

Major changes in cropping systems are usually slow. And the role of post-harvest technology in achieving them has seldom been studied. The case you are now reading illustrates how collaboration of an international agricultural research center, a National Research Program, and Extension has started to lead to rapid improvement in seed potato storage practices which may have far-reaching effects on cropping patterns in Sri Lanka's Badulla and Nuwara Eliya areas. Introduction of diffused light seed storage (DLS) helps farmers plant at optimal times, increase yields, reduce storage losses, and fit other crops into the rotation. The successful DLS program also reduces dependence on imported seed and boosts the prestige of local researchers and extensionists.

English planters grew potatoes in home gardens in Sri Lanka (Ceylon) as early as 1850, but only in the mid-1950s were organized government attempts made to promote potato production. Still, in the mid-1960s most of the 60,000 tons of consumer potatoes required to feed the nation were imported, mainly from Europe.

A ban imposed on importation of consumer potatoes in May 1967 to save foreign exchange resulted in increased potato prices and returns to farmers. Production expanded rapidly and potatoes became one of the main commercial vegetable crops in highland areas.

Since that time, potato production in Sri Lanka has been strongly influenced by the interplay of two countervailing factors: (1) the shortage of quality domestic seed and (2) the Sri Lankan government's desire to save foreign exchange by reducing seed potato imports.

In the early 1970s, a CIP scientist visiting Sri Lanka noted:

> "The government of Sri Lanka has issued a 10-year warning that potato seed imports will be gradually decreased from current levels of about 5,000 tons to near zero. This will be possible only if the farm storage of seed has a sound technological base." — John Niederhauser.

By 1980, the government had stepped up its efforts to reduce imports by adopting a three-point program:

1. Develop a national seed multiplication program.
2. Improve seed storage.
3. Introduce use of true potato seed.

Regarding the second point, CIP and potato specialists in Sri Lanka's Department of Agriculture have collaborated since late 1979 to solve

> *Diffused light storage . . . helps farmers keep seed potatoes longer . . . enabling extension of planting times and better distribution of production. Its major strengths are simplicity, adaptability, and appropriateness to local situations.*
>
> — **W. D. Albert, Sri Lanka.**

post-harvest problems. As a result, as many as 1,500 Sri Lankan farmers have begun storing their seed in diffused light.

Potato Production in Sri Lanka

Potatoes are grown during different months in distinct agro-ecological zones of three main districts in Sri Lanka: Jaffna, Badulla, and Nuwara Eliya. Jaffna is at sea level on the northern coast. Badulla and Nuwara Eliya are at approximately 1,300 and 1,900 meters above sea level in the "up-country" zone in southern Sri Lanka.

Badulla and Nuwara Eliya, which together account for about 80% of the growing area and 90% of national production, have two main production seasons:

Yala referring to the southwest monsoon which lasts from mid-May to mid-September, and in this report is termed "early," and

Maha, referring to the northeast monsoon which lasts from October to mid-January, designated here as "late.'

In Badulla, late planting occurs mainly in an upland zone while early planting is confined to the paddy lowlands. The late planting uses imported seed mainly which is multiplied for early planting in the paddy zone. Nuwara Eliya is in a higher, cooler, and more humid zone that Badulla. It is fundamentally a vegetable production zone for the Colombo market as well as the main seed potato production area. Government seed farms are in this district. In addition to the major season crops, small amounts of potatoes are grown throughout the year.

Until 1979, the government allowed importation of foreign seed for both late and early seasons. The seed for late season came mainly from the Netherlands, although West Germany, Denmark, and Scotland also exported seed to Sri Lanka. Approximately 1,300 tons of seed were imported annually from Australia for the early season crop especially in Badulla District.

Due to difficulties in obtaining seed and government targets of reducing imports, a decision was reached in 1979 to stop the Australian importation for the early season. The only importation allowed now is for the late season, thereby creating a serious shortage of seed for the early season.

Introduction of Diffused Light Storage

The diffused light storage (DLS) technique is based on using natural indirect light instead of low temperatures to control excessive sprout growth and storage losses.

A Sri Lankan scientist was trained in the DLS technology and CIP's Farmer-Back-to-Farmer research model in a 1979 course in the Philippines. Upon his return to Sri Lanka, four experimental stores were established on government farms in the main potato producing districts of Badulla and Nuwara Eliya. These compared traditional practices of dark storage with diffused light (Table 1).

During a second storage course in 1981 a Sri Lankan extensionist

Table 1. Comparison of diffused light vs. dark storage of seed potatoes, Sri Lanka.

	Storage System	
	Dark	Diffused Light
Variety	Desiree	Desiree
Qnty. stored (kg)	500	500
Qnty. planted (kg)	355	446
% Loss during storage	29	11
Total yield (kg)	2,665	4,899

Source: Data provided by W.D. Albert of Sri Lanka.

visited the Philippine's Mountain Province where diffused light storage technology was being rapidly adopted by farmers. Upon his return, he assisted in setting up 16 experimental stores on farms in Sri Lanka similar to those developed by CIP in Peru and elsewhere. Extension workers also started farmer training classes in seed production and storage.

As demand for potatoes expanded and seed imports were curtailed, farmers had to fall back on their own seed stored from earlier harvests or secure it from other farmers or the government. Seed storage thus became a crucial link between seasons, especially when farmers produced their own seed. National seed potato production has gradually increased in recent years, to more than 60% of total requirements (Table 2).

Farmer Response

From 1979 to 1983 farmers built more than 500 diffused light stores in Badulla and Nuwara Eliya Districts on the recommendation of the Department of Agriculture. An additional estimated thousand farmers modified their existing storage system.

The pattern of adoption/adaptation in Sri Lanka is strikingly similar to that observed in other countries, such as Peru and the Philippines, where diffused light storage technology has been introduced. Farmers seldom copy demonstration models, but modify them to meet their own needs and budgets. Many farmers integrated diffused light storage principles into existing sheds, garages, and rooms attached to their houses.

Adopting farmers note the following benefits of the DLS system:

- sprouting is reduced,
- stem density is greater,
- losses are reduced,
- field emergence is earlier,
- tuber moth control is easier,
- handling and diagnosis of storage problems are easier.

In addition, farmers point out that seed tubers stored in light sell for a higher price than tubers stored in darkness.

Changes and Impact

The diffused light storage system was introduced into Sri Lanka in early 1980. In only its third year of

Table 2. Sri Lanka seed requirements and production.

Year	Seed requirement (000 t)	Quantity produced by local farmers (000 t)	%
1979/80	10.5	4.5	43
1980/81	11.4	5.1	45
1981/82	12.0	5.7	48
1982/83	12.0	7.5	62

Seed flows and storage patterns in the Badulla District of Sri Lanka prior to 1979 (Figure 1, below) and the situation after 1979 (Figure 2, facing page).

diffusion there, some significant effects of adoption of this technology were observable.

Alteration of Seed Flows

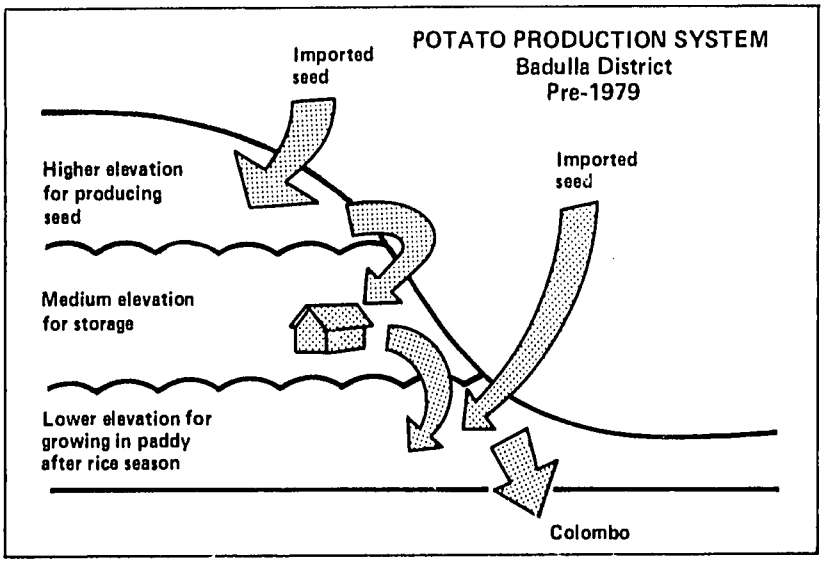
Seed flows and storage patterns in Badulla district before introduction of DLS are illustrated in Figure 1. Two importations of foreign seed were required: one for late planting in the upland zone for seed production, and, the second for early planting in the paddy zone for consumer potatoes. Due to the ban on foreign seed importation for early season, farmers were forced to expand production in the upland zone to meet the seed requirements of the paddy zone.

The situation after 1979, when importation of seed was allowed only for late planting, is illustrated in Figure 2. This led to creation of a new post-harvest system and seed flows. Due to the possibility of longer storage with diffused light storage, farmers are now keeping seed from late season harvest (February-March) to the next late season planting October-December. A new storage strategy is to hold seed tubers harvested on well-drained paddy slopes (in diffused light stores) for planting the next March.

Yield Increases

Farmers are especially interested in diffused light storage because it allows them to plant when climatic and/or market conditions are optimal. Instead of the 1 to 3 multiplication rate farmers report from imported seed arriving late or in an improper physiological condition, farmers report a 1 to 7 multiplication rate. This reflects a 133% increase in yield due to availability of seed in the proper planting condition.

Based on current average yields, this means increasing production



from 4.8 tons to 16.8 tons per hectare by having seed available when planting conditions are optimal. If all farmers opted for this strategy, it could mean an increase in late season production from around 20,000 metric tons to more than 38,000 metric tons, principally by taking advantage of proper planting times.

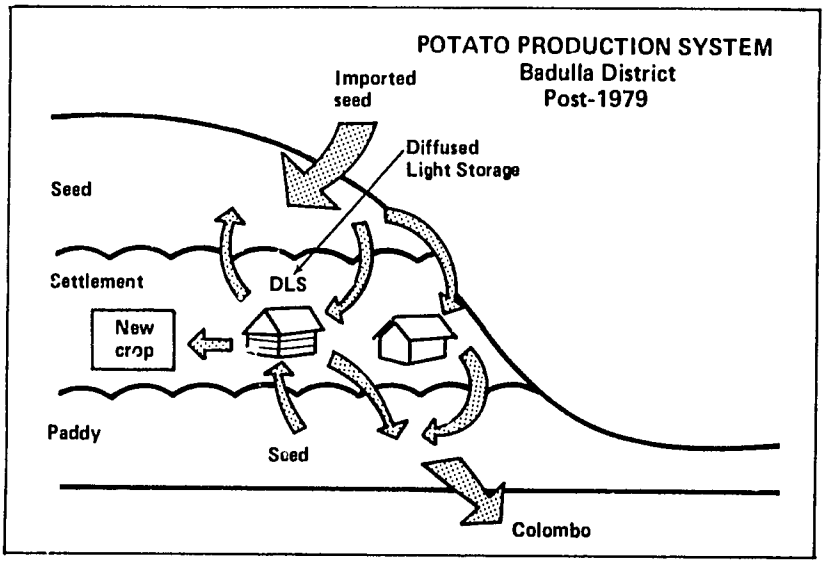
Reduction of Losses

Traditional seed storage methods for smaller farmers involve storage under the bed, or in baskets or seed crates stacked in a room, sometimes near the kitchen fire. Larger farmers who tend to store their potatoes in multipurpose storage buildings, often leave them in crates in dark areas. In two story houses, potatoes are sometimes stored in attics where temperatures are high. Farmers complain that potato losses were high — especially due to rats — when seed is stored in boxes. Additional losses result from excessive sprouting, tuber moth, mealy bugs, and soft rot.

During storage periods for which diffused light storage replaces existing practices, surveyed farmers report a 20% reduction in storage losses. Farmers pointed out that excessive sprouting was reduced and management became easier because insects could be more easily monitored and rotting tubers could be quickly discarded.

Changes in Cropping Patterns

Two changes have begun to occur as a result of introducing diffused light storage. First, with early availability of diffused light storage seed for an October planting, the harvest can be completed by January 25, leaving open a period of 8 to 9 months, in the highlands for cultivating another crop such as a rotation with potatoes. Second, use



of diffused light storage makes it possible for farmers to store seed potatoes harvested from well-drained paddy slopes for a new March planting.

Reduction in Seed Imports

Sri Lanka spends more than a million dollars annually to import seed potatoes. Use of diffused light storage and increased local seed production is permitting a reduction in seed imports and savings in foreign exchange.

Prestige for National Potato Program and Extension

A survey of extension workers from the potato producing zones revealed that 75% feel that introduction of diffused light storage has been the most successful research-extension effort with any crop in the past 5 years. The government has officially recognized the importance of post-harvest technology, and government financing for building stores is expected in 1984.

Conclusions, Future Research Directions

The Sri Lankan case illustrates that changes in seed systems and storage can have marked and unexpected consequences for production not only of potatoes but other crops. It also shows that successful post-harvest projects can bring other benefits in addition to cutting losses.

The ultimate impact of DLS in Sri Lanka depends on availability and consumption of potatoes. At this early stage it is impossible to measure availability and consumption changes resulting from use of new storage methods. However, consider a few speculations:

In Sri Lanka, the cost of seed in Nuwara Eliya and Badulla is between 40% and 50% of the total cost of production. Diffused light storage allows substitution of own seed for purchased seed thereby reducing seed cost per hectare. Furthermore, diffused light storage allows planting at optimal times leading to increased yields. These two effects should result in reduced costs and prices per kilogram, and increased consumption.

In regard to the latter, Sri Lankan economists believe that low-income potato consumers restrict their consumption to those months when prices are low, and estimate that the price elasticity of demand for potatoes is -1.2. This implies that a 10% price reduction would result in a 12% increase in consumption. Thus it can be concluded that a decrease in average prices (or leveling of prices) will stimulate greater potato consumption, especially by low-income households.

Further research is needed to measure precisely the impact on consumption made possible by lower production costs. Monitoring of the technology is also necessary to determine its consequences in terms of welfare and nutrition.

As a link between season, production zones, farmers, merchants, and consumers, seed storage plays many roles in farming systems, and positive changes can have far-reaching benefits. Finally, the Sri Lankan case shows how international centers, national research programs, and extension can coordinate in providing practical solutions to farmers problems.

This account is based on Rhoades, R. (1984). Changing a Post-Harvest System: Impact of Diffused Light Potato Stores in Sri Lanka. *Social Science Department Working Paper 1984—1.* International Potato Center, Lima.

No. 7 Illustrative Case

PRECODEPA: A Collaborative Research Network

Establishment of the Network

While each country in the Central America area was capable of conducting certain lines of investigation, none had sufficient human and physical resources to support a comprehensive potato research program.

The basic reason for PRECODEPA was to exploit each country's "speciality" and create a combined, comprehensive potato research program.

Additionally, CIP personnel could more effectively interact with specialists concentrated in only one country.

Establishing the network required each country program to specialize in certain research subject areas and rely on other national programs for research in another area. Mutual trust and dependence was part of the reason for success.

Based on the positive responses of country leaders in 1977 discussions, CIP convened a meeting in March 1978 to formally discuss creation of a collaborative research network. Six countries — Costa Rica, Dominican Republic, Guatemala, Honduras, Mexico, and Panama — were represented as well as a number of possible donors.

Discussions focused on main factors limiting potato production and use in the region. Participants outlined their own country's problems, and then identified those common to several countries. (Seed production is one example.)

The next step was to analyze research interests and capabilities of each country. Finally, specific research responsibilities were assigned to specific national programs. Requests were also made to CIP for assistance in certain areas, such as research on bacterial wilt.

At this meeting an agreement was signed by the country representatives and CIP to implement the collaborative network.

> *An important example [of collaboration within PRACIPA] is that Colombia gave us varieties produced by them to evaluate under our conditions. Jointly with our program of genetic improvement we can evaluate these materials with a true desire for one Andean country to support another.*
>
> — **Abelardo Rodriguez Voight, Venezuela.**

The representative of the Swiss Development Cooperation (SDC) indicated his government's interest in financing the program.

A budget for research, training, consultancies. and coordination activities was proposed, based on collective financial requirements of individual country programs. After SDC approval of the budget, the program became operative in mid-1978.

Organization

The ultimate authority of PRECODEPA is the "Permanent Regional Committee." Each member country has two representatives — one the national coordinator of potato research and the other the country's director of agricultural research. CIP is represented by two staff members of the Regional Research and Training Program.

In its annual meetings, the Permanent Committee evaluates and approves members' budgets and work programs and makes related policy decisions. In charge of project execution is an "Executive Committee" consisting of a Coordinator and two other country representatives. This committee usually meets three or four times each year.

PRECODEPA has no legal status. For this reason, and at the request of the Permanent Committee and the SDC, CIP agreed to receive funds, disburse them according to the approved budget, and arranged for accounting and auditing. For the first 2 years CIP provided the network's coordinator. Then the Permanent Committee appointed a coordinator from among the participating national scientists. In 1981 and 1982 this role was assigned to the leader of Mexico's national potato program; in 1983 and 1984 the coordinator was the head of Panama's national program.

PRECODEPA recognized from the beginning that research projects should have periodic external review, and the coordinator has arranged for evaluations of each.

Current Research Status

Nine projects were established in 1978, of which seven continue. In two cases — bacterial wilt and socioeconomics — country leadership has changed. Three projects, virology, intermediate storage, and early blight, have been terminated. Processing was added as a new project in 1983. Also in 1983 El Salvador and Cuba joined the network (Table 1). These changes demonstrate PRECODEPA's dynamism, flexibility, and critical self analysis.

Originally, research projects were executed in the respective leader countries. But as local expertise has developed other countries have joined in the research process, receiving advice and support from specialists in the leader countries. CIP has assisted by providing specialized training as requested.

Technologies most widely evaluated and transferred include

With the good example of PRECODEPA, we have joined South Asian Regional Cooperation for which CIP has provided substantial support.

— R. B. Rana, Bhutan.

seed production, late blight resistant varieties (mainly of Mexican origin) and rustic storage techniques. Recently, country evaluations on control of the potato tuber moth and golden nematode have also begun.

Farm-Level Impact

Improved seed production systems, late blight resistant varieties and rustic storages are all having farm-level impact. Seed production schemes are now operating in all six original member countries, some with additional bilateral assistance, as in Honduras and the Dominican Republic.

Five countries are commercially producing the Mexican late blight resistant variety "Tollucan."

The outstanding case of technology adoption in the region is rustic storage. Diffused light seed stores are extensively used by farmers in Guatemala, and this technology has contributed to the recent, successful establishment of Honduras' seed program.

Institutional Development

A key factor in institutional development is training. During PRECODEPA's 6 years, 14 regional seminars, workshops and production courses have been organized. The participation of 110 individuals in these events has strengthened technical capacity of member countries. An additional 22

Table 1. PRECODEPA research projects and country project leaders.

Research Topic	Project Leader	
	Original	Current
Late blight	Mexico	Mexico
Seed production	Mexico/Costa Rica	Mexico
Tuber moth	Costa Rica	Costa Rica
Virus diseases	Costa Rica	**
Golden nematode	Panama	Panama
Bacterial wilt	CIP	Costa Rica
Rustic storage	Guatemala	Guatemala
Socioeconomics	Mexico	Regional
Intermediate storage	Honduras	**
Early blight	Dominican Republic	**
Processing	*	Guatemala
Regional trials	*	Honduras Dominican Republic Cuba*** El Salvador*** & other members

*New projects in 1983.
**Projects terminated.
***New members in 1983.

Burundi fully supports the policy of encouraging country networks, one of which (PRAPAC) it is a member. Such networks relieve pressure on limited national resources and also enable a freer and more frequent interchange of personnel.

— J. Kafurera, Burundi.

national courses for technicians, extensionists, and farmers have included 470 participants. CIP provided individual training to 20 scientists to up-date them on the latest research techniques and results in their areas of work.

Certain intangible results of PRECODEPA are important. For example, stability of personnel in the member countries' potato programs is now greater than before, and greater than that in either of the two principal crops of the region, beans and maize. In a recent evaluation, a study team concluded that the feeling of mutual support, expanded research functions, and frequent participation in regional workshops, seminars, and training courses (both as trainees and also as instructors) has been instrumental in raising the level of job satisfaction.

A more tangible, and very significant, phenomenon is the sharp increase in the number of potato research and extension staff in member countries (Table 2). These positions are financed entirely from national budgets.

Table 2. Personnel of national potato programs before PRECODEPA and at present.

	1977/78			1983/84		
	Full time	Part time	Total	Full time	Part time	Total
Mexico	2	2	4	8	10	18
Guatemala	2	2	4	11	20	31
Honduras	1		1	3	8	11
Costa Rica	1		1	6	3	9
Panama	1	1	2	4	5	9
Dominican Rep.	2		2	12	5	17
	9	5	14	44	51	95

Note: All salaries are financed entirely from local government budgets.

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