International Potato Center

PROGRAM REPORT
1993-1994

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Cover:
A yacón (*Polymnia sonchifolia*) flower. This Andean root crop belongs to the sunflower family. Its edible roots, which are similar in appearance to sweetpotato roots, grow at altitudes up to 3,300 m, from Venezuela to northwestern Argentina.

Photo by Gigi Chang

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INTERNATIONAL POTATO CENTER (CIP)

The International Potato Center (CIP) is a not-for-profit, autonomous scientific institution established in 1971 by agreement with the Government of Peru. CIP is one of 16 international research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the United Nations Development Programme (UNDP), and the World Bank, and comprises more than 45 countries, international organizations, and private foundations. The information and conclusions reported in this publication reflect the views of CIP.

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Questioning the Conventional Wisdom

Today's conventional wisdom holds that tomorrow's food will come from a relatively small number of crops, chiefly cereals such as wheat and rice. This assumes, of course, that all of the cereal technologies now in the research pipeline will prove successful. A growing number of experts fear, however, that if we continue to think of solving food problems only in terms of traditional crops, many of which are now fast approaching their yield ceilings, we may be limiting our options for meeting future challenges.

CIP scientists have questioned this conventional wisdom. The belief that potatoes could be widely grown in developing countries, for example, challenged traditional beliefs about limitations on the types of food that could be made available to three-quarters of the world's consumers.

Production statistics recently published by the Food and Agriculture Organization of the United Nations (FAO), in conjunction with CIP, demonstrate that developing-country potato production is expanding at an annual rate of 2.8 percent, exceeding population growth rates in most countries. The report notes that, by the year 2000, annual potato production should increase by more than 30 million tons over 1987-89 levels. At that point, developing countries will be growing more than a third of the world's potato crop.

During the past 25 years, CIP researchers have also challenged the idea that potatoes could only be grown if supported by intensive applications of pesticides. We now know that most of the insecticides used by developing-country potato farmers are not only unnecessary, but can be effectively replaced with safer and cheaper integrated pest management practices. The FAO-CIP report forecast that new production technologies, such as resistant varieties and the use of true potato seed, would help farmers further reduce their use of agricultural chemicals and imported seed tubers in the years ahead. We were greatly encouraged this past year when the government of Egypt went a step further by banning a highly toxic pesticide commonly used to control the potato tuber moth. New regulations, based on data from CIP and the Egyptian national potato program, are now helping to stimulate wide-scale production and use of naturally occurring bacteria and viruses that control the pest just as effectively as the most popular chemicals.

The effectiveness of CIP-developed IPM practices was reconfirmed during a recent review commissioned by the CGIAR's Technical Advisory Committee. The review team members commended CIP for progress made at a time of political upheaval and funding uncertainties, noting that donors are receiving "good-value" research and technology for their investment. Whereas the review team presented CIP with many new challenges, work on integrated pest management, impact assessment, and virology merited special commendation. The review team also noted the rapid progress being made with true potato seed, particularly in India, where this technology could produce annual benefits of $200 million by the year 2010.

While global commodity research will continue to be a CIP priority, sustainability and environmental issues are becoming an increasingly important part of our research portfolio. The environment has always been part of CIP's mainstream commodity research, focusing mainly on integrated pest management to reduce the amount of pesticide used on potato and sweetpotato. More recently, CIP has taken steps to elevate natural resources research, particularly in the areas of soil and water management and biodiversity. Currently, this research represents only about 10 percent of our budget, but it will be important if we are going to contribute to sustainable food crop production, especially in mountain environments. To achieve that goal, the Center and its partners have established a regional research consortium aimed at halting the deterioration of natural resources in the Andes and creating a more sustainable base for future food increases.

Although initially controversial, the ecoregional concept and the consortium, called CONDESAN (Consortium for the Sustainable Development of the Andean Ecoregion), now have strong backing from donors and other national, international, and private organizations. United Nations Secretary-General Boutros Boutros-Ghali has characterized CONDESAN as a "novel approach" to mountain development research that looks at ecoregional issues in a comprehensive way through a variety of partners.

The Center has also recently taken on the responsibility of establishing a global ecoregional research program. In addition to CONDESAN, CIP, in conjunction with other national and international institutions, is convening a mountain agricultural development program for the African highlands and the Himalayas. This initiative, along with CONDESAN, will be aimed at halting the degradation of mountain ecosystems and protecting the vast areas of productive agricultural land that lie below.

Despite the conventional wisdom, it is quite clear that we must address agricultural sustainability and production issues simultaneously if we are going to feed an additional 2 billion people in the year 2020. By linking production and environmental research in innovative ways, and advancing the best of our research capacities—wherever they may be—we at CIP believe the world stands a good chance of achieving that objective.

Hubert Zandstra
Director General

CIP's Strategy

CIP begins by identifying, in close association with its clients, needs for research and technology. If these are addressed elsewhere, the Center makes the appropriate information available through its cooperative linkages. If not, comparative advantage and priority of needs are analyzed to determine CIP's approach, involving one or more of the following operational modes:

- encouraging the pursuit of the necessary research in other institutions;
- promoting research collaboration among countries;
- conducting appropriate research in cooperation with national agricultural research systems (NARS) colleagues;
- initiating specialized research in the Center's areas of comparative advantage.

The effective transfer of research results, technology, and capabilities to partner countries is accomplished through training, information dissemination, and collaborative research designed to assist NARS in reaching and maintaining their fullest potential.

Charting the Scientific Course

In a publicly funded research institute, assessing impact serves a dual purpose. First, it provides accountability to those who invest in the research. Second, it produces valuable lessons and feedback that assist management in research planning.

Recently, CIP increased its ability to measure the impact that its technologies have on production, and farm and consumer income. This past year, the Center completed nine case studies related to varietal improvement, integrated pest management (IPM), and seed systems. Each of the studies demonstrated that CIP-related technologies are providing attractive returns to our constituents.

On average, the nine selected projects, which represent only a portion of the Center's research, were calculated to have an 11 percent annual return on total investment in CIP. Annual internal rates of return ranged from 27 percent for the impact of our late blight breeding program in Peru to 106 percent for varietal development work in China. A study on the impact of pesticides used in potato production was also recently completed in Ecuador (see CIP's 1994 *Annual Report*), which will provide a basis for future environmental impact assessment.

Results from the studies provide further evidence that potato agriculture is growing rapidly worldwide. Remembering the skeptics and their warnings years ago about investing in warm-climate potato research, the study's conclusions reinforce the case for continued investment in potato research in developing countries. This raises the question: Which specific activities should we focus upon to realize the potato's full potential?

Unlike many cereal crops, potatoes—as well as sweetpotatoes—are already high yielding. Therefore, our biggest challenge is to focus on research problems affecting the environment and the sustainability of production systems, rather than on yield per se. Of particular concern is a new, more aggressive form of late blight disease that is threatening to destabilize, and in some cases eliminate, production in the world's major potato-producing regions. In addition, we are beginning to see a number of new pest problems. Among these is the spread of the Central American tuber moth (*Tecia solanivora*) and the migration of the Colorado potato beetle (*Leptinotarsa decemlineata*) into previously uninfested countries.

The CIP external review panel suggested that these problems could best be tackled by drawing down staff and financial resources from regional locations to create a stronger research base at headquarters. The Center will pursue this goal, but perhaps not to the extent that the review team suggested. For example, over the next year we hope to establish a global late blight network involving researchers from many institutions and disciplines. This will be complemented by stronger in-house research capability with an emphasis on molecular pathology.

At the same time, the Center will push ahead to solve problems dealing with genetic resources. This subject is part of an ongoing discussion among a broad range of constituent groups within the CGIAR. As a center focused on root and tuber crops, CIP is presented with a unique set of challenges. The Center currently maintains nearly 12,000 potato and sweetpotato accessions. To date, we have managed to clean only about 10 percent of the sweetpotato and 30 percent of the potato clones in the collection to standards that meet international plant quarantine requirements. One review panel recommendation was that CIP accelerate the cleanup of its clonal collection, a proposal estimated to cost about $600 for each accession, or a total cost of more than $4 million.

Many CIP scientists argue that the Center's most important task for genetic resources is to preserve genes, rather than genotypes, and that this is already being done in our potato and sweetpotato botanical seed collections. Others say it is essential to maintain these collections as clones, thus ensuring the integrity of how the genes are packaged and expressed in the field. The problem is that the number of genotypes increases constantly, meaning conservation costs will become more and more expensive.

Although a decision has yet to be made, it is likely that CIP will establish a core collection—a collection of potatoes and sweetpotatoes with a limited set of clonal accessions chosen to represent the broad genetic spectrum of the current collection. The entire collection, including accessions not designated as core, would eventually be returned in disease-free form to their countries of origin. The question of establishing a core collection is on the agenda of an external review of the CGIAR system's genebank operations, which will take place at CIP in August 1995.

CIP is also taking steps to quickly and economically move potato and sweetpotato genetic material to national partners. In 1994, the Center began developing seed production units for Africa, Asia, and Latin America. The units are run collaboratively with national agricultural research systems, and are responsible for cleaning and multiplying large quantities of elite clones and clearing them through plant quarantine. The seed units distribute only the most promising materials, thus cutting costs, but also enhance prospects for impact at the farm level. In addition, by monitoring germplasm performance closely through the units, CIP should be able to quickly determine the prospects for success of each distributed cultivar and where additional breeding is required.

Refining our long-term research priorities will also be helped by plans for an internal study of our work on true potato seed (TPS). CIP pioneered the strategy of using TPS as an alternative to the conventional planting of seed tubers. While we need to further improve true-seed varieties, this alternative technology is now well developed. For this reason, CIP intends to conduct an ex ante impact assessment of TPS versus traditional clonal seeds. Virtually all of our research, including pest and disease control, would be affected by having better information on how and where TPS is likely to have an impact.

Another future challenge for CIP falls in the area of training. Since its establishment, the Center has trained more than 10,000 researchers, extension workers, educators, and agribusiness specialists. In recent years, training has moved from centralized instruction to regional and international courses, particularly in specialized areas using programmed learning techniques.

Recently, CIP held its first electronic training program in Bolivia for national program researchers working in IPM. The course featured new, long-distance learning techniques, including the presentation of prerecorded video lectures and follow-up by electronic mail and telephone conferencing.

Training is one of several immediate challenges now before CIP scientists. Clearly, the next few years will bring even greater ones if the Center is to achieve its goal of fulfilling long-term food requirements, while, at the same time, preserving the natural resource base for future generations. In this report, CIP program leaders describe in detail the advances, achievements, and impact of their research in 1993-94. Their reports provide an indication of the scientific progress we are making, the magnitude of the problems that we face, and the potential for meeting challenges in the most efficient way possible. Comments from readers on the work and issues discussed are most welcome.

Peter Gregory

Peter Gregory
Deputy Director General
for Research

PROGRAM 1

Production Systems

Characterization of Potato Production Constraints and Opportunities

Analyzing patterns and implications of varietal change

In developed countries, potato varieties, once established in the market, can lay claim to large areas of production for many decades. In North America, the rate of replacement of older varieties by newer ones appears to be slower in potatoes than in other arable crops. The durability of popular potato varieties should be a source of concern to crop improvement scientists and to research administrators. The rate of varietal replacement is thus an important parameter in estimating the economic impact of a plant breeding program.

In order to derive implications for potato crop improvement programs in developing countries, CIP assessed the historical record of varietal change in developed countries. The study uncovered several empirical facts that led to three conclusions with potentially important implications for agricultural research on potatoes in developing countries. The first conclusion is: *Increasing specialization and intensification in production and stronger preferences for market quality in consumption are associated with a slowing in varietal change.*

This conclusion comes from two sources of evidence: (1) a historical analysis of the adoption performance of public-sector released potato varieties in the United States and Canada and (2) a cross-sectional evaluation of varietal change in several other developed countries where potatoes are a staple food.

Figure 1 summarizes the first source of evidence by plotting the average age of potato varieties (from the date of their release) from 1934 to 1992 for the United States and Canada. At the release of the "first-generation" public-sector varieties in the early 1930s, all the potato-growing area in these two countries was planted to varieties selected by hobby breeders in the late 19th century. Those varieties were on average about 50 years old in the early 1930s. The adoption of varieties released in the 1930s peaked in the late 1950s and early 1960s. The decline in varietal age in the 1930s, '40s, and '50s is consistent with a scenario of rapid technical change. With the release of about 40 to 60 varieties per decade during the past 40 years, we would have expected this downward trend to continue. Surprisingly, the early 1960s marked a turning point–the rate of varietal replacement slowed to such a degree that average varietal age rose until, by the mid-1980s, varieties approached the age of those planted in the mid-1930s.

The cross-sectional evidence for 1990 (Figure 2) confirms an inverse relationship between varietal change and annual growth rate in potato production between 1961 and 1990. Rapid varietal change has taken place in countries where total production in the recent past was decreasing; varietal turnover has been slow in countries where total production was increasing. The growth rate in total

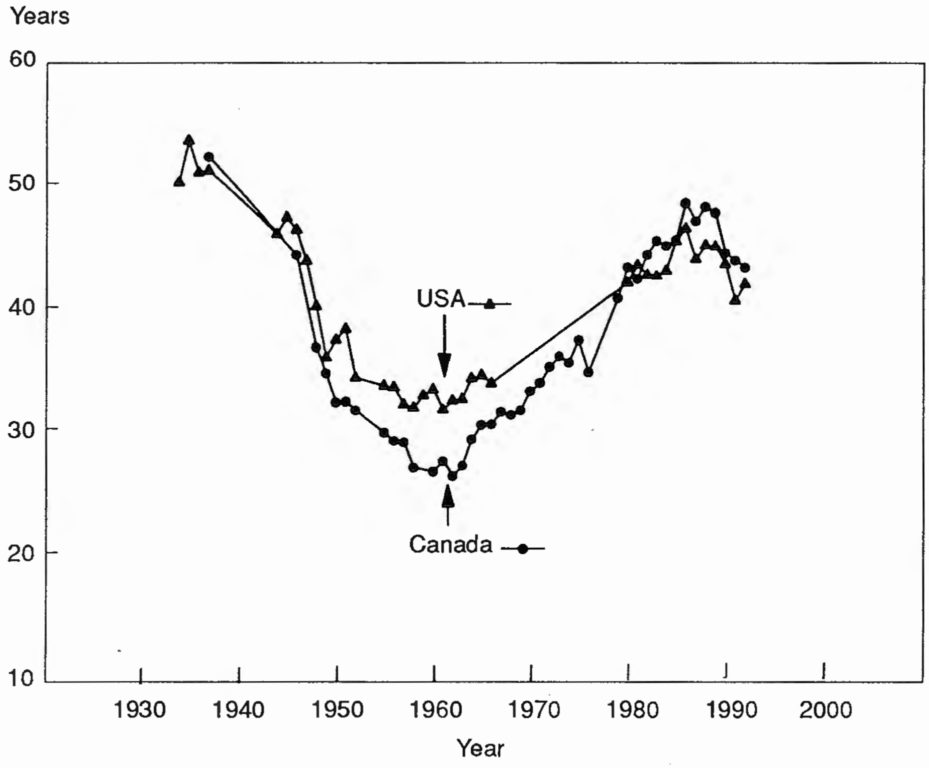

Figure 1. Average age of potato varieties in the United States and Canada from 1934 to 1992.

production is a proxy measure for the quality and maturity of the marketplace and production environment.

Several factors contribute to the unexpected outcomes shown in Figures 1 and 2. Well-developed institutional seed programs and intensive crop management practices in a high-value crop such as potato decrease the demand for varietal disease resistance as specialization in production occurs. Consumers and processors become accustomed to higher quality varieties in the market and are reluctant to change. Increasing concern for the environment could eventually lead to an acceleration in varietal change in developed countries, if the presumed high social costs of growing varieties susceptible to diseases and pests were effectively internalized in the economy.

The second conclusion is closely related to the first: *Varietal turnover is likely to be faster in producing regions that are less endowed and more rainfed than in more protected environments characterized by higher yield potential.* Based on data from 1990, varietal age and yield were positively correlated in the 11 most important potato-producing states in the United States (Figure 3). The common criticism of the Green Revolution that varietal change has bypassed the more marginal production regions cannot be leveled at potato breeding in North America.

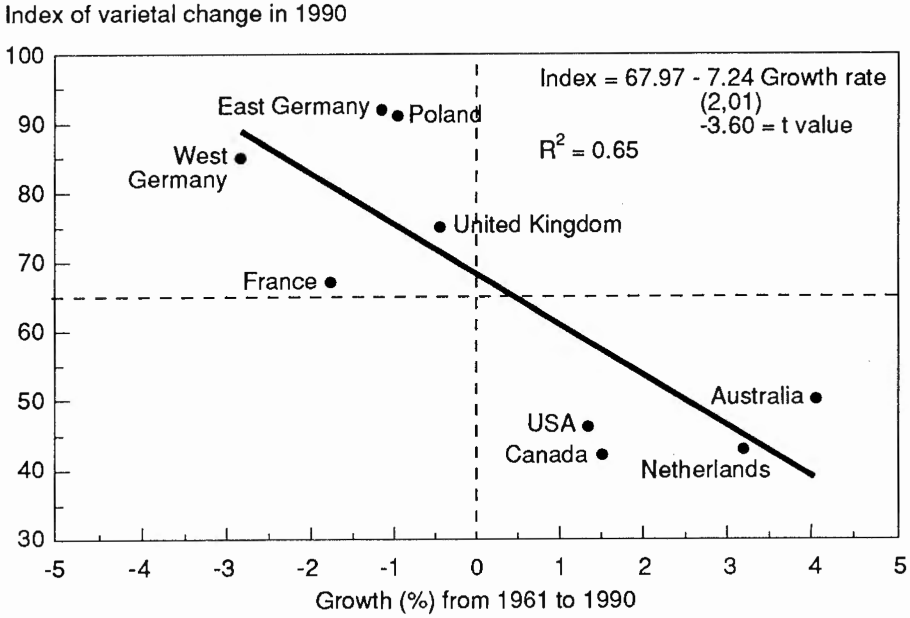

Figure 2. Growth in potato production and varietal change.

Indeed, potato breeders have registered more success in the more marginal regions.

The third conclusion is not as counterintuitive as the first and second, but it is also somewhat unexpected: *Potato varieties are more widely adaptable than we commonly believe.* With increasing market integration and production specialization, demand for local adaptation declined in North America. With one exception, varieties targeted for narrow ecological or seasonal niches did not survive exclusively in a restricted production domain. Again, with another exception, all the commercially important varieties in Canada have been bred in the United States. In terms of adoption performance, North Dakota has had the most successful state breeding program. Varieties from the North Dakota program account for about 15-20% of certified seed area in the U.S. and Canada. They are most popular in the Red River Valley of North Dakota and in the north-central region, but they are not confined there. In eight of the 11 major potato-producing states, at least one North Dakota variety figured among the most common four varieties in 1990.

What do these three conclusions imply for potato crop improvement in developing-country agriculture? Several factors make varietal change more likely in developing countries than in developed countries with a mature potato industry. First, institutional seed programs, if they exist, may not function well. Without clean seed from government-supported programs, it is hard to transfer new varieties. But the scarcity of such seed means that any new varieties, which are produced through ad hoc special projects in the public

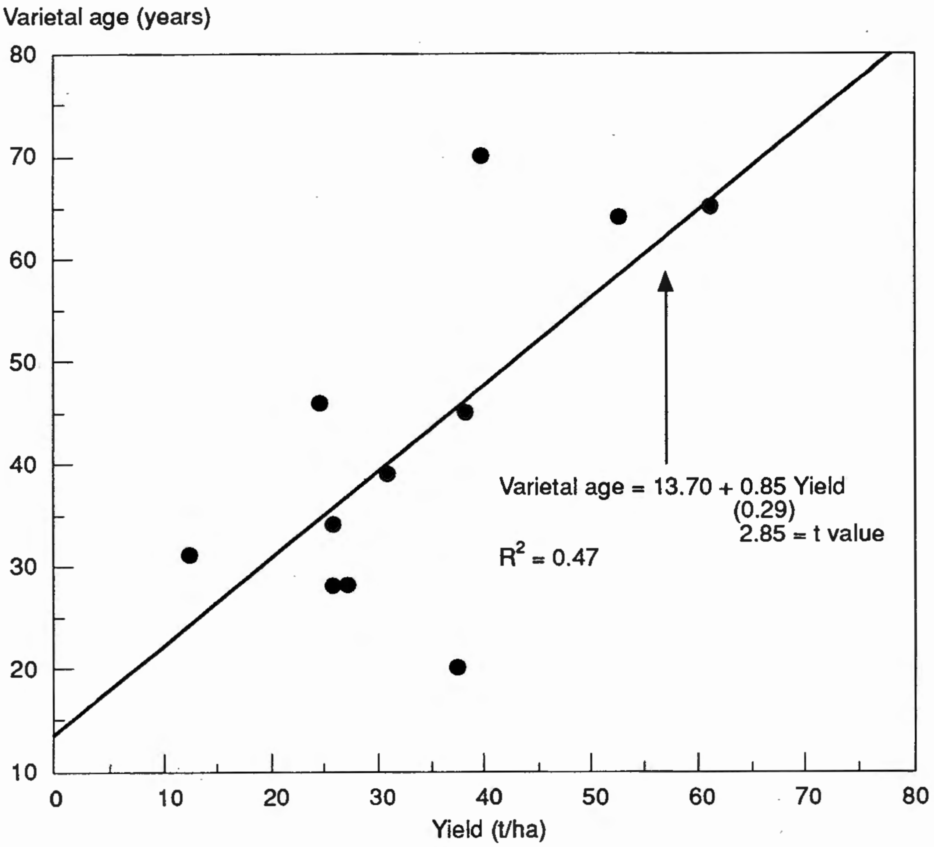

Figure 3. Varietal age and yields in the 11 most important potato-producing states in the United States in 1990.

sector or in the informal sector, compete with farmers' degenerating seed. The demand for virus resistance is therefore strong.

Second, chemical control is widespread in developing-country agriculture, but farmers have fewer resources and infrastructure is less developed. Disease pressure, particularly from late blight, is often more intense.

Third, except for the Andean region, preferences are not as marked as in developed countries. Although potatoes are too precious to be fed to livestock and although demand for processed potatoes is increasing, the potato market in many tropical and subtropical countries is not yet that differentiated.

We can cite several examples in which the nexus between adoption performance and disease resistance is positive and significant, in contrast to developed-country potato agriculture. The demand for stable-yielding rustic clones is also high, particularly in rainfed environments.

The comparison of varietal change between developed and developing potato-producing countries has thus far emphasized the contrasts, but the driving forces behind the relationships in Figures 1 and 2 are the same. As quality becomes more prized in the market and as production becomes more specialized and commercially oriented, the prospects for varietal change diminish.

Figure 4 depicts this stylized relationship. At the right end of the figure, we find the environments of high production potential together with markets of marked consumer preferences. Presently, perhaps no low- or even middle-income developing countries would fall to the right of C, but several countries would lie in segment BC, characterized by high production potential in a relatively discriminating market. These conditions describe well potato production in Southern Cone countries where the prevailing varieties in the intensive commercial farming sector come mainly from the Netherlands. In such a context, prospects for obtaining a practical impact from the excellent national breeding programs in this region are often brighter with smaller, less commercially oriented producers in more marginal production regions or seasons.

A few countries in North Africa could also fit the production and market conditions described in interval BC. Because varietal production potential is still not a constraint to yield and because yield potential is high, returns to research on crop and water management should be attractive in these well-endowed environments for potato production. The relative homogeneity within these environments should lead to reduced location specificity in applying the results of crop and water management research. In addition, the commercial orientation and small number of relatively large producers should enhance the prospects

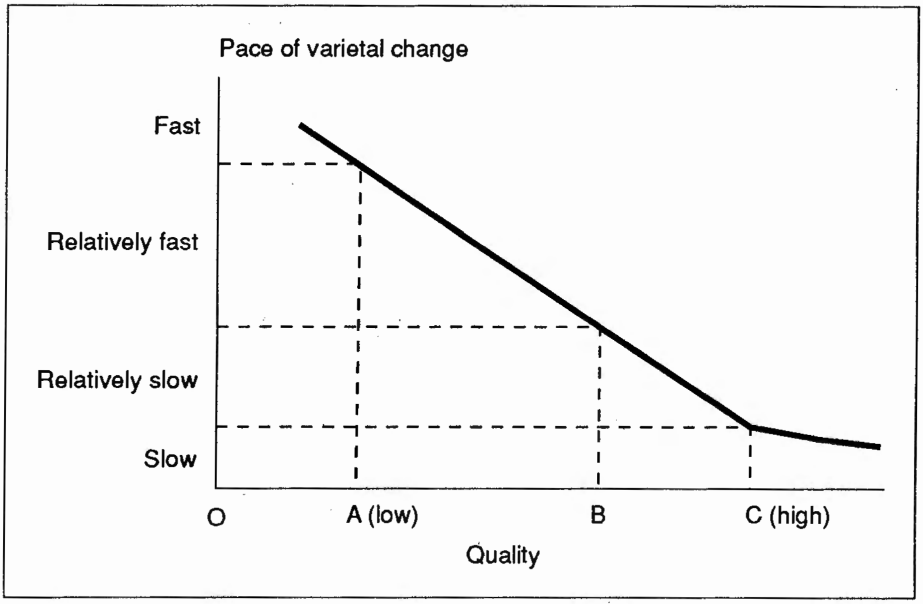

Figure 4. The hypothesized relationship between varietal change and the quality of production and consumption environments.

for adoption of practices requiring group action such as recommendations from integrated pest management research.

Finally, the production and market conditions in these countries should be conducive to the emergence of strong seed programs. Investments in seed program development should generate attractive rates of return.

At the other extreme, we encounter environments of lower yield potential accompanied by markets that do not significantly reward quality. Potato cultivation in countries falling into segment OA is largely rainfed and both biotic and abiotic stresses exact a high toll on production. Prime examples of countries in this group are China and almost all the nations (except for South Africa) in sub-Saharan Africa where potatoes can be grown.

Most developing-country potato producers would fall somewhere in AB. If the supply of new varieties were forthcoming and field multiplication were effective, we would expect a fairly rapid rate of varietal replacement in environments with high or moderate production potential and a moderately discriminating market (the northern Andes), or relatively low production potential with a discerning market (the southern Andes), or relatively high production potential with a less discriminating market (irrigated dry-season production in South Asia).

Another implication of the patterns of varietal change in developed countries pertains to the scope for and desirability of wide adaptation. We can muster some empirical support for fairly wide adaptation in potato production in developing-country agriculture. Ample potential for wide adaptation enhances the value of multilocational testing. Based on the North American experience in varietal change, the notion that every national program can make a practical impact by selecting material uniquely suited to its conditions would appear to fly in the face of reality. The challenge facing CIP and other international institutions is to maximize the potential that strong or key programs within larger regions or agroecologies have for generating regional and global spillover benefits.

Expanding the frontier of potato cultivation into the lowland tropics of Southeast Asia

Demand for potato as a vegetable crop in Southeast Asia is robust and rapidly expanding. Many observers believe that in the tropics potato simply has nowhere to go but to lower elevations because land in the highlands is limited and environmentally fragile. It is also hard to see how productivity increases in such relatively small areas can keep pace with the burgeoning demand for potato products. Based on the experience of the SAPPRAD countries, encompassing Indonesia, Malaysia, Papua New Guinea, the Philippines, Sri Lanka, and Thailand, E.T. Rasco and F.B. Aromin provided a comprehensive assessment of the scope for expanding potato production in the lowland tropics in a keynote address delivered at the 4th Triennial Meeting of the Asian Potato Association in July 1994.

In the SAPPRAD region, the downward movement of potato has taken place in the postpaddy rice areas of northern Thailand and central Java, in the sandy soils of the Jaffna and Kalpitiya peninsulas in Sri Lanka, and in the river floodplains of the Cagayan Valley in the Philippines. Although no dramatic expansion in potato hectareage has been reported in these areas in the past few years, improved technologies for production, marketing, and utilization could make sustained growth a reality.

SAPPRAD recognizes several advantages of growing potatoes in the lowland tropics. Lowland potato is harvested earlier than both highland potato and many competing lowland crops. The lowlands also offer opportunities for mechanized potato production when labor becomes more expensive.

The limitations of cultivating potato in the lowlands are also well known. Year-round production is not possible. Potatoes can only be grown in the coolest and driest part of the year (Figure 5).

Potatoes grown in the lowlands are usually inferior in quality to those cultivated in the highlands. High temperatures, particularly during tuber maturation, result in lower quality. Dry matter is usually lower than that of the same variety grown in high elevations and tuber skin formation does not take place normally. Dormancy is also shorter, resulting in faster sprouting and weight loss during storage and handling.

At present levels of technology, the production cost per unit of area of lowland potato is estimated to be lower than that of highland potato. But because of lower yield in the lowlands, the cost of production per kg of tubers is usually higher in the lowlands than in the highlands.

The most exciting prospect for extending potato production into the lowlands in the SAPPRAD region is in the postpaddy rice agroecology. About 1,500 hectares of potato are planted in this agroecology in Chiangmai Province, Thailand, where cultivation on a commercial scale has been taking place for at least 20 years and recently has been increasing at 6.5% per annum.

The greatest advantage of the postpaddy rice agroecology is that the soil is relatively pest-free. The flooded condition of the preceding rice crop substantially reduces soil-borne pests such as bacterial wilt, nematodes, and grubs, along with weeds. Potatoes can tap into the usually high residual fertility from the preceding rice crop. Irrigation can be used to support the potato crop during the dry season when the water supply is inadequate for rice and low temperatures are favorable for potato. A more subtle benefit is the availability of rice straw for mulching to reduce soil temperature, conserve moisture, and control weeds.

This agroecology also has several limitations to expanding potato production. Land preparation is difficult because of puddled soil. The risk of flooding during the early part of the growing season necessitates the preparation of elevated beds, resulting in a high cost of field preparation compared with that of upland soils. During extended rains, even elevated beds fail to prevent the rotting of seed tubers. Potatoes also compete with other high-value crops that are easier to grow and require less investment. In many instances, potato area has been observed to fluctuate according to the price of competing crops.

Thai farmers have successfully cultivated potatoes in the postpaddy rice agroecology with several innovative crop management practices. Beds that are at least 30 cm high and 120 cm apart are prepared using the hoe following plowing and harrowing with a 4-wheel tractor. Seeds imported from Europe are cut into small pieces, the so-called "Thai cut." Large tubers can produce as many as 10-12 cut seeds; thus, the seed requirement is only 400-600 kg/ha, instead of the usual 2,000 kg with whole seed. Cut seeds are sprouted in sand beds

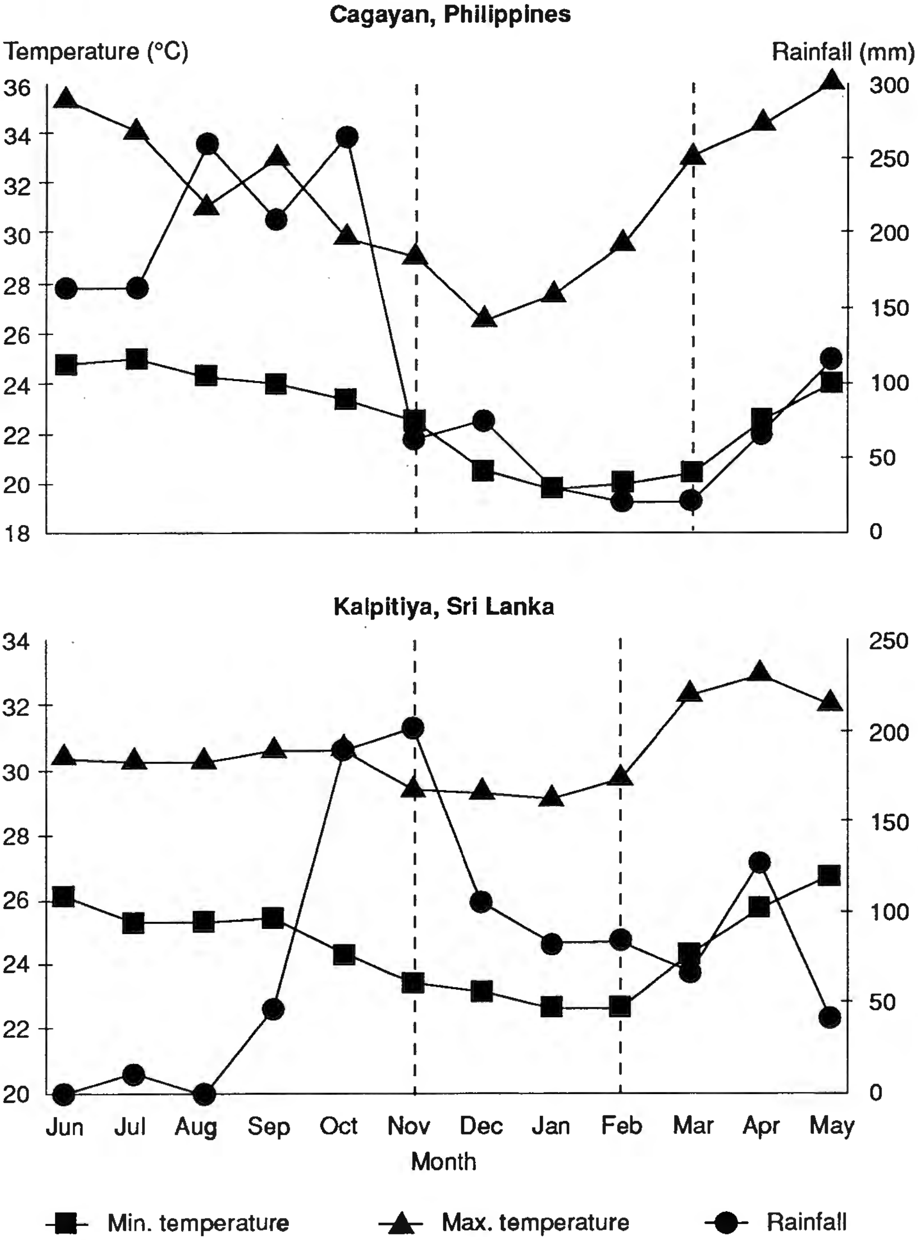

Figure 5. Potato production season (between dotted lines) in the low-elevation tropics.

in the shade until sprouts reach 1 cm length, then they are planted and covered in the field with a thin layer of soil, which is kept moist by furrow irrigation.

Potatoes are normally harvested after vine maturity (90 days). But if prices are unusually favorable, harvesting may take place as early as 60 or 70 days after planting.

What can be done to improve potato productivity in the postrice agroecology, particularly in Thailand? Dramatic increases in productivity through improvements in fertilizer management, irrigation, or pest management are unlikely, as farmers have constantly improved these areas of crop management by trial and error over many years. For example, tuber moth has ceased to be a problem in Thailand, partly because of control measures that have been largely adopted by Thai farmers. Other control measures, such as the use of *Bacillus thuringiensis* (Bt) and granulosis virus, have proven to be effective, but have not yet been introduced to producers because the problem of tuber moth is no longer perceived to be important.

An obvious hope for improving productivity is a new variety, which can be produced domestically, that is resistant to viruses and has good storability. One such variety, Fang 60 (Achirana INTA), was released by Thailand's Department of Agriculture after five years of testing. Fang 60 has consistently provided higher yields than imported seed varieties. Seed of Fang 60 can be produced at low elevations, stored in cold storage for 7-8 months, then allowed to sprout for one month before planting under diffused light. Seed-sized tubers can easily be attained in Fang 60 because its tuber size is innately small and round. The major drawback of Fang 60 is its inferior market acceptance. Ware potatoes of Fang 60 fetch only about two-thirds the price of ware potatoes of imported varieties. The search for a better variety is likely more difficult in Thailand because its growers and consumers are more discriminating than those in the Philippines or Sri Lanka.

In conclusion, a lot remains to be done to firmly establish potato cultivation in the harsh environment of the lowland tropics. Potato cultivation in these agroecologies will still continue even if new production technologies are not forthcoming. But we should not miss opportunities to make the highly nutritious potato affordable to a broader section of humanity sooner.

Characterization of Sweetpotato Production Constraints and Opportunities

The baseline surveys characterizing sweetpotato production systems in several African countries neared completion. We finished a draft report for Uganda in 1994 and held a workshop in Tanzania in November 1994 to collect all the zonal survey data and begin preparation of the final report for Tanzania.

Research also began in 1994 in three case study areas to explore the factors leading to the intensification or disintensification of sweetpotato production in densely populated areas of East Africa. In particular, we will examine the gender-related welfare effects associated with the increasing commercialization of sweetpotato.

Characterizing production constraints and opportunities in Uganda

Uganda is the largest producer of sweetpotato in Africa. In 1989, researchers in the sweetpotato program of the Namulonge Agricultural and Animal Production Research Institute (NAARI) began baseline diagnostic surveys in nine major sweetpotato-producing regions or districts of Uganda. These surveys sought to:

- Document the role of sweetpotato in the farming and food systems of Uganda;
- Identify production constraints and opportunities;
- Identify utilization constraints and enhance understanding of the current patterns of sweetpotato marketing, preservation, and consumption;
- Generate information to guide on-farm research; and
- Establish general ex ante information (baseline data) as a basis for future impact assessment.

The majority of respondents in the production survey were women. Piecemeal harvesting is an important gender-specific practice documented in the baseline surveys (Figure 6). In subsistence and semisubsistence production, piecemeal harvesting is common, and was reported consistently by more than 85% of the survey respondents. A single harvest is usually done when sweetpotato is destined for the market.

Piecemeal harvesting starts from around 2 months after planting for some varieties and is usually carried out by women who move around the field looking for cracks on mounds (indicative of a sizeable tuber). One to two tubers are carefully removed using a sharp metallic rod or stick, then the mound is again properly covered with soil. Usually, enough sweetpotatoes for one or more meals for 1-2 days are harvested. Piecemeal harvesting usually lasts 4-5 months. The length of a piecemeal harvest seems to be a function of variety, soil type, availability of other foods, household size, disease and pest infestation, and weather conditions. Harvesting too early resulted in reduced yields, whereas harvesting too late exposed tubers to weevil attack.

N.E.J.M. SMIT

Figure 6. Piecemeal harvesting of sweetpotato by women in Uganda.

Different varieties respond differently to piecemeal harvest, with some varieties producing larger tubers. Varieties with longer maturity periods were most suitable for piecemeal harvesting.

Whereas most farmers reported planting and harvesting sweetpotato throughout the year, planting is concentrated around March/April. When labor becomes too limiting, sweetpotato planting is extended to May, when rains are tapering off. Usually, crops that are less tolerant of water stress are planted earlier in the season, with more hardy crops, such as sweetpotato and cassava, sown later. Sweetpotato thus fits well in the farm labor profile as farmers can afford to postpone its cultivation for a few weeks, usually without disastrous consequences.

Sweetpotato is mainly cultivated as a sole crop, but intercropping is important in some districts. Associating sweetpotato with beans is the most popular intercropping system.

Districts with high population pressures experienced reductions in area devoted to sweetpotato over the past five years. In contrast, sweetpotato area is expanding in sparsely populated districts.

The vast majority of farmers obtain vines for planting from their own fields. Under extreme weather conditions, vines are bought and sold.

Over time, farmers have selected a number of sweetpotato varieties that are identified by local names. The nomenclature is based on varietal characteristics such as yield, maturity period, tuber size, tuber shape, size and shape of leaves, and other factors such as place of origin and person who introduced the variety. From 20 to 50 varieties were listed per district and characterized according to their perceived traits. A list of varieties that farmers had abandoned was also compiled in each district.

Even though varieties vary across farms and districts, many varieties cut across farms, districts, and regions. Such varieties usually tolerate a range of climatic conditions, have high disease and pest resistance, and yield well.

Preferred varieties tend to be high yielding, resistant to common pests and diseases, of medium maturity with good in-ground storability characteristics, suitable for piecemeal harvest with no fibers, and of good marketability, medium sweetness, and powdery texture. We perceived some varieties to be stable, that is, they have been grown for 20-30 years without changing their culinary qualities or becoming extremely susceptible to diseases and pests. We attributed varietal stability to pest and disease tolerance or resistance, maturity period, taste, yield, and in-ground storability.

We used a scoring system to elicit information on the severity of constraints to increasing sweetpotato productivity. Possible scores ranged from 0 (not a problem) to 4 (a very serious problem). We assessed perceptions on 19 potential constraints presumed to be common to the seven surveyed districts, and also gathered information on other more location-specific problems. Of the constraints listed in Table 1 for the seven districts appearing in the main report, labor and transport costs received the highest average scores. The availability of labor and transport was usually perceived to be less of a problem than their cost. This difference between perceived cost and availability reflects the cash and capital shortages facing poor sweetpotato-growing households. In contrast to labor costs and availability, a shortage of land was not perceived as a

Table 1. Farmers scoring[a] of constraints to sweetpotato production in Uganda by district.

Constraint	Average	District						
	score	Kabarole	Iganga	Gulu	Mpgi	Luwero	Arua	Kabale
High labor cost	2.32	2.82	2.15	2.07	2.98	1.86	2.31	2.04
High transport cost	2.31	2.49	2.31	2.60	2.31	0.90	2.85	2.74
Weevils	2.18	2.18	2.65	1.91	2.56	1.42	2.57	1.94
Sweetpotato butterfly	2.13	2.51	2.67	1.92	2.28	1.88	1.96	1.69
Lack of transport	2.12	2.14	2.09	2.43	2.11	1.04	2.50	2.56
Drought	1.95	2.04	2.02	1.69	1.83	1.78	2.27	2.12
Low market prices	1.95	2.58	1.69	2.28	1.51	1.44	2.09	2.07
Other rodents	1.91	2.80	2.13	1.74	1.50	1.66	2.00	1.51
Moles and rats	1.88	1.64	3.71	1.43	1.58	1.08	1.59	2.12
Shortage of farm implements	1.82	1.56	2.27	1.91	2.07	0.70	2.45	1.79
Lack of sacks	1.51	1.60	1.14	2.10	1.54	0.54	2.07	1.60
Tuber rot	1.49	1.82	1.55	1.55	1.48	1.24	1.59	1.20
Monkeys	1.48	0	3.83	0	3.00	0	3.50	0
Labor shortage	1.38	0.91	1.67	1.38	1.66	0.96	1.57	1.48
Lack of "clean material"	1.32	1.38	1.73	1.60	1.02	0.46	1.71	1.35
Virus	1.31	1.49	1.47	0.62	1.44	0.84	1.24	2.04
Land shortage	1.30	0.98	1.73	1.36	1.56	0.68	1.74	1.04
Lack of planting material	1.17	0.84	1.35	1.25	0.53	0.84	1.98	1.42
Porcupines	0.81	2.67	0	0	3	0	0	0
Wild pigs	0.53	1.09	0	0	1	1.18	0.37	0.06
Flooding	0.52	0.24	0.23	0.25	0.07	0.60	0.76	1.46
Mites	0.45	2.17	1	0	0	0	0	0
Squirrels	0.29	2.00	0	0	0	0	0	0
Average	—	1.74	1.71	1.30	1.61	0.92	1.70	1.40
No. of observations		46	49	53	47	50	49	52

a. On a scale of 0 to 4, where 0 = not a problem, 1 = minor, 2 = moderate, 3 = serious, 4 = very serious.

serious problem. This perception reinforces the observation that these sweetpotato-growing households are relatively labor scarce and land abundant.

Weevils and sweetpotato butterflies were viewed as the next highest ranking constraints and were perceived as moderate to serious problems in the seven districts (Table 1).

Drought figured as an important source of abiotic stress. In contrast, except for Kabale, waterlogging and flooding were perceived as insignificant or minor problems.

Pest infestation, especially the sweetpotato butterfly caterpillar, *Acraea acerata*, was reported to be severe during the dry season. Prolonged drought also leads to scarcity of vines and deterioration of tuber quality.

Vertebrate pests, mainly monkeys, moles, and rats, were a source of serious concern in several districts. In general, the perception of the severity of these pests varied markedly across districts (Table 1).

Sweetpotato diseases, notably viruses and tuber rot, were observed and reported. Farmers seem not to recognize the economic importance of viruses, hence their low ranking. In most districts, lack of clean planting material was reported more constraining than lack of planting material per se. Low market prices, a shortage of farm implements, and a lack of packaging material were also reported as minor to serious problems.

We have used the information from these surveys to investigate the effects of the piecemeal harvesting system within which varieties and management practices are being evaluated to improve sweetpotato productivity in more subsistence-oriented production in Uganda. Initial trial results at Namulonge station, reported in the *PRAPACE Annual Report 1992-93*, show that piecemeal harvesting competes favorably in yield with the optimal single harvesting date. Piecemeal harvesting is not characterized by a higher incidence of weevil infestation and damage compared with single-date harvesting.

Homegardening with sweetpotato in Southeast Asia

With increasing urbanization, growing sweetpotato in homegardens has a high potential to contribute to peri-urban and urban household nutrition and food security. UPWARD has supported a homegardening technology development project since 1992, primarily aiming to increase both the volume and nutritional diversity of garden output. The assumption is that such an increase will improve the nutritional well-being of peri-urban and urban families.

The project strategy has involved a participatory evaluation of selected technologies by a group of women homegardeners, and in a small number of school gardens. This is followed by the transfer and diffusion of the results of these evaluations to other gardeners and schools through the involvement of the local Nutrition Division of the Department of Health (DOH) and the Department of Education, Culture, and Sports (DECS). Members of the original research team and the homegardener-evaluators trained homegarden trainers within DOH and DECS.

The greatest impact was noted in the adoption of new sweetpotato varieties: two-thirds of the original gardeners selected four of the evaluated varieties for some or all of the following reasons: taste, yield, ability to use tops for vegetables, suitability for piecemeal harvesting, and the violet flesh of one variety.

There was also a notable increase in the diversity of gardens as a result of the evaluations of mixed cropping with other species. Although the school gardens, which tested different organic fertilizers, showed impressive results, homegardeners were reluctant to evaluate either organic fertilizers or composts, for financial or time reasons. Given the poor quality of the soils in most of these urban gardens, this area needs a continued effort. The project has now moved into a monitoring, evaluation, and diffusion stage. We are monitoring the autonomous expansion of gardening activities and technologies and making additional efforts to encourage that expansion.

Drawing on this experience, a homegardening project also started in southern Philippines, where we are investigating the role of gardens in biodiversity conservation as well as their contribution to household health. Some 120 women from all areas of a single watershed are involved in the documentation process, and 30 women are partners in technology evaluation and ethnobotanical assessment.

Adaptation and Integration of Potato Production Technologies

The objectives of this project are to provide NARS with advanced genetic materials, particularly ones incorporating virus resistance, heat tolerance, and earliness in desirable agronomic and market backgrounds, for varietal selection and release, and to develop progenitors for use in CIP and NARS breeding programs. In general, the release of varieties by NARS is a necessary but not a sufficient condition for making a practical impact via varietal change. Table 2 lists CIP-related varieties released by NARS in 1993-1994.

Assessing CIP's role in NARS varietal releases

In 1992 and 1993, CIP surveyed major potato-producing NARS in developing countries to establish a database on potato crop improvement programs and to evaluate how CIP could more effectively contribute to those programs. By the end of 1994, 24 of the 34 potential respondents had returned the questionnaire. These included the largest potato-producing NARS and those with the most developed breeding programs.

According to these responses, the pace of varietal releases has been accelerating over time. In the 1960s, the 24 programs in total were releasing about three varieties per year; the same programs are now generating about 15 releases per year (Figure 7). This upward trend is consistent with the increasing growth and development of potato crop improvement programs in developing-country agriculture.

Table 2. New CIP-related varieties released by NARS in 1993 and 1994.

Country	Origin	CIP number	Original name/code	Name	Major attributes[a]
Peru	CIP	377744.1	P-8	Kori-INIA	LB
	CIP	379706.27	LT-8	Costanera	PVX, PVY
	CIP	384866.5	85LB70.5	Amarilis-INIA	LB
	CIP	390478.9	C90.170	Tacna	PVX, PVY, PLRV, salinity
Dominican Rep.	Argentina	720088	B-71-240.2	Ocoa	PLRV, LB
Guatemala	Mexico	575049	CEW-69-1	ICTA Alaska	LB, EB
Venezuela	Mexico	575049	CEW-69-1	Caribay	LB, EB
Turkey	CIP	378681.10	TR 79023/10	Sultan	PVX, PVY, S, earliness
	CIP	380543.2	TR 81040/2	Yayla Kizi	PVX, PVY, storability
Madagascar	India	573079	I-1035	Mailaka	LB
	Mexico	720084	CFK-69-1	Pota	LB
	USA	800934	MS-35.9	Miova	BW
Uganda	CIP	374080.5	P-3	Kabale	LB
Cameroon	Mexico	720055	65-ZA-5	Bamira	LB
Bangladesh	CIP	384073.457	TF	Chamak	Earliness
	CIP	385079.364	TF	Dheera	Earliness
Philippines	Mexico	676089	I-1085	BSU P-04	
	CIP	BP86500.5	LBR 1-5	BSU P-03	
China	India	676089	I-1085	?	

[a] BW = bacterial wilt, EB = early blight, LB = late blight, PVY = potato virus Y, PVX = potato virus X, PLRV = potato leafroll virus, S = scab.

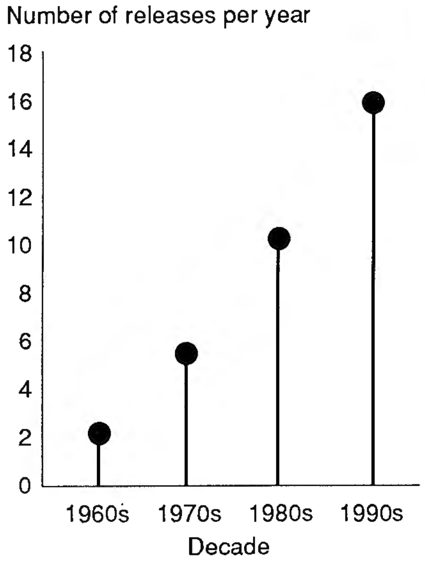

Figure 7. Pace of varietal releases by NARS by decade.

The composition of these releases has also changed over time. The questionnaires reported a total of 225 national releases. Chronologically dividing that total into three equal sets gives 75 varieties released before 1980, 75 between 1980 and 1986, and 75 between 1987 and 1993. In the first period, most released varieties were elite clones introduced from developed countries or were varieties bred by NARS with no involvement from CIP (Figure 8). In the second period, NARS-bred clones, identified by CIP for pathogen testing and distribution to other NARS, particularly smaller programs in which potatoes were not economically important enough to justify a breeding effort, became a major source of released varieties. As CIP's headquarters and regional breeding programs matured, varieties selected by NARS from CIP-bred populations figured prominently in the most recent period.

Figure 8 charts the expected evolution of an international commodity improvement program. Documenting an increasing contribution of CIP progenitors as parents of NARS-bred releases would be the final stage in this development.

Providing NARS with advanced materials and progenitors

Largely because of demand from NARS, we made many crosses in greenhouses in La Molina and Huancayo, Peru, in 1993 and 1994. We distributed this material as TPS progenies for selection by breeders in national programs (Table 3).

The number of duplex and triplex progenitors carrying immunity to PVY and PVX continues to expand. Nine clones, highly resistant to these important seed-borne diseases, are in the process of pathogen elimination and will soon be added to the pathogen-tested list (Table 4). Three are PVX and PVY immune identified as duplex for both loci, one is PVY immune triplex, and six are immune to PVY and immune to PVX or resistant to PLRV.

Evaluation of clones from CIP's virus-based populations for earliness and heat tolerance continued in 1993 and 1994 on the Coast of Peru. We conducted these trials in different seasons when average temperatures usually exceeded 20°C and when it was considered too hot to cultivate potatoes (Table 5). Three clones were particularly outstanding and are targeted for pathogen testing and subsequent distribution. They outperformed the local check, a recently released CIP-bred variety. Clone C89.315 is immune to PVY and PLRV; clones C91.612 and C91.640 are both immune to PVY and PVX and carry a high level of resistance to PLRV. This material offers an opportunity for earlier or later than

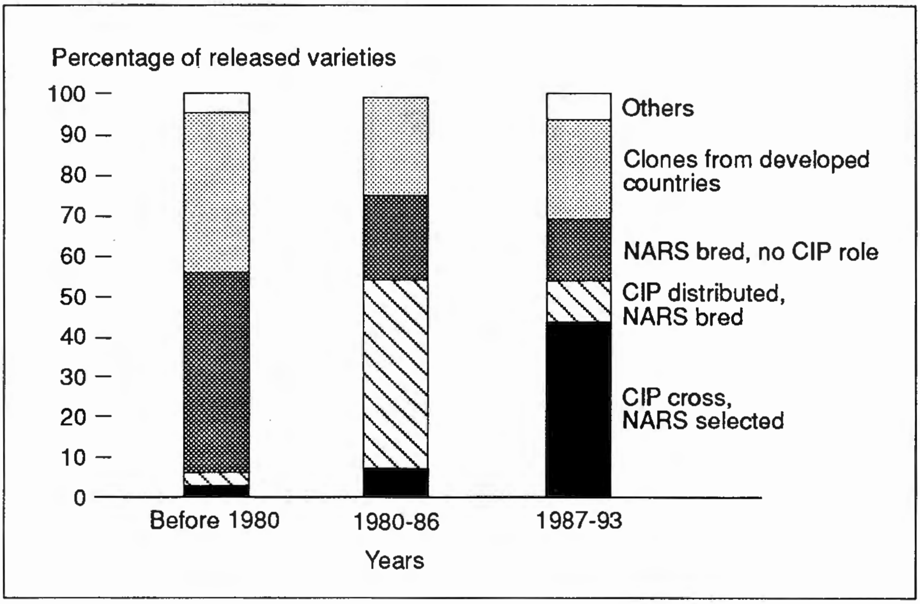

Figure 8. Trends in CIP's role in the generation of potato varieties by NARS.

normal planting in environments where high temperatures affect productivity. Extending the length of the planting season stabilizes seasonal potato prices for both producers and consumers.

Drought and frost are the most serious abiotic stresses affecting crop production in the Andes, where potatoes are often grown at above 3,000 m. After more than a decade of plant breeding, two frost-tolerant base populations have been developed in Peru. Presently, frost-tolerant clones with excellent agronomic attributes, high yielding capacity, and attractive external appearance are available for both the Andes and tropical and subtropical highlands outside the Andes. The advanced breeding materials under development for the Andean region segregate for resistances to cyst nematodes (*Globodera pallida*), and immunities to viruses (PVY, PVX) and late blight for specific locations. The materials for tropical highlands outside the Andes are early maturing and appropriate for markets with *tuberosum* standards of quality.

In partnership with CIP, PROINPA, the national potato crop improvement program in Bolivia, has also obtained excellent results from its work in breeding and screening for frost tolerance. In the future, PROINPA will lead this research area in the Andean region. We have scaled down work on frost tolerance at CIP headquarters and will eventually phase it out in 1995. We will clean a selected sample of clones from each of the two base populations for viruses for in vitro maintenance and further distribution as needed. We will intercross the rest of the selected clones to produce true seeds to preserve this source of resistance in long-term storage. Likewise, we will transfer all field-grown clones to the Peruvian national program.

Table 3. TPS progenies distributed to NARS during 1993-1994.

Country	Number of progenies	Amount of seeds	Attributes[a]
1993			
USA	11	2,200	X, Y, E
Brazil	187	37,400	X, Y, EB, E
Colombia	40	8,000	X, Y
Czech Republic	24	4,750	X, Y, LR, E
Philippines	106	21,200	X, Y
China	228	74,450	X, Y, LR, LB
Spain	41	8,200	X, Y, E
South Korea	53	10,600	X, Y
Vietnam	55	11,000	X, Y, E
Argentina	55	11,000	X, Y, LR, E
Ecuador	27	5,400	X, Y, LB
France	52	10,400	X, Y
Taiwan	23	4,600	X, Y, LB
Bangladesh	23	4,600	X, Y
Turkey	39	7,800	X, Y
Chile	61	12,200	X, Y, LR, E
Argentina	33	4,000	X, Y, LR
Peru (Huánuco)	105	19,110	X, Y, LB
1994			
Argentina	55	11,000	X, Y, LR, E
Chile	105	47,400	X, Y, LR, E
Brazil	308	41,600	X, Y, EB, E
Colombia	40	8,000	X, Y
Ecuador	27	5,400	X, Y, LB
Vietnam	133	22,600	X, Y, LB, BW
South Korea	87	17,400	X, Y, LR, LB
China	184	37,000	X, Y, LB, BW
Philippines	186	37,200	X, Y, LB, BW
Mauritius	32	32,690	X, Y, LR, E
Czech Republic	24	4,750	X, Y, LR, E
France	52	10,400	X, Y, E
Spain	41	8,200	X, Y, E
USA	11	2,200	X, Y, E
Turkey[b]	39	7,800	X, Y, LR
Bangladesh[b]	23	4,600	X, Y, LR
Taiwan	23	4,600	X, Y, LR
Tunisia[b]	20	4,000	X, Y
Uruguay	50	10,000	X, Y, LR, EB, E
Peru	200	40,000	X, Y, LB, LR
Total	2,803	613,750	

a. BW = bacterial wilt, E = earliness, EB = early blight, LB = late blight, LR = potato leafroll virus, X = potato virus X, Y = potato virus Y.

b. Sent as tuber families.

Table 4. New group of PVX and PVY immune progenitors in process of cleanup of pathogens for distribution and use.

Code	CIP number	Pedigree	Resistance
TY.4	392760.1	YY.1 x YY.3	PVY
DXY.7	391894.7	XY.14 x XY.9	PVX+PVY
DXY.10	391895.10	XY.9 x XY.13	PVX+PVY
DXY.15	391896.15	XY.19 x XY.14	PVX+PVY
C89.315	388972.22	XY.20 x 377964.5	PVY+PLRV
C91.640	388615.22	B71-240.2 x XY.16	PVX+PVY+PLRV
C91.612	388611.22	MEX-32 x XY.9	PVX+PVY+PLRV
C92.172	392780.1	Sedafin x YY.3	PVX+PVY
C91.906	392781.1	B71-7449.12 x XY.13	PVX+PVY

Daylength is potentially an important variable in determining varietal adaptation in potato. In 1991, CIP began a breeding project with the Instituto Nacional de Investigaciones Agropecuarias (INIA) in Chile to expand the range of elite clones with adaptation to long, short to long, long to short, and short daylength conditions (Figure 9). The latitudes of the four testing sites ranged from 30 to 41 degrees. Thus far, 24 clones have been selected for superior performance for yield, commercial tuber attributes, and adaptation to varying daylength conditions. These clones have been sent in vitro to CIP-Lima for further evaluation and international distribution.

This collaborative research also helped INIA to accelerate the evaluation of elite clone R-82248.B-3, which was named as variety Pukara in 1993. We confirmed Pukara's high yield, desirable market traits, PLRV resistance, and adaptation to short and long daylength in multilocational and multiseasonal trials.

Adaptation and Integration of Sweetpotato Production Technologies

The objectives of this CIP project are to:

- Test elite sweetpotato germplasm in selected countries, with a focus on achieving rapid impact.

Table 5. Evaluation of advanced clones under stress and hot conditions.

Clone	Pedigree	Lima			Tacna		Ica	Junín	Mean
		La Molina Spring 1993	La Molina Summer 1994	Cañete Summer 1994	Calana Summer 1994	Yarada Summer 1994	Ica Summer 1994	San Ramón Rainy 1994	
C91.640	B71.240.2 x XY.16	25.17	15.41	20.33	25.63	16.87	16.75	26.67	20.98
C91.612	MEX-32 x XY.9	29.40	14.30	15.50	23.13	15.77	12.37	16.67	18.16
C89.315	XY.20 x 377964.5	20.87	16.83	15.33	26.83	10.83	10.80	20.94	17.49
C90.170	Serrana x XY.4	28.37	13.40	9.43	19.63	9.30	10.15	21.10	15.91
C91.028	C88.196 x XY.16	31.60	12.10	13.17	13.93	10.37	11.93	16.00	15.59
C90.182	CUP.199 x XY.9	27.77	10.50	14.60	18.33	8.43	9.50	15.42	14.94
C89.262	Serrana x LT-7	15.27	10.05	21.67	21.57	12.77	11.30	13.25	15.13
C90.266	XY.9 x LT-7	24.97	10.27	18.10	16.17	7.33	8.22	14.30	14.19
C91.759	381382.34 x YY.2	30.87	12.53	15.07	14.33	5.37	12.64	12.22	14.72
C89.294	YY.7 x 377964.5	21.30	14.72	11.60	16.50	8.57	7.50	12.11	13.19
LT-8	Check	15.32	10.20	9.83	9.20	5.00	5.64	17.78	10.42
Mean		24.63	12.76	14.97	18.66	10.06	10.62	16.95	15.52

P. ACCATINO

Figure 9. Breeding material for evaluation under short to long daylength in Curacavi, Chile.

- Support varietal selection and dissemination efforts by national programs in selected countries.
- Analyze and report the results of international testing efforts.

As such, the output of this project manifests CIP's sweetpotato breeding strategy in partnership with NARS.

Refining the sweetpotato breeding strategy

In June 1994, a group of sweetpotato breeders met at CIP-Lima to review and update CIP's global sweetpotato breeding strategy. The group recommended that breeding priorities focus on processing characteristics, drought tolerance, and weevil resistance in addition to earliness and root yield.

Table 6 shows goals and priorities by region. Processing characteristics—such as high dry matter content—for feed and food are particularly important in East and Southeast Asia and the Pacific (ESEAP), where more than 90% of the developing world's sweetpotatoes are grown. Weevil resistance was assigned a high priority in each of the four regions listed. Drought tolerance was most important in South and West Asia (SWA) and sub-Saharan Africa (SSA), with secondary importance in Latin America and the Caribbean (LAC) and ESEAP. Viruses appear to be a major constraint to increased sweetpotato production in eastern Africa, particularly in Kenya, Rwanda, Tanzania, and Uganda.

CIP's program emphasizes decentralized sweetpotato breeding activities. But available resources are limited. The group therefore agreed that Peru, Indonesia, and eastern Africa (Kenya and Uganda) be considered the main regional sites where CIP's sweetpotato breeding activities will be continued or further developed. The group acknowledged and approved the differentiation of breeding goals across the main breeding sites (Table 7). It recommended that China, India, and the Philippines continue to be secondary regional sites where CIP should use available expertise and improved germplasm.

Table 6. Main breeding goals by region after assessment of constraints and opportunities in sweetpotato.

Constraints and characteristics	CIP region			
	LAC	SWA	ESEAP	SSA
Weevil	x	x	x	x
Virus				x
Drought	x	x	x	x
Dry matter (starch)	x		x	x
Foliage	(x)[a]	(x)		(x)
Nonsweet varieties				West Africa
Storability	x	x		x

a. (x) = potential demand for forage-type sweetpotato (forage only).
Note: Improved earliness and yield are important objectives in all regions.

Table 7. Goals for CIP sweetpotato breeding.

Breeding site	Main breeding goal
Peru	High dry matter/starch
	Drought
Indonesia	High dry matter/starch
	Weevil
Eastern Africa	Drought
	Virus
	Weevil
	High dry matter/starch

Note: Improved earliness and yield are important objectives in all regions. Evaluation for high dry matter and/or starch content will be considered according to regional needs.

Given recent trends in sweetpotato production and utilization, 15 priority countries, considered to have the highest potential for greater impact from CIP activities in sweetpotato breeding, were identified. These countries are China, Vietnam, Indonesia, and the Philippines in ESEAP; India and Bangladesh in SWA; Peru, Cuba, and Brazil in LAC; and Uganda, Kenya, Rwanda, Tanzania, Nigeria, and Cameroon in SSA.

Evaluating introduced pathogen-tested sweetpotato clones

The distribution and evaluation of elite clones accomplishes three purposes in CIP's global sweetpotato breeding strategy. First, it offers a fast track to rapid impact. Second, it helps to identify progenitors for crossing for future varietal development. Finally, information on the performance of elite material from various sources is valuable in predicting and understanding varietal adaptation.

We conducted initial evaluations of pathogen-tested sweetpotato clones introduced by CIP in Kenya and Uganda in 1993 and 1994. In Kenya, 14 trials were planted; we evaluated 60 introduced clones in both the short rainy season (October planting) and long rainy season (April planting). The trials were located in one of four mid-elevation sites ranging in altitude from about 1,500 to 1,800 m and in annual rainfall from 700 to 1,900 mm. The introduced clones were mainly from Peru, the United States, Puerto Rico, and the International Institute for Tropical Agriculture (IITA) in Nigeria, with some introductions from Argentina, Burundi, Cuba, China, and Papua New Guinea.

As a group, the Peruvian clones performed better than any other source of germplasm, particularly at the cooler Nairobi and drier Katumani sites. Superior performance at these mid-elevation sites may be related to the adaptation of Peruvian clones to the cool night temperatures prevalent during the Peruvian winter and in the East African highlands.

CIP number 420027 was an outstanding performer in several trials. CIP virologists have reported this clone to be immune to sweetpotato feathery mottle virus (SPFMV); therefore, it may be virus resistant in East Africa. Moreover, the excellent performance of 420027 and several other Peruvian clones in these trials parallels their superior performance in drought-stress trials in Lima, Peru (see Program 5, page 112). This consistent performance again draws attention to the unexpected similarity of agroecological conditions, particularly temperature, between the Kenyan highlands and Peru.

Unfortunately, consumers do not favor this clone and several other outstanding performers. Number 420027 ("Zapallo," which means squash in Spanish) tastes like a squash, which is not what consumers in East Africa expect of a sweetpotato. This clone is high in provitamin A; consequently, it may have potential for acceptance for baby feeding or processing. We also need to assess the clone's potential as a progenitor.

In Uganda, we evaluated a small subset of 14 pathogen-tested clones in two trials at five locations. The introduced clones were highly susceptible to viruses at the five sites. Virus infection stunted foliage growth, preventing propagation by vine cuttings and increasing competition from weeds. Nonetheless, trial yields were generally good, and in some cases excellent. Ugandan consumers considered several varieties to have good taste, and plant breeders included four in the crossing block.

In the Philippines, we obtained mixed results on the relative performance of introduced clones relative to local checks. In one trial, NC 262 and IITA-TIS 8250 confirmed their status as consistent performers. In another trial, local checks outyielded a different set of introduced clones.

In contrast to the results obtained in Kenya, introduced clones from South America performed poorly in Indonesia, where 99 were introduced from Lima in 1993 and multiplied to evaluate adaptability in 1994 in Bogor. Of these, 24 were selected for advanced yield testing. Selection was based on yield, weevil resistance, root flesh color, size, and shape.

The frequency of selection, when compared by clonal origin (Table 8), suggests that South American varieties are not adapted to Bogor conditions. Only one of 27 varieties was selected. Japanese varieties had the highest selection index.

We obtained similar results in the evaluation of seed families from diverse origins. Proportionally, more seedlings were selected for future evaluation from Japanese families than from other origins. In particular, Japanese selections were characterized by their high dry matter content. The adaptability of Japanese material to Southeast Asian conditions could stem from agroecological similarities or the strong sweetpotato breeding program in Japan. Whatever the case, obtaining more breeding material and elite clones from Japan would appear to substantially enhance the prospects for sweetpotato improvement in Southeast Asia.

Table 8. Origin of CIP pathogen-tested clones selected in Bogor, Indonesia.

Origin	Varieties tested	Varieties selected	Selection index (%)
South America	27	1	3.7
CIP-Lima	10	0	0.0
North America	25	5	20.0
Africa	26	10	38.5
IITA	20	5	25.0
Asia	21	8	38.1
China	6	2	33.3
Japan	9	5	55.6
Total	99	24	24.2

Evaluation of Impact and Sustainability of Potato Production Technologies

Impact case studies

The impact case studies and CIP's approach to impact assessment were reported in *CIP in 1992: Program Report* (see pages xxii-xxviii). December 1994 marked the completion of the last of the nine case studies. CIP will publish a monograph reporting the results of the case study project in 1995.

The objectives of the case studies were to document CIP's accountability in making a production impact with NARS in farmers' fields and to generate information that could be used by scientists in technology design and by research administrators in resource allocation. Scientists from NARS and CIP were jointly involved in the case studies.

We used conventional benefit-cost analysis to assess the rate of return to research and extension in each of the case studies. We focused on the production context, component technologies, sources of benefit, and adoption profiles. We chose conservative assumptions to ensure that benefits would not be overestimated.

Varietal, integrated pest management (IPM), and seed technologies are equally represented in the case studies described in Table 9. The case studies are also a mix of small- and large-country success stories. Actual or projected area coverage ranges from 400 ha for farmer-based rapid multiplication in Da Lat, Vietnam (Figure 10), to 250,000 ha for true potato seed (TPS) in India.

As much as possible, the case studies are based on concrete historical information, that is, the timing of benefits in Figure 11 is mainly ex post. Presently, technology adoption in all the case studies extends to at least 100 ha in unsubsidized conditions in farmers' fields. A few of the case studies focus on technologies that are still in the pipeline or for which transfer is starting. Of these, perhaps the greatest source of uncertainty is attached to TPS in India, where benefits are also projected to be the highest.

Table 9. Impact case studies.

Technology		Country	Time span for project appraisal
General	Specific		
Varietal	Late blight resistance	Rwanda, Burundi, Zaire, Uganda	1978-1993
	Resistance to drought and viruses	China	1978-2000
	Late blight resistance	Peru	1979-2020
Integrated pest management	Potato tuber moth	Tunisia	1976-2000
	Sweetpotato weevil	Dominican Republic	1989-2019
	Andean potato weevil	Peru	1988-2018
Seed	Strengthen seed program	Tunisia	1976-1985
	Rapid multiplication	Vietnam	1978-1993
	True potato seed	India	1978-2015

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Figure 10. Farmer-based, rapid multiplication in Vietnam.

We selected the case studies to represent the range of CIP-related technologies and to illustrate the different roles of an international agricultural research center (Figure 12). These roles range from strategic research, as exemplified by the case of TPS in India, to facilitating technology borrowing, as epitomized by the case of the Argentine-bred variety Achirana-INTA, which was named CIP-24 in China.

In the literature, technological success in agricultural research is often accompanied by a rate of return on

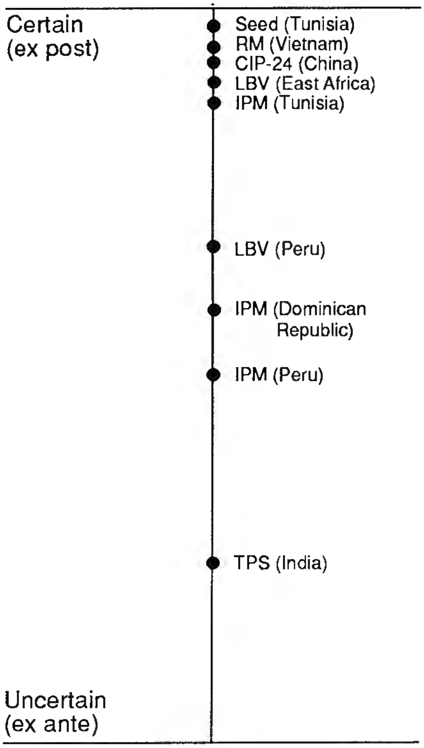

Figure 11. Degree of certainty of impact in the case studies. RM = rapid multiplication, LBV = late blight varieties, IPM = integrated pest management, TPS = true potato seed.

investment between 30% and 50%. The economic profitability of several of the case studies exceeded the modal range of 30%-50% (Figure 13). The flow of benefits started sooner for the success stories than for "typical" agricultural research, which is usually associated with a fairly long gestation period before benefits are generated.

The most profitable project per unit of investment was the case of CIP-24 in China. This case study illustrates the profitability of borrowing technologies that are well adapted to the production and market conditions of the recipient of these spillover benefits.

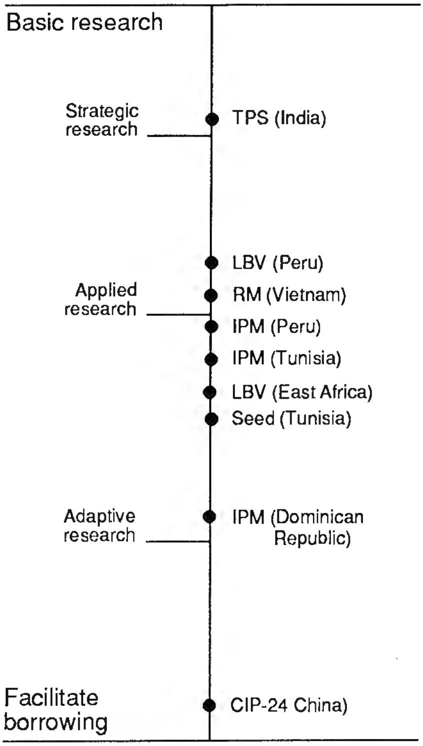

Figure 12. CIP's role in technology generation in the impact case studies. TPS = true potato seed, LBV = late blight varieties, RM = rapid multiplication, IPM = integrated pest management.

The highest net benefits per hectare from CIP-related technological change were associated with the adoption of plantlets from tissue culture as a source of planting material in Vietnam. Degenerated seed of varieties susceptible to late blight was quickly replaced with clean seed of resistant varieties with a low-cost, farmer-based multiplication system that has prospered over the past 15 years.

Estimates of net present value show the return on investment, taking into consideration the size of the project (Figure 13). The variation in these estimates reflects the small- versus large-country mix in the case studies.

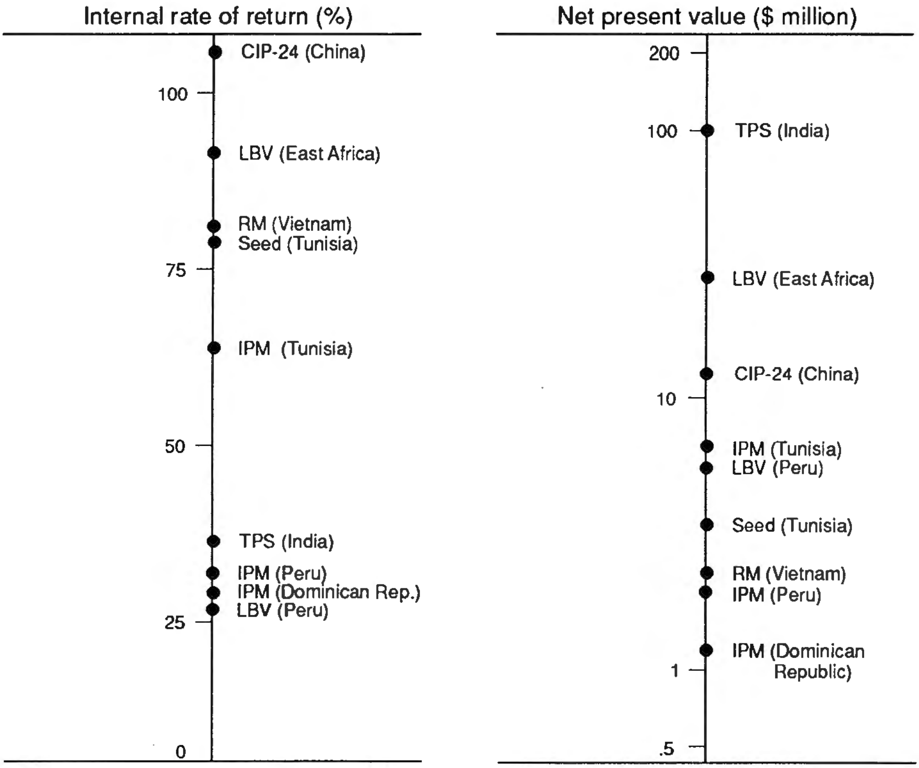

Figure 13. Economic results of the impact case studies. LBV = late blight varieties, RM = rapid multiplication, IPM = integrated pest management, TPS = true potato seed.

The case studies have generated useful information for the design of technologies and pointed to priority areas for further research. Perhaps the most apparent implications for technology design come from the varietal case studies, in which information is elicited on farmers' perceptions of the comparative value of competing varieties.

The case studies have also pointed to areas for further study. For example, the fate of TPS in India is closely linked to the economic performance of and prospects for cold storage in the subcontinent. Close substitutes for technical change, in this case cold storage, warrant more research attention.

The case studies underscored several recurring themes in technology generation and transfer. One of these applies to IPM technologies that are quite location-specific and knowledge-intensive. Imparting more basic information on the life cycle and behavior of pests is essential to unleashing the potential of farmers to participate in technology design and innovation. Indeed, educating farmers about pest management principles and general procedures is often as important as or more important than giving recommendations about specific practices.

Another theme relates to the size of economic benefits between "first- and second-generation" technological change

(Figure 14). The main message emerging is the amount of leverage clean seed and new varieties can have on productivity. The diffusion benefit of speeding up adoption in the initial years is also sizable. Additional varietal change once an efficient seed system is in place makes a welcome but—in relative terms—a much more modest contribution to increased production. In other words, the initial establishment of an efficient seed system with varieties that are well adapted and resistant to late blight results in an abrupt shift upward in productivity.

The case studies also contained some surprises. Reductions in pesticide use were not as large as expected or were overshadowed by the size of other economic benefits. In the case study of IPM for the Andean potato weevil, farmers at the pilot testing site still make two chemical applications with the use of IPM practices, but they have become substantially more selective in their use of different types of pesticides (Figure 15).

Returning to the issue of CIP accountability, the economic estimates in Figure 13 support the conclusion that technologies related to CIP and its partners have more than paid for the investments made and have benefited many small producers and low-income consumers. Adding the net benefit streams of the nine case studies and deducting CIP's total past and projected core resource expenditures result in a positive rate of return on investment. This "heroic" calculation is based on the very conservative and restrictive assumption that all past and future practical impact from CIP's work is restricted to these nine success stories. Even excluding TPS in India, the largest and most uncertain case study, the rate of return on investment is still positive.

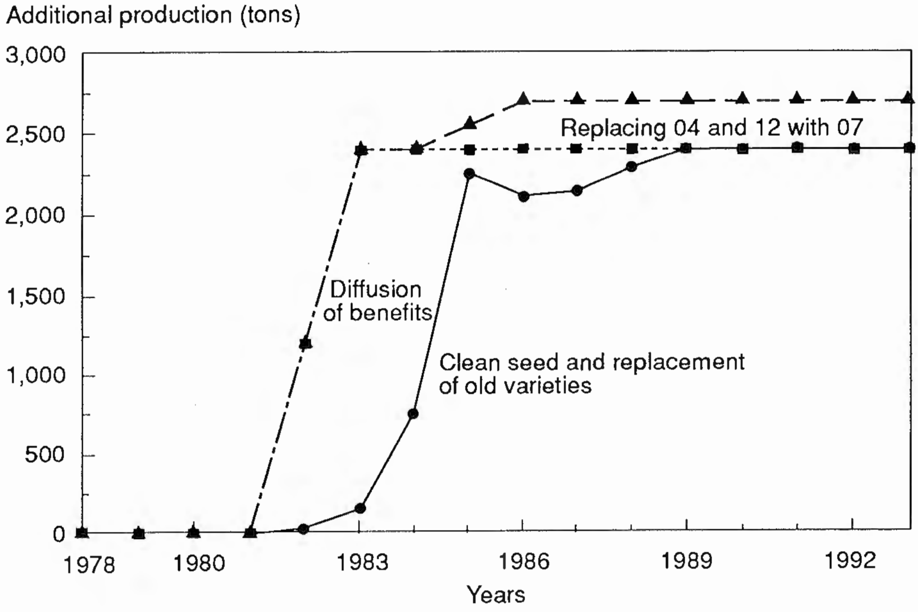

Figure 14. Components of productivity benefits from the adoption of rapid multiplication and improved potato varieties in Da Lat, Vietnam.

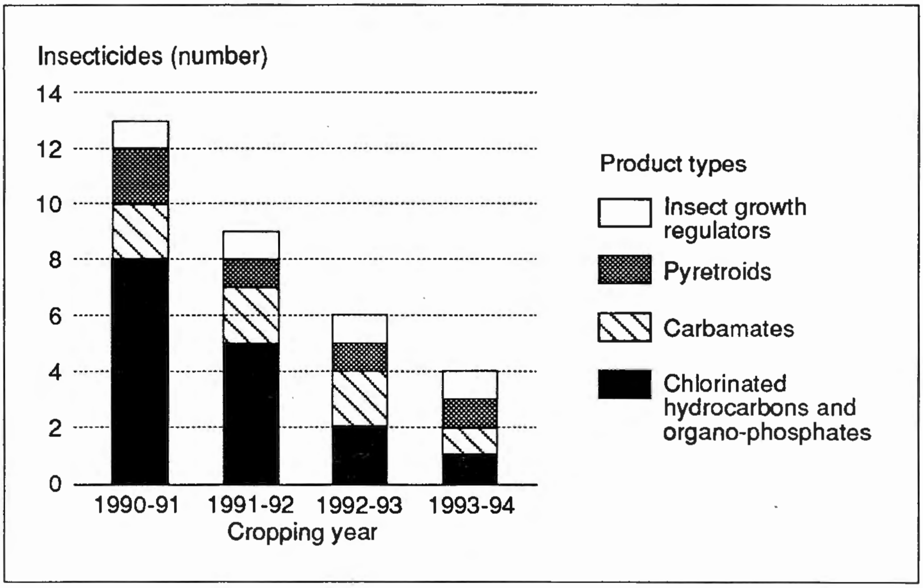

Figure 15. Trend in the number of different insecticides used in Huatata, Peru.

We could list a similar number of case studies for a second-generation research project. These would be somewhat more ex ante and, therefore, subject to greater uncertainty in benefit estimation. Several of these would focus on more intermediate consequences such as the elimination or reduction of diseases in breeding, seed, and production programs. Therefore, benefit evaluation would not be as straightforward as in the present case studies. Nonetheless, the case study project has not exhausted the number of past and prospective success stories of economic impact from CIP-related technologies. Overall, the returns on investment in agricultural research at CIP have been attractive and are at the level one would expect from an international commodity improvement program.

Training

During the past two years, Program 1 has concentrated training activities in Southeast Asia. The newly formulated International Sweetpotato Variety Development Network, within the context of the larger SAPPRAD network, held three training workshops. Participants developed standard procedures for collaborative trials during the training, and trained prospective collaborators on how to use them. The training was skill-oriented and intensive. After three years of courses, a two-volume book on variety evaluation was published in May 1994.

During the first year of its second or main phase, the UPWARD network actively engaged in an array of training and capacity-building activities in 1994. The network held more than 20 workshops on topics ranging from training for researchers on farm household diagnostic skills to training for farmers on sweetpotato production and management.

1993-94 Research Projects and Partners

This list contains titles of research projects, names of principal research partners and responsible CIP scientists, collaborating institutions, and, when applicable, countries where work is conducted.

Characterization of constraints and opportunities for potato production. T. Walker, P. Malagamba.

- Yield gaps and productivity constraints. J. Korva.
- Characterization of benchmark sites to support CIP's Andean Sustainable Land Use Initiative. CONDESAN, Wageningen U. C. Crissman, R. Hijmans.
- Incorporating farmers' perspectives in the development and diffusion of technological alternatives in specific agroecologies in Bolivia. PROINPA, COTESU. J. Quiroga.
- Diagnostic research and priority setting of small potato farmers in Cotopaxi, Chimborazo, and Cañar and investigation of the dynamics of the potato sector in Ecuador. FORTIPAPA, COTESU. A. Hibon.
- Characterization of potato production systems in the PRAPACE network countries. PRAPACE, USAID. P. Ewell.

Characterization of sweetpotato constraints and opportunities. G. Prain, P. Ewell.

- Sweetpotato in African food systems. P. Ewell, J. Low.
- Sweetpotato in Asian food systems. UPWARD, DGIS. G. Prain.
- Socioeconomic studies on sweetpotato in India. V. Khatana.

Adaptation and integration of potato production technologies. H. Mendoza.

- Adaptation and utilization of potato populations in breeding. H. Mendoza, W. Amorós.
- Adaptation and utilization of potato populations for the hot tropics. H. Mendoza, J. Espinoza.
- Breeding for resistance to frost, wide adaptability, and other major constraints of the highlands. J. Landeo.
- Genetic improvement of potato incorporating greater variability using conventional and innovative methods. P. Accatino.
- Introduction and utilization of potato germplasm in North China. Song Bo Fu.
- Evaluation of potato germplasm in the Philippines. E. Chujoy.
- Sustainable potato production in the Dominican Republic. F. Payton.
- Improvements of potato cropping patterns to extend the supply of fresh tubers through intercropping in Tunisia. C. Martin.
- Breeding and adaptation of cultivated diploid potato species. NCSU. W. Collins.
- On-farm trials to introduce cultivars to improve potato production in Burundi and yield improvements through agronomic practices. ISABU, AGCD. D. Berríos.

Adaptation and integration of sweetpotato production technologies. E. Carey.

- Evaluation of sweetpotato clones in various environments in Peru. E. Carey, C. Fonseca.
- Evaluation and documentation of performance of elite sweetpotato germplasm in agroecologies of Latin

America and the Caribbean. E. Carey, D. Reynoso.

- Evaluation and development of suitable sweetpotato germplasm for eastern, central, and southern Africa. E. Carey, H. Kidane-Mariam.
- Introduction, evaluation, and multiplication of sweetpotato germplasm in West Africa. H. Mendoza.
- Improvement of sweetpotato in Egypt. R. El-Bedewy.
- Breeding sweetpotato populations having short duration and high stable yields for tropical and subtropical regions of South Asia. T.R. Dayal.
- Breeding sweetpotato propulations for tropical and subtropical regions of India. T.R. Dayal.
- Testing of advanced sweetpotato germplasm in China. I. Gin Mok, Song Bo Fu.
- Development of improved sweetpotato germplasm for warm and cool tropics of Southeast Asia. E. Chujoy.
- Development and testing of advanced sweetpotato germplasm in Southeast Asia. I. Gin Mok.

Evaluation of the impact and sustainability of potato production technologies. C. Crissman, T. Walker.

- Impact case studies. T. Walker.
- Diffusion of CIP-related breeding materials. C. Crissman.
- Economics and institutional factors determining impact and beneficiaries of TPS. A. Chilver.
- Agricultural chemical use and sustainability of Andean potato production. Rockefeller Foundation. C. Crissman.

PROGRAM 2

Germplasm Management and Enhancement

Potato Collection and Characterization

Wild potato collection

Of the 6,214 accessions in the potato genebank maintained at CIP, 1,500 are wild *Solanum* accessions comprising 93 species from 10 countries (Figure 1).

During 1993, seeds of 347 additional accessions of wild potatoes collected by Carlos Ochoa before the creation of CIP were obtained from potato genebanks in the United States (289 accessions) and Germany (37 from Braunschweig and 21 from Gross Lusewitz).

Seed increase by controlled pollinations, of accessions in the wild potato collection, has continued in collaboration with the Peruvian universities of Cajamarca and Cusco, and at CIP's Huancayo experiment station. We increased the seed stock of 186 accessions comprising 42 tuber-bearing *Solanum* species in 1993, and of 311 accessions comprising 62 species in 1994. Furthermore, the U.S. potato genebank increased the seed of 85 accessions representing 15 wild potato species.

With collaboration from CIP's Virology Department, reactions to PLRV,

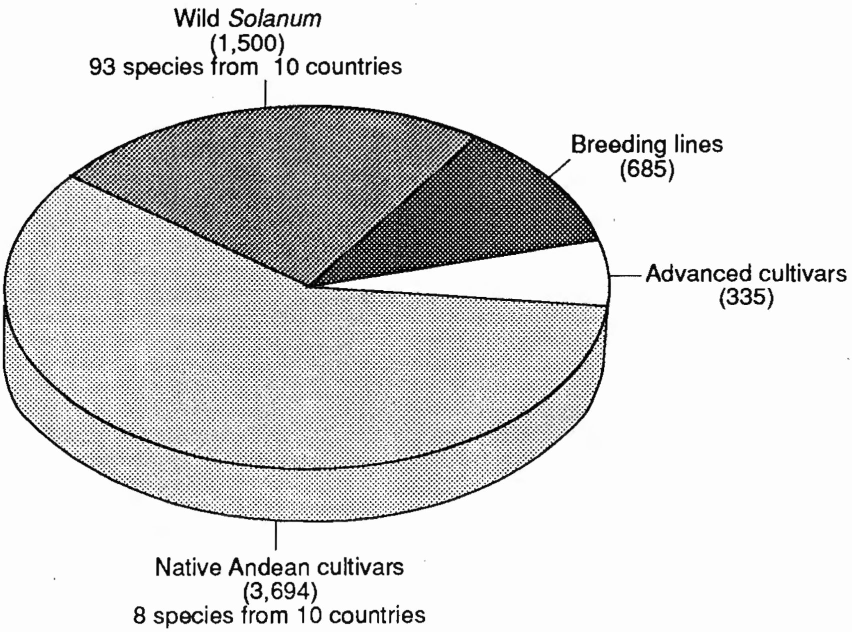

Figure 1. Number of accessions of *Solanum* germplasm maintained in the genebank at CIP (total = 6,214).

PVY, PVX, PVS, and PSTVd in populations of 21 wild potato accessions were evaluated in 1993 and for another 19 accessions in 1994. We found genotypes resistant to PVX strain HB only in the progenies of accessions CIP 761946 of *S. acaule* and CIP 761194 of *S. ambosinum*. CIP 761946 was also the only accession that produced genotypes resistant to PVX strain C. Several accessions tested had genotypes resistant to PLRV, PVY strain O, PVS, and PSTVd (Table 1). We also evaluated accessions for resistances to bacterial wilt (49), potato tuber moth (152), and Andean potato weevil (152).

One outcome of potato intergenebank collaboration was the production of the first version of a joint data file with passport data on 11,256 accessions of wild potato species maintained in the

Table 1. Reactions of wild *Solanum* species to PVX strains HB and C, PLRV, PVY strain O, PVS, and PSTVd.

CIP number	Collector number	Reaction[a] to:					
		PVX^{HB}	PVX^{C}	PLRV	PVY^{O}	PVS	PSTVd
S. acaule							
761946	OCH 14267	R2	R	R	R2	S	S
762038	OCH 14397	S	S	R	R2	R8	S
S. ancophilum							
761448	OCH 12086	S	S	S	R4	S	S
761449	OCH 12086A	S	S			S	R6
S. alandiae							
761392	OCH 12011	S	S	R	R	R6	R8
761395	OCH 12016	S	S	R	R	R8	R8
S. albicans							
761433	OCH 12067	S	S	S	S	S	S
761472	OCH 13014	S	S	R	R8	S	S
S. ambosinum							
761194	OCHS 11298	R	S	R6	S	R2	R6
762070	OCH 14603	S	S	R8	S	R2	S
S. chomatophilum							
762568	OCHS 12553	S	S	S	R8	R8	R8
762571	OCHS 12564	S	S	R		R8	S
761582	OCHS 13325	S	S	S	R2	R	S
762575	OCHS 12570	S	S	R		R6	S
S. chiquidenum							
762052	OCHS 14482	S	S		R	R8	S
762056	OCHS 14487	S	S			R5	
S. huancabambense							
761238	OCH 11619	S	S	S		S	S
762123	OCHS 14865	S	S	S	R	S	S
S. irosinum							
762257	OCHS 15210	S	S	R	R4	R8	R6

a. S = susceptible, R = resistant. The number R2 indicates the percentage of resistant genotypes in the population; therefore, R2 = 20% resistant genotypes in the progeny. R alone indicates that all plants evaluated were resistant.

United States, Germany, Scotland, Russia, Argentina, and CIP. We will publish these data jointly, along with evaluation data.

Andean cultivated potato collection

The cultivated potato collection maintained at CIP received 710 new accessions donated by the Instituto Nacional de Tecnología Agropecuaria (INTA) in Argentina (170) and by Peruvian NGOs (540). This genebank now holds 3,694 cultivated potato accessions, comprising eight species from 10 countries (Figure 1).

We completed characterization of key morphological traits of the main Andean potato collection in 1993. At the same time, 556 duplicate accessions were identified in materials donated by national agricultural research systems (NARS) in previous years. Some 102 new cultivars from the accessions remaining from these donations were selected, and we have incorporated them into the potato collection for long-term conservation (Figure 2). In 1994, we eliminated 173 duplicate accessions.

CIP also continued with genetic diversity studies on the cultivated potato collection. We obtained data on 600 Andean cultivars for alleles of the enzymes malate dehydrogenase (MDH-1, MDH-2), isocitric acid dehydrogenase (IDH-1), phosphoglucose isomerase (PGI-1), diaphorase (DIA-1), phosphoglucomutase (PGM-1, PGM-2), and glutamate oxaloacetate transaminase (GOT-2). A preliminary comparison of allele frequencies for the 8 isozyme loci analyzed in these 600 Andean cultivars (Acvs) was made with data published for 96 North American varieties (NAvs). The following alleles were present in the Acvs but absent in the NAvs: allele 3 of PGI-1 (0.006 frequency), a new allele of GOT-2 tentatively named 7 (0.115 frequency), allele 0 of PGM-1 (0.054 frequency), allele 1 of PGM-2 (0.096 frequency), and allele 3 of DIA-1 (0.014 frequency). In 1994, we also characterized 2,800 additional accessions using isozymes.

Researchers investigated the degree of virus infection in the cultivated collection by serological tests for PLRV, PVY, PVX, PVS, APLV, and APMV using tuber sprouts of 2,905 accessions. Of the 2,905 accessions analyzed, only 142 did not produce positive reactions for any of the six viruses tested. The rest were found to be infected with one to six viruses (Figure 3). These results confirmed the great need to improve the phytosanitary status of the cultivated collection by a systematic program of virus eradication. In 1994, 604 accessions in the collection that were heavily infected with viruses underwent in vitro thermotherapy and

J. DEUSTUA

Figure 2. New Andean potato cultivars are maintained at CIP.

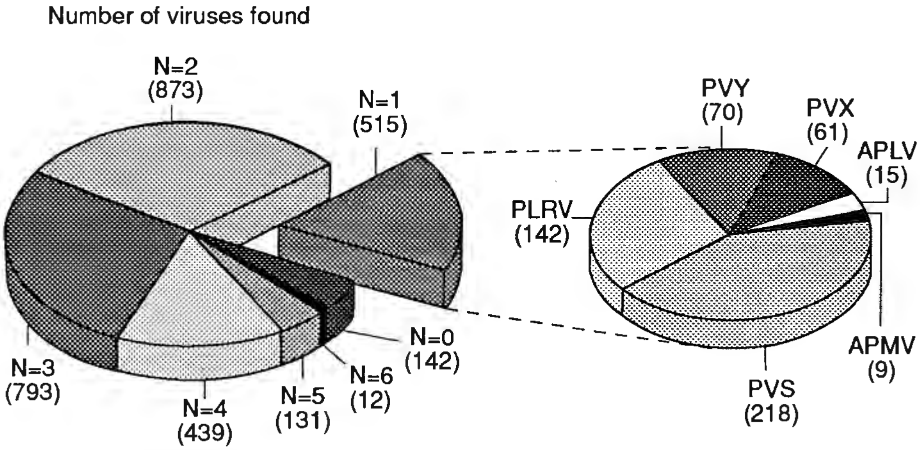

Figure 3. Number of Andean potato accessions infected with the six most common viruses (2,905 analyzed). N = number of viruses.

meristem culture. Serological tests for the most important potato viruses gave negative reactions. This demonstrates the feasibility of cleaning the entire collection in a few years.

In vitro conservation of the cultivated collection

The in vitro potato collection maintained at CIP contains 6,232 accessions, including 895 pathogen-tested clones and other clonal research materials including the late blight differentials, and the Andean cultivated potato collection. In 1994, we transferred 446 accessions of Andean cultivars representing unique genotypes or new synonym groups from the field collection to in vitro culture.

In 1994, we also propagated a complete duplicate set of the in vitro collection in standardized growth restriction media and sent it to the Instituto Nacional de Investigaciones Agropecuarias (INIAP) in Ecuador for safekeeping under long-term storage conditions (6°C, 2,000 lux/10 hours).

Evaluation of potato genetic resources

Open-pollinated seed lots of 285 accessions in the field collection were tested for PVT infection in true potato seed (TPS) of plants grown in the field at Huancayo (3,200 m), Peru. None was found positive using a modified NASH test with a probe developed in CIP's virology laboratory. CIP now tests seeds for international distribution for presence of PVT, in addition to PSTVd.

We evaluated tuber dormancy period on freshly harvested tubers of 2,201 accessions in the cultivated collection and identified accessions with dormancy of about 7 months in *S. tuberosum* ssp. *andigena* (31 out of 1,953) and in *S. stenotomum* (10 out of 150). Although *S. phureja* tubers are known for their lack of dormancy period, four out of 15 accessions evaluated sprouted at about 45 days. Dry matter content was measured in tubers of 948 cultivated accessions, and 12 accessions identified with more than 30% DM. Evaluation of culinary quality on the basis of texture and flavor after boiling of tubers showed 21 out of 936 accessions to be highly starchy and quite tasty. These cultivars have culinary attributes similar to those of cultivar Papa Amarilla, which is highly appreciated in Peru.

Screening for pest resistance included evaluations of 956 accessions in the world collection for their reaction to potato tuber moth. As a result, we identified 12 accessions as moderately resistant. Laboratory tests showed that seven of 47 accessions, resistant to the Andean potato weevil *Premnotrypes vorax* from Cajamarca, combined resistance to that species with resistance to *P. suturicallus* from Huancayo and *P. latithorax* from Cusco (Table 2).

Table 2. Potato accessions that combine resistance[a] to the Andean potato weevil *Premnotrypes vorax*, *P. suturicallus*, and *P. latithorax* under laboratory tests.

CIP accession number	Premnotrypes species		
	P. vorax	*P. suturicallus*	*P. latithorax*
703675	MR	R	R
703787	MR	R	R
704338	MR?	R	R
704342	R	MR	MR
700124	MR	MR	R
704337	MR?	MR	R
704341	MR?	MR	MR

a. R = resistant, MR = moderately resistant.

Utilization of native *S. tuberosum* ssp. *tuberosum* from Chile

The collection of *S. tuberosum* ssp. *tuberosum* native to Chile maintained at Austral University in Valdivia contains 738 accessions representing about 300 different cultivars.

Through a collaborative project involving the Instituto Nacional de Investigaciones Agropecuarias (INIA), Austral University, and CIP, we evaluated the best clones selected over the years under long daylength in Valdivia at La Serena for short-daylength adaptation. Several clones showed a neutral reaction to photoperiod and had an excellent performance. Eight clones outperformed the commercial variety Cardinal at 120 days from planting under short-daylength conditions. Further comparisons under farmer conditions in a temperate climate and short daylength showed that clone 314-84-5875-14 yielded 19.2 t/ha versus 17.7 t/ha for Cardinal. Another selected clone–85-1930-1–also outyielded Cardinal and was selected because of its chipping quality; it has been informally named "Batman" because of its purple skin color.

Distribution of potato genetic resources

CIP distributed accessions of the potato collection as tubers, in vitro plantlets, and true seeds to 17 countries in 1993 and to 13 countries in 1994. Distribution of in vitro plantlets included 3,194 cultures in 1993 and 5,050 cultures in 1994.

One 1993 shipment contained 403 accessions of Andean cultivars collected in Ecuador. We sent these to FORTIPAPA in Quito to restore accessions lost from the INIAP potato collection as well as to provide a complete duplicate set of accessions maintained in in vitro culture at CIP. Besides the germplasm, this shipment contained data files accumulated in the database at CIP on collecting sites, morphological characterization, and evaluation for desirable traits.

In 1994, CIP sent 28 seed lots of crosses between progenitors resistant to *Erwinia* derived from *S. tuberosum* ssp. *andigena* and virus-resistant advanced clones with adaptation to long days to INTA in Balcarce, Argentina, for further selection under field conditions.

Training

CIP provided training on management of potato germplasm to four scientists from Peruvian institutions--Universidad Nacional del Centro (3) and the Instituto Nacional de Investigación Agraria (INIA) (1).

CIP also provided group and individual training in tissue culture techniques and germplasm management for potato to 17 scientists from national programs in six countries.

Potato Germplasm Enhancement

CIP made major efforts in potato germplasm enhancement to improve resistance to insects and late blight, especially using wild potato species. We emphasized improving agronomic characters and resistances to pests and pathogens in diploid potato breeding clones, which yielded between 25 and 40 t/ha under experimental conditions at Lima and at Huancayo, Peru.

Insect resistance

Glandular trichome-mediated general resistance to insects derived from *S. berthaultii* has been incorporated into various potato breeding lines at both the diploid and tetraploid levels (Figure 4). We also conducted work simultaneously at the Comitato Nazionale per la Ricerca e per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative (ENEA), Casaccia, Italy, and Cornell University (USA) for adaptation to long-day conditions, and at CIP, for short-day conditions. Collaborators in developing countries supported this effort by evaluating breeding lines with quantitatively inherited trichome traits. These included researchers at INIA, Chile; INTA, Argentina; Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA); University of the Philippines, Los Baños (UPLB); and the Kenyan

K. WATANABE

Figure 4. Field evaluation of diploid potato clones with potential for glandular trichome-mediated insect resistance. Resistance to the Colorado potato beetle was evaluated at Freeville, New York. Several collaborators in developing countries are conducting a similar type of field evaluation for insect pests such as aphids, thrips, and mites.

Agricultural Research Institute (KARI), among others. They provided feedback on the utility of glandular trichome-related insect resistance as well as adaptation to diverse environments. This group of potato germplasm with genetic backgrounds from *S. berthaultii* was evaluated at Cornell University for resistance to the Colorado potato beetle, and clones were evaluated to assess value for production of advanced tetraploid germplasm.

CIP and Cornell University now have available for distribution as clones and true-seed families a wide range of diploid and tetraploid germplasm possessing the trichome traits.

CIP-bred diploid and tetraploid potato breeding lines with resistance to potato tuber moth were evaluated at Lima, San Ramón, and Huancayo, Peru, for tuber resistance to this insect pest. We observed antixenosis and antibiosis on tubers, and therefore evaluated selected germplasm repeatedly for both resistance and agronomic traits in Peru as well as at collaborating institutions. Sources of resistance included *S. sparsipilum*, *S. multidissectum*, *S. gourlayi*, *S. infundibuliforme*, and *S. vernei*.

Horizontal resistance to late blight

Diploid and tetraploid germplasm was evaluated in the field mainly at Cajamarca, Peru, for leaf resistance to late blight in order to develop a potato breeding population with horizontal resistance to this disease.

We also surveyed wild potato species in the collection held at CIP for potentially high levels of horizontal resistance to late blight, but free of R genes. Researchers selected 300 clones from these species for resistance at Santa Catalina, Ecuador, and also selected 34 *S. phureja* clones for horizontal resistance to late blight for use in molecular marker studies and in breeding.

A series of dihaploids from *S. tuberosum* ssp. *andigena* cultivars with putative late blight resistance will be used to combine resistance genes from the clones selected from wild species.

Exploiting germplasm enhancement methods and generating unique germplasm

We made progress in introducing genes from *S. acaule* into advanced clones by using embryo rescue and molecular markers (Figure 5). These methods could accelerate the use of other species such as disomic tetraploid species and some diploid species that are normally cross-incompatible with cultivated potatoes, but which contain genes for resistance to pests and pathogens.

Landrace cultivars that belong to *S. tuberosum* ssp. *andigena*, *S. stenotomum*, and *S. phureja* as well as several wild species unique to Argentina were used at INTA-Balcarce to increase genetic diversity and culinary quality. A series of dihaploids was obtained from various cultivars at INTA-Balcarce and at CIP in order to widen the genetic backgrounds of our diploid populations.

A broad range of 2x x 2x, 4x x 2x, and 4x x 4x true-seed families as well as diploid and tetraploid clones that are resistant to pathogens (such as bacterial wilt, late blight, and PLRV) are now available at CIP for use by NARS and others in breeding or for selection of varieties.

Application of Molecular Technology to Potato Breeding

CIP made a thorough phenotypic evaluation of target, quantitatively inherited resistance traits together with molecular marker linkage analyses. We attempted to refine techniques for nonradioactive labeling and detection of DNA probes to facilitate the laboratory research capability of national program clients (Figure 6).

Testing genetic markers for glandular trichome traits and resistance to Colorado potato beetle

We tested RFLP markers associated with glandular trichome traits and resistance to the Colorado potato beetle (CPB) using diploid and tetraploid breeding lines that share the same genetic backgrounds with the original resistance donor, an *S. berthaultii* clone. Selfed progenies of tetraploid trichome clone L235-4 and another 4x family from L235-4 x N 140-201 were used to apply specific markers at Cornell University, especially for resistance to CPB.

K. WATANABE

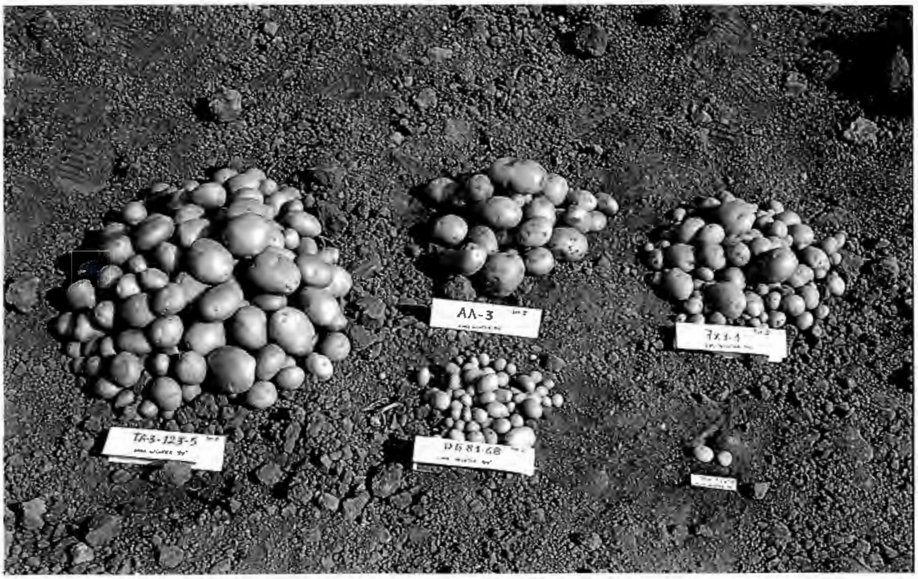

Figure 5. Rapid introgression of *S. acaule* germplasm by an innovative enhancement method using embryo rescue, compatible rescue pollination, ploidy manipulation, and molecular markers. This work took four years, whereas classical breeding required 20 years.

M R. HERRERA

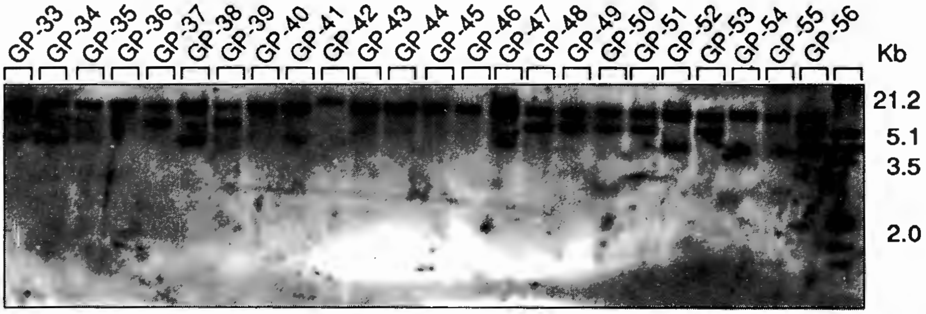

Figure 6. Nonradioactive labeling and detection with an RFLP probe on the segregating population gp for late blight resistance. Detection can be achieved in 1-2 hours with good resolution.

Collaborators in developing countries tested specific markers simultaneously for insect resistance in both 2x and 4x potato germplasm possessing glandular trichomes.

DNA fingerprinting of the potato collection

The potato collection held at CIP has been assembled on different occasions, and by different collectors working in several locations. This has resulted in many duplicates. We now expect DNA fingerprinting to identify closely related genotypes as well as provide new insights into the genetic diversity of this potato germplasm collection.

The species *S. phureja* was chosen as the model for this DNA fingerprinting exercise for the following reasons: duplicates are likely to be present, it has a good potential for improvement, and we are already using a small subset of *phureja* accessions for genetic mapping of late blight resistance. We have extracted DNA from about 25 accessions and begun a RAPD screening of primer amplification and identified polymorphism in eight genotypes (Figure 7). We will continue this screening to select for primers that produce a reliable and informative amplification pattern in order to use these primers to analyze the *S. phureja* collection.

Genetic mapping for tuber resistance to potato tuber moth

CIP evaluated 115 interspecific hybrids derived from a cross between *S. phureja* CCC 1386.26 and *S. sparsipilum* clone PI123050.2 three times for tuber resistance to PTM. One resistant, 12 moderately resistant, and 102 susceptible clones were identified. We will use this

D. FAJARDO

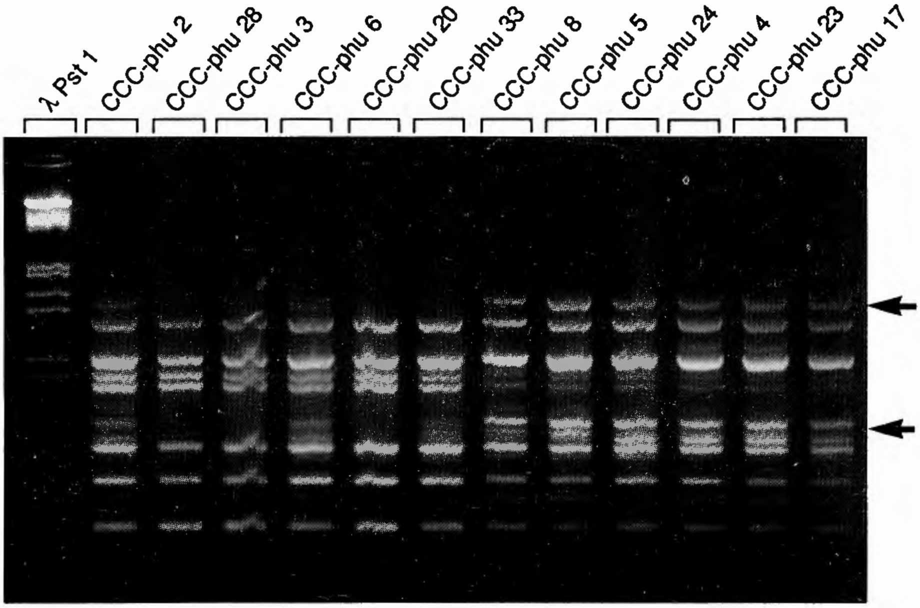

Figure 7. DNA fingerprints of 12 *S. phureja* accessions using RAPD primer OPZ-4. The arrows point to a polymorphic band among closely related genotypes.

PTM resistance segregation for preliminary mapping of this quantitative trait. Simultaneously, using the 13 resistant clones, backcrosses have been made to generate populations to permit a higher resolution in genetic linkage mapping.

Basic studies for mapping horizontal leaf resistance to late blight

CIP established several candidate diploid populations for mapping quantitative loci of horizontal leaf resistance to late blight. We achieved clonal propagation of these candidate diploid families and conducted repeated laboratory and field evaluations in Cajamarca, Peru, and Morochata, Bolivia, for this resistance.

We have now focused on linkage analysis with molecular markers and phenotypic evaluation resistance in two diploid interspecific hybrid progenies: (1) 103 clones derived from a cross –*S. verrucosum* PI116163 x *S. phureja* CCC81 cv. Yema de Huevo–and (2) 133 clones from *S. goniocalyx* cv. Amarilla x *S. phureja* CCC81 cv. Yema de Huevo.

Monitoring introgression with molecular markers

CIP conducted model studies on monitoring introgression with molecular markers in-house and with collaborators. Somatic fusion progenies derived from *S. commersonii* and cultivated potatoes' were employed to monitor the introgression of genes from the wild parent (at the University of Naples, Italy). Introgression lines derived from *S. acaule* for germplasm enhancement are also useful for screening with molecular markers to identify hybrids (CIP and Cornell University). We are now applying these molecular markers gradually for germplasm enhancement as a means to accelerate the breeding process.

Genetic engineering for insect and disease resistance in potato

We conducted diverse activities at CIP and with collaborators to test genetically engineered potatoes. Activities included the use of: (1) lytic peptide genes derived from the giant silk moth provided by Louisiana State University to prevent devastation caused by bacteria (Universidad Católica, Chile, and CIP for bacterial wilt) and fungi (University of Tuscia, Italy, for late blight); (2) virus coat-protein genes for resistance to PVX, PVY, and PLRV (CIP); (3) antisense technology to control PSTVd infestation in potato plants (CIP); and (4) *Bacillus thuringiensis* (Bt) endotoxin genes for insect resistance (CIP, in collaboration with Plant Genetic Systems (PGS), a private Belgian firm). Putative transgenic plants were selected by using kanamycin resistance and GUS marker genes, or testing for the presence of foreign genes in the laboratory (Figure 8). We maintained the transgenic plants in the lab for further testing of resistance by phenotypic evaluation in regulatory agency-approved environments, following biosafety rules. Major activities in genetic engineering of potato continue to focus on improving insect and bacterial disease resistance.

Bt endotoxin-based insect resistance

CIP concentrated on the introduction of artificial insect resistance genes into potato varieties, targeting PTM resistance by using Bt endotoxin protein genes for varietal improvement. CIP made arrangements with PGS for the use of Bt genes by CIP in transgenic versions of potatoes for developing countries. We used major potato varieties from North African countries as well as representatives of CIP's breeding lines.

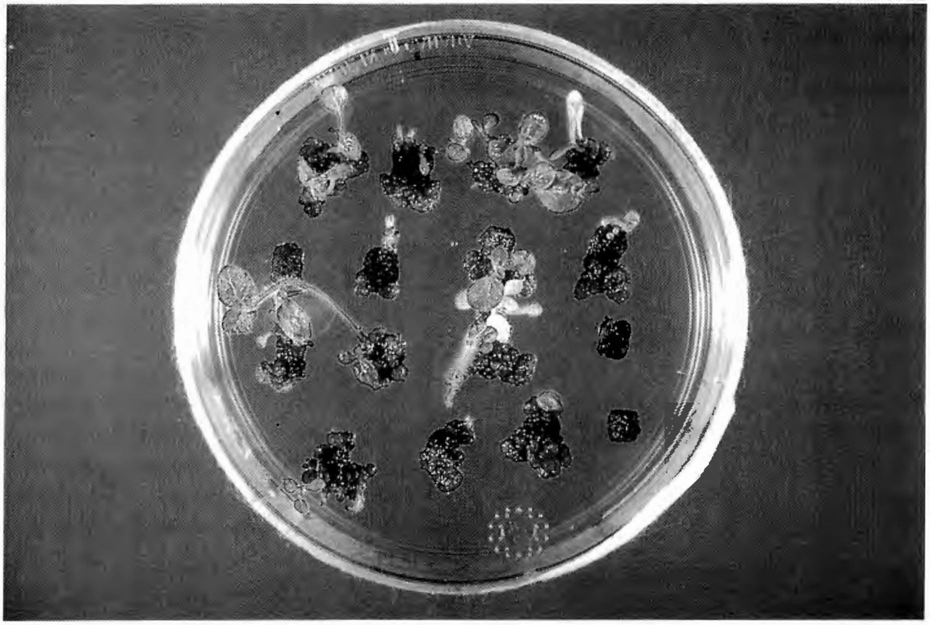

Figure 8. Vigorous regeneration of putative transgenic plants from cultivar Serrana-INTA using an *Agrobacterium tumefaciens*-based transformation system.

CIP is now testing 41 transgenic lines from varieties Sangema and Cruza-148 against PTM under screenhouse conditions. Most of the transgenic plants showed a high level of resistance to PTM in both tubers and foliage. We conducted field evaluations in San Ramón, Peru, following Peruvian biosafety guidelines, which CIP and the Peruvian government jointly established. Fourteen other transgenic lines showing adaptation to subtropical conditions, derived from LT-8 and Sangema, were tested in the field under PTM infestation, and resistance evaluation is ongoing.

Bacterial disease control using lytic peptide genes

CIP evaluated in the field a series of transgenic lines that had lytic peptide genes for bacterial wilt resistance in potato production under subtropical conditions at San Ramón. Three out of 19 transgenic lines produced tubers and showed some field resistance to bacterial wilt disease.

We are working to design and improve gene constructs and employed cecropin B and attacin E gene constructs to optimize their gene expression. We considered three levels for improving gene expression: (1) nucleotide sequence improvement for transcriptional and translational activities, (2) extracellular targeting of lytic peptides, and (3) exploitation of promoters that would be suitable for a strong constitutive and tissue-specific expression. Smart Plant International Inc. (USA) provided a bovine lysozyme gene construct for research purposes, in this case also with potential for bacterial disease control.

Workshops and individualized training on molecular markers

With support from a United Nations Development Programme (UNDP) project on biotechnology-assisted breeding, three major workshops on the application of molecular markers to potato breeding were held in Uruguay, the Philippines, and Kenya in 1993-1994. In addition, several regional planning sessions were held so that project participants could work together on the application of molecular markers. Individualized training was conducted, principally at CIP and Cornell University, for the use of RFLP- and PCR-generated markers in potato breeding. These activities also permitted exchanges of scientists among participating institutions.

Sweetpotato Collection and Characterization

Wild *Ipomoea* collection

CIP maintains 1,204 wild *Ipomoea* accessions as seeds, comprising 11 species of section Batatas, 51 species of other sections, and weed types of *I. batatas* (Figure 9).

Because the number of seeds from wild *Ipomoea* species obtained during collecting expeditions is generally low, seed increase is a high-priority activity. In 1993, we obtained open-pollinated seeds from 238 accessions of 11 species of section Batatas and six accessions of other sections. We also obtained a total of 7,157 seeds by intercrossing accessions of *I. x leucantha* (lca), *I. tiliacea* (tlc), *I. trifida* (trf), and *I. triloba* (trl). In 1994, we produced more than 32,000 seeds by controlled pollinations of 172 accessions comprising 18 wild *Ipomoea* species.

We made taxonomic identifications of 136 wild *Ipomoea* accessions in collaboration with Florida Atlantic University (USA). Within this batch, a relatively high frequency of tetraploid *I. batatas* among wild materials collected in Ecuador and Colombia was identified.

Sweetpotato collection

We added 498 new accessions to the sweetpotato collection maintained at CIP. Of these, 24 were donations from Peruvian institutions, 47 came from collecting expeditions in Peru, and 427 were sent from the Asian Vegetable Research and Development Center (AVRDC) in Taiwan.

The cultivated collection now contains 5,318 accessions that are clonally maintained, including 3,985 native and advanced cultivars from 43 countries and 1,333 breeding lines (Figure 9).

Since 1993, we have decreased the number of Peruvian sweetpotato cultivars maintained in the field at La Molina from 1,458 to 1,068 having verified the duplicate status of all morphologically identical accessions by electrophoretic comparisons of total proteins and esterases. As a standard procedure, we also obtain seeds before eliminating clonal materials.

Of 978 accessions from 10 countries in Latin America and the Caribbean maintained in the quarantine screenhouse at La Molina, 131 accessions have been grouped as potential duplicates.

In-country characterization of sweetpotato collections

In Argentina, of 320 accessions gathered during INTA-CIP collecting expeditions, the field genebank maintained at the Estación Experimental El Colorado, Formosa, contained 262 accessions in 1993. Some losses occurred in 1994 because of unfavorable climatic conditions. The remaining 177 accessions were sorted into 37 duplicate groups. Electrophoretic comparisons of proteins and esterases made on 48 accessions showed that they comprised only seven different cultivars.

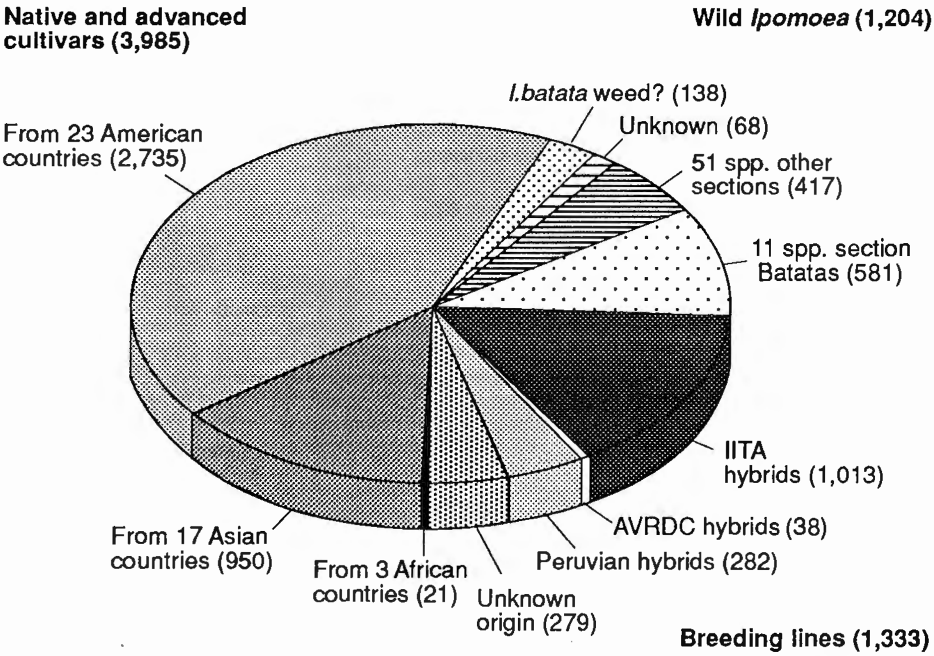

Figure 9. Number of accessions of *Ipomoea* germplasm maintained in the genebank at CIP (total = 6,522).

We concluded morphological characterization of the sweetpotato collection in Paraguay in 1994. The collection contains 71 accessions representing 44 potentially different cultivars. Accessions with good potential for drought tolerance, with yields ranging from 20 to 26 t/ha after 150 days, were identified. Two accessions considered duplicates (Yeti Manduvi DLP 4232 and Moroti PRY 18) had the highest yields. Most accessions showed *Euscepes* weevil damage, but cultivar Anda I (DLP 5229) showed no insect damage.

In Brazil, 460 sweetpotato accessions maintained in the field at EMBRAPA's Centro Nacional de Pesquisa de Hortaliças (CNPH) near Brasília were characterized; 271 were found to comprise 68 potentially different cultivars.

In Mexico, of 259 accessions maintained by the Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) in the Campo Experimental Cotaxtla near Veracruz in 1993, 89 accessions collected on farms located near Huimanguillo, Tabasco, were identified as duplicates of one cultivar. In 1994, 124 other accessions were found to comprise 31 different cultivars. We recorded storage-root yield data for the entire Mexican collection and selected some accessions that combined high yield, very low *Cylas* damage, and good storage-root characteristics.

In Honduras, two CIP-Centro Universitario Regional del Litoral Atlántico (CURLA) collecting expeditions in 1990 and 1991 gathered 311 accessions of *I. batatas*. In 1994, CURLA maintained only 168 accessions, and none is duplicated at CIP. A first attempt to identify duplicates in this collection showed that 87 accessions could represent 35 different cultivars.

The morphologically identical groups found in the sweetpotato collections of Argentina, Paraguay, Brazil, and Mexico need to be verified by electrophoretic analyses of proteins and esterases from storage roots or by DNA fingerprinting.

Indigenous knowledge on sweetpotato in Irian Jaya

The diversity of the natural environment and long history of human settlement in Irian Jaya (Indonesia) fostered a wide range of agricultural systems and practices. Although sweetpotato is the most important staple overall, its relative importance varies. Most sweetpotato grows at higher altitudes (up to 2,800 m), where population densities are also relatively high. More than 90% of sweetpotato is produced in the two mountain divisions of Paniai and Jayawijaya, where less than half of the population lives.

Germplasm collection carried out in 1993 in the Jayawijaya division showed the richness of both local sweetpotato germplasm and the cultural knowledge related to it. Within a somewhat restricted area, 224 sweetpotato accessions were collected. The number of cultivars per location varied between 15 and 43, with an average of 30.

The major cause of the rapid adoption and spread of sweetpotato appears to be its higher tolerance of drought and low temperatures than that of other staples such as taro. In addition, sweetpotato is more productive than other crops and can be used as pig feed. Sweetpotato enabled highland societies to shift their subsistence base from hunting to horticulture, and to raise more pigs, which can be used to barter for other goods.

Cultivar names often refer to distinct properties, such as morphological similarities to other plants and animals, the color of milk or blood, and adjectives of size, or to people who brought the cultivars to a village. Sweetpotato is locally called ipere, sipuru, or mbi, depending on the area.

Women know more than men about the characteristics of sweetpotato cultivars (Figure 10). They recognize clones adapted for cultivation in valley bottoms or on slopes, early- and late-maturing ones (from 90 to 240 days), and others that require special cultural practices such as staking because of their long vines that could cover other cultivars and cause rotting. Sweetpotatoes are also differentiated by their palatability and suitability of the leaves as a vegetable. For baby food, consumers prefer soft and sweet cultivars with a colored flesh. Cultivars fed to pigs are large and fibrous. Humans eat these cultivars only during food shortages.

In vitro conservation of the cultivated collection

The in vitro sweetpotato collection contains 4,671 accessions. The number of pathogen-tested clones has increased to 403 accessions, and 247 more clones are in the process of pathogen cleanup.

Some sweetpotato cultures that we received from other laboratories were contaminated with a Gram-positive cocobacillus and a Gram-negative bacillus. A thesis research project is looking into their control with antibiotics.

Another problem found in some donated accessions was lack of root development in meristems when they were transferred to the media used at CIP. Research showed that all genotypes had different root development under different culture media.

We also began research to develop a protocol for the storage of sweetpotato in in vitro cultures for at least two years without subcultures. A culture medium consisting of 20 g of mannitol and 20 g of sorbitol and storage temperature of 22°C showed much promise. Cultures remained in good condition for up to 16 months.

CIP sent a complete duplicate set of the in vitro sweetpotato collection to the Instituto Internacional de Estudios Avanzados (IDEA) in Venezuela for safekeeping.

Evaluation and utilization of sweetpotato genetic resources

Screening of 975 accessions in the collection maintained at CIP showed five accessions resistant to the weevil *Euscepes postfasciatus*, 65 resistant to the nematode *Meloidogyne incognita*, and 42 resistant to the fungus *Plenodomus destruens*.

We evaluated vegetative period for the production of commercial-sized storage roots in 1,718 accessions of native cultivars, hybrids, and advanced cultivars. We found 217 accessions to be potentially early (harvest at 90 days from planting), and will reevaluate these results. We measured dry matter content for 182 additional accessions and, of 416 accessions evaluated for reaction to the fungus *Diplodia gossypina*, 23 showed resistance. Similarly, of 118 accessions from the pathogen-tested list, we found 23 to be drought tolerant. Four Peruvian accessions with good potential for use as forage were identified.

Collaborative research on the sweetpotato collection in China identified clones Xu43-14 and Lushu2 as cold tolerant. They yielded 24 and 22.5 t/ha, respectively, at Wumeng

J. SCHNEIDER

Figure 10. Irian Jayan women help with a sweetpotato harvest.

Institute in Inner Mongolia. We obtained similar results at the Bao Steel Plant farm of Baotou City in Shanxi Province. Two other clones, Beijing 553 and Zhaoyuan 15, were planted at the Inner Mongolia Academy of Agricultural Sciences to determine the effect of mulching on yield under cold conditions. Beijing 553 yielded 7.9 t/ha and Zhaoyuan 15 yielded 12 t/ha of fresh roots without mulching. With mulching, Beijing 553 increased its yield by 100% and Zhaoyuan 15 by 75%. Further yield trials were conducted at the Hohhot Municipal Extension Center for Agricultural Technology with Xu43-14, Lushu2, Taishu2, Satsumahikari, and Lizixiang. Yields were 45.9, 36.6, 27.0, 17.7, and 22.9 t/ha, respectively, in replicated trials.

In Bangladesh, we selected clones SP-277, SP-281, SP-320, and SP-503 for tolerance of salinity out of 378 accessions maintained in the national collection. We selected eight other accessions with more than 35% dry matter at 130 days. Of 102 early-maturing accessions, SP-284 had the highest yield—11.24 t/ha at 90 days from planting. From 3,200 seedlings from crosses between SP-092 and standard cultivars Kamalasundri and Daulatpuri, we selected 55 clones. The two most promising clones were identified as D-44 and D-53, with yields of about 35 t/ha. D-53 has a vitamin C content of about 14 mg/100 g. The National Seed Board of Bangladesh has approved both clones for release as commercial cultivars under the names BARI-Sweetpotato-4 and BARI-Sweetpotato-5.

Distribution of sweetpotato genetic resources

CIP distributed genetic materials by sending true seeds from 34 accessions of wild *Ipomoea* species to four countries. CIP also sent 638 accessions of pathogen-tested cultivated materials to 27 countries in 1993, and sent 937 accessions to 31 countries in 1994.

Training

CIP provided on-the-job training on duplicate identification and germplasm management to sweetpotato curators of the Instituto de Investigación Agropecuaria de Panamá (IDIAP) and CIP-Bogor (Indonesia). A scientist from INTA-Bellavista, Corrientes, Argentina, received training on electrophoretic comparisons of total proteins and esterases from storage-root extracts.

CIP-INIFAP organized a training course on characterization and duplicate identification of sweetpotato collections in 1994 at Campo Cotaxtla, Veracruz, Mexico (Figure 11). Eleven participants came from Mexico, Honduras, Guatemala, Nicaragua, Cuba, and Venezuela.

In Irian Jaya (Indonesia), training has consisted primarily of participation by NARS scientists in all phases of collection trips. Researchers discussed questionnaires, collected data in the field, and collaborated in writing a report.

Sweetpotato Germplasm and Molecular Techniques

Germplasm enhancement and population improvement using cultivated species and wild relatives, and the application of molecular techniques to sweetpotato breeding, are important components of CIP's global sweetpotato improvement program. Other CIP research programs do complementary work. The goal is to establish a core collection of sweetpotato with wide genetic diversity, using conventional and nonconventional techniques to improve varieties, especially for insect and disease resistance and nutritional quality.

Figure 11. Participants at the training course on maintenance and characterization of sweetpotato collections held in Veracruz, Mexico.

Germplasm enhancement and population improvement of cultivated sweetpotato species

Materials generated by germplasm enhancement activities are a major source of improved genetic materials for international distribution and testing, both as seed and as clones. Breeding activities focus on improvement of storage-root yield, earliness, and DM content of sweetpotato for the principal global agroecologies. To address differences among sweetpotato-producing regions in important diseases, pests, and other production constraints, our program is decentralized; breeding activities are conducted in Peru, Indonesia, China, and East Africa. At each location, we cross important local varieties and introduced elite clones using either hand pollinations or polycross nurseries. We use seed from these crossing blocks in regional breeding programs, and distribute it to other breeding programs—regionally and globally.

At CIP headquarters in Peru, we conducted work under two subprojects. The first concentrated on irrigated sites in the arid coastal zone and a mid-elevation humid tropical site at San Ramón (866 m) in the Amazon basin. We used progeny tests to identify superior progenitors for inclusion in crossing blocks to produce seed for local selection and international distribution. We selected superior clones with high storage-root yields and DM content, and with a range of skin and flesh colors. The second subproject, conducted at Yurimaguas, a hot, moist, lowland tropical site (151 m) in the Amazon basin with acid, infertile soils, made good progress in selecting clones with adaptation to that environment. Most Peruvian germplasm, however, was not well adapted to the hot, humid environment (Table 3). Almost all genotypes selected at Yurimaguas came from foreign germplasm, providing little justification for continuation of the work there, because it is not an important sweetpotato production area. The subproject was terminated, and selection for hot, humid environments continued in Indonesia.

Table 3. Selection frequencies for Peruvian and foreign sweetpotato clones evaluated in the lowland humid tropics at Yurimaguas, Peru, in 1993. The trial was an unreplicated observational trial repeated during the rainy and dry seasons, on alluvial and acid upland soils.

Source of germplasm	Number of clones	Soil conditions		
		Alluvial		Upland
		87 DAP[a]	117 DAP	121 DAP
			(%)	
Peruvian clones	492	0.2	0.2	0.2
Foreign clones	146	17.0	13.3	4.2
Foreign seed	73	17.6	14.1	7.1

a. DAP = days after planting.

In Bogor, Indonesia, CIP breeders Il Gin Mok and Nina Lisna Ningsih, in collaboration with M. Djazuli of the Bogor Research Institute for Food Crops (BORIF), focused on the improvement of sweetpotato adapted to lowland humid tropics, an important production environment in Southeast Asia. This subproject emphasized the selection of high-yielding genotypes with high DM content in a background of resistance to major constraints such as scab caused by *Sphaceloma batatas*, sweetpotato weevil (*Cylas formicarius*), and acid, infertile soils. In 1994, this subproject produced and exported 31,200 seeds to breeding programs, mainly within the lowland humid tropics of Asia, but also in China and Africa. In China, a subproject led by Dai Qiwei at the Nanjing Academy of Agricultural Sciences, with collaborators at the Guangdong AAS, hybridized elite Chinese varieties with foreign clones to produce populations for use by Chinese and foreign breeding programs. During 1993 and 1994, this subproject produced 18,503 seeds for export.

A subproject led by CIP breeders Edward Carey and Simon Gichuki, in collaboration with national program scientists Robert Mwanga of NARO in Uganda, Phillip Ndolo and J.W. Kamau of KARI in Kenya, and Regina Kapinga of the RTIP in Tanzania, focused on improving sweetpotato for the major production systems and agroecologies of eastern Africa. Work has involved strengthening of the hybridization program at the Namulonge Agricultural and Animal Production Research Institute (AARI) in Uganda and progeny-testing at sites in important sweetpotato production zones (mainly semiarid and highland agroecologies) in Kenya, Uganda, and Tanzania. Resistance to sweetpotato virus disease complex (SPVDC) is an important focus of this program because local varieties have high levels of resistance, whereas most introduced germplasm is highly susceptible.

The subproject benefited greatly from a contribution of 168,000 seeds made by Rwandan sweetpotato breeder, Georges Ndamage, who was killed during the 1994 strife in that country. The seed was mainly used by selection programs within eastern and southern Africa, but was also distributed to programs in Asia and Latin America, including CIP headquarters.

Use of wild species

The wild relatives of sweetpotato are a potentially valuable source of traits that are not readily available in the primary gene pool of the cultivated species. The collection of wild relatives maintained by CIP represents a large stock of newly collected materials to be evaluated. But the evaluation and use of wild species for sweetpotato improvement presents serious challenges to sweetpotato breeders. This is because most of the wild relatives do not cross readily with the cultivated species, and because most wild relatives do not produce storage roots, which means that they cannot be evaluated for storage-root characteristics.

Work in this project, conducted by CIP researchers, has focused on developing 4x tester genotypes (hybrids between 6x sweetpotato and 2x *I. trifida*), which produce storage roots and might cross relatively easily with wild relatives of sweetpotato. Progenies from these crosses are then evaluated for storage-root characteristics, and might also serve as bridges for introgression of selected traits into the cultivated species.

We continued to develop 4x tester clones and use them to evaluate wild relatives of sweetpotato. In 1993 and 1994, we reconfirmed previous findings (see *CIP in 1992, Program Report*) that hybrid seed was extremely difficult to produce from crosses between 2x wild species (except for *I. trifida)* and 4x tester clones. Crosses made using the 2x species as females produced significant quantities of seed, but all plants were 2x and resembled their female parents, indicating that they were probably the result of apomixis or self-pollination. The reciprocal crosses produced virtually no seed. Field assessments of the reaction of populations of 4x tester clones to weevil (*Euscepes postfasciatus*) revealed greater susceptibility of both vines and storage roots to weevils in the population of 4x tester clones than in the varieties used as parents to produce the 4x tester populations.

Given the difficulties we have encountered in developing and using 4x storage-root-inducing testers to evaluate and use wild relatives of sweetpotato in breeding, we will change our strategy to focus on screening wild species for traits that can be assessed directly through screening of foliage. These include reaction to important diseases, such as viruses, and pests, such as weevils. Our efforts will now focus on first evaluating *I. trifida* germplasm accessions, followed by introgression of promising traits identified into sweetpotato.

Application of molecular techniques for sweetpotato improvement

In this area, we have continued to work on using transformation to genetically engineer sweetpotato to improve characteristics such as weevil resistance. We also began work and made good progress in developing RAPD techniques for use in sweetpotato breeding and germplasm management.

Our research on sweetpotato genetic engineering continues to concentrate on developing reliable and efficient transformation protocols. At CIP headquarters, researchers evaluated the influence of explant sources and different media on the regeneration of 10 globally important sweetpotato varieties targeted for improvement by genetic engineering. They also improved a gene construct for use in engineering weevil resistance. They did this by fusing the promoter of the sweetpotato ß-amylase gene with the Kunitz chymotrypsin inhibitor gene (WCI-3) from winged bean (*Psophocarpus tetragonolobus*). This gene was cloned in the plasmid pBIKH3 for *Agrobacterium tumefaciens*-mediated transformation of sweetpotato.

Molecular techniques such as the use of RAPDs can be a powerful tool for sweetpotato breeding and germplasm management. Work conducted by Dapeng Zhang at North Carolina State University detected significant RAPD polymorphism in sweetpotato and three related species, *I. trifida*, *I. triloba*, and *I. x leucantha*. Genetic distances calculated from this work allowed a clear discrimination of species and genotypes. Duplicate accessions analyzed were also accurately identified. We conducted additional work using the RAPD technique at CIP headquarters, where we reduced the cost of the procedure considerably by using locally produced reagents. We are now using this technique to identify genotypes, and will use it to assist with breeding through the assessment of genetic diversity in germplasm, and through marker-assisted selection.

Collection and Characterization of Andean Root and Tuber Crops

Systematic work on efficient collection, conservation, and use of the biodiversity of Andean root and tuber crops (ARTC) is under way in cooperation with many Andean NARS and NGOs to protect these resources from genetic erosion. This work will help develop the Andean ecoregion.

Germplasm acquisition Several limited germplasm collecting expeditions were undertaken with graduate students of the Universidad Nacional Agraria and scientists from the universities of Ayacucho, Tacna, and Cerro de Pasco in different parts of Peru. These missions collected 76 ARTC accessions: 19 oca, 19 arracacha, 15 mashua, 9 ulluco, 7 achira, 6 maca, and 1 yacón; and 62 of their possible wild allies—39 oca, 15 ulluco, 3 mashua, 2 yacón, 1 arracacha, 1 maca, and 1 mauka.

Three NGOs working in three different departments of the northern, central, and southern Andes of Peru helped increase the ARTC collection maintained by CIP through important donations. CIP received 42 oca, 18 ulluco, and 8 mashua accessions from the NGO Jorge Basadre in Cajamarca. The NGO Centro de Investigaciones de Recursos Naturales y Medio Ambiente (CIRNMA) in Puno donated 21 oca, 10 ulluco, and 8 mashua accessions. The NGO Proyecto de Desarrollo Rural Integral (PRODE-KON) in Ancash donated 12 oca and 8 ulluco accessions.

Three Peruvian universities entrusted CIP with important collections of ulluco, oca, and mashua. As a result, 113 accessions of these Andean tubers (53 ulluco, 52 oca, and 8 mashua) came from the University of Ayacucho, through the University of San Marcos, where these valuable genetic resources have been maintained under in vitro conditions since 1985. The University of Cerro de Pasco also gave CIP custody of 90 accessions: 38 ulluco, 34 oca, and 18 mashua. Some 13 accessions of ulluco and 22 of oca arrived from the University of Cajamarca.

In collaboration with Austral University and the University of Arica in Chile, a collecting expedition for ARTC germplasm was undertaken in that country's northern Andes, which resulted in the collection of 21 accessions. These ARTC are becoming extinct because of the introduction of cash crops, rural migration, and lack of alternatives for their use.

Collaborative collecting trips undertaken with INIAP, Ecuador, to several parts of that country gathered eight accessions of achira and 15 of wild arracacha. An exploratory trip to Cundinamarca, Colombia, undertaken jointly with CORPOICA, resulted in the collection of four achira accessions. Based on the exploratory expeditions in Ecuador and Colombia, we believe that achira has a considerable variation in its starch content and ecological adaptation that we should tap for plant improvement.

Conservation

Maca and ahipa are the only ARTC that are conserved exclusively in the form of seed. CIP maintains field collections of the other seven species of ARTC. As of December 1994, CIP maintained a total of 1,221 accessions (1,131 cultivated ARTC and 90 wild allies) (Table 4). In addition, we are using in vitro cultures of ulluco, oca, mashua, and yacón to safeguard the germplasm of these species (Figure 12).

Although CIP is developing long-term in vitro conservation techniques in a coordinated effort with INIAP (Ecuador) and INIA and the universities of San Marcos and Ayacucho (Peru), in vitro introduction and propagation of these four species are routinely done at CIP. We obtained the best results for in vitro introduction of ulluco, oca, and mashua by using a Murashige & Skoog (MS) medium with calcium pantothenate (2 ppm), gibberellic acid (0.5 ppm), sucrose (2%), and agar (0.8%). Oca also uses activated charcoal (1%). Yacón, on the other hand, uses an MS medium with calcium pantothenate (2 ppm), gibberellic acid (10 ppm), sucrose (2%), putrescine (20 ppm), and phytagel (0.35%).

In vitro propagation of ulluco, oca, mashua, and yacón uses similar media. Ulluco uses an MS with calcium pantothenate (2%), sucrose (2%), and agar (0.8%). Gibberellic acid is added to this medium for the propagation of oca (0.5 ppm) and mashua (0.25 ppm). Yacón media have to be complemented with gibberellic acid (0.5 ppm), naphthalene acetic acid (0.05 ppm), and sucrose (3%).

For vegetative propagation of ulluco and oca under greenhouse conditions, we found that ulluco was easily propagated through young apical cuttings, 6 cm long, rooted in tap water. Rooting usually took place after 4-6 days in the cold season

Table 4. Accessions of Andean root and tuber crops and their wild allies maintained by CIP (December 1994).

Species	Common name	Country[a]							Total
		COL	ECU	PER	BOL	ARG	CHL	BRA	
Oxalis tuberosa	Oca	—	—	336	80	41	7	—	464
Ullucus tuberosus	Ulluco	4	2	320	72	39	—	—	437
Tropaeolum tuberosum	Mashua	—	—	72	4	—	—	—	76
Arracacia xanthorrhiza	Arracacha	1	—	27	—	—	—	20	48
Canna edulis	Achira	3	4	20	1	—	7	—	35
Polymnia sonchifolia	Yacón	—	2	26	4	1	—	—	33
Lepidium meyenii	Maca	—	—	33	—	—	—	—	33
Mirabilis expansa	Mauka	—	—	3	—	—	—	—	3
Pachyrhizus ahipa	Ahipa	—	—	—	2	—	—	—	2
Wild allies of ARTC		—	4	84	2	—	—	—	90
Total		8	12	921	165	81	14	20	1,221

a. COL = Colombia, ECU = Ecuador, PER = Peru, ARG = Argentina, CHL = Chile, BRA = Brazil.

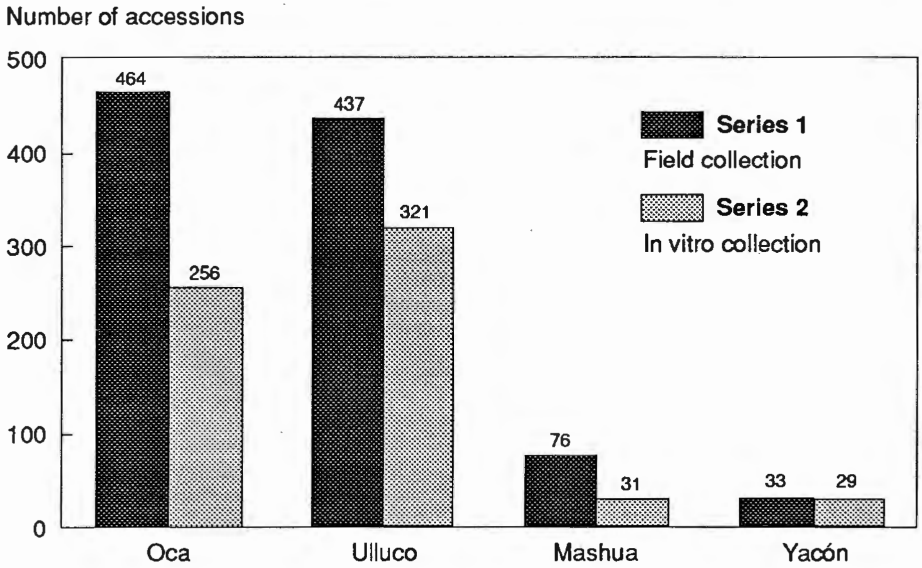

Figure 12. Status of oca, ulluco, mashua, and yacón germplasm maintained at CIP (December 1994).

(14-20°C) at La Molina, Peru. We also found oca to be easily propagated through young apical or axillary cuttings, 12 cm long, rooted in moss. Rooting of oca took place after 5-7 days in the cold season (13-18°C) at La Molina. We did not need a hormone solution for successful rooting in either ulluco or oca.

Characterization

We conducted morphological characterization and preliminary evaluation of 170 accessions of oca, 120 of ulluco, and 35 of mashua from Peru at CIP's Huancayo experiment station. So far, one important finding for this trio of Andean tubers in Huancayo was the identification of 110 morphotypes of oca, 74 of ulluco, and 30 of mashua, out of the 325 accessions mentioned.

In collaborative work between the University of Ayacucho and CIP, 20 Peruvian accessions of cultivated achira were morphologically characterized and evaluated agronomically under on-farm conditions in the rural community of San Sebastián de Sacraca in the region of Pauza, Ayacucho. Achira is a staple in several villages of Pauza in southern Ayacucho. Achira used to play a major role in bartering with other staples in rural markets. Achira starch is now used in bakery goods for special occasions in the villages of Pauza. Achira starch has also become an excellent income generator in places where the starch fetches relatively high prices (US$3-5/kg).

A collaborative effort between the Universidad Nacional Agraria La Molina and CIP characterized 25 Peruvian accessions of cultivated achira morphologically. So far, 13 achira morphotypes appear to have emerged from the 25 tested in Ayacucho and La Molina.

Studies on the reproductive biology of oca indicated that flowering time ranges from 5 to 9 weeks (average–37 days), anthesis within one inflorescence takes place during 5 days, and 5-6 weeks are required after the opening of a flower to obtain mature seeds. Counts of pollen grains contained in one anther revealed that the average number of grains in an upper-level anther was 614, a mid-level anther contained 911, and a low-level anther had 1,244. Although viability of oca pollen depends on the genotype, it is usually high (more than 90% of grains stainable with acetocarmine). The pollen appears to be binucleate and is storable at room temperature for at least 2 weeks. Our next step will be to produce a large amount of true oca seeds for breeding purposes, and for improving conservation strategies for the crop.

In cooperation with INIAP, we characterized the collection of Ecuadorian arracacha morphologically and electrophoretically. Whereas morphological characterization discriminated 13 morphotypes, electrophoretic characterization recognized 22 out of 120 accessions. Therefore, the degree of duplication would surpass 80% in this collection. For isozyme electrophoresis in arracacha, the histidine-citrate buffers gave the best results with PGM, PGI, MDH, esterases (EST), and acid phosphatase (ACP). Polymorphism, however, was observed in only EST and ACP (in Ecuadorian and Peruvian materials).

We determined the main biochemical features of oca tubers, such as degrees Brix (°Brix, to measure the concentration of sugar solutions), pH, DM content, starch, and mean weight, in 258 accessions from Ecuador, Peru, Bolivia, Argentina, and Chile. Variation coefficients of the observed characters were highly variable, particularly for dry matter (24%) and starch content (47%). °Brix varied between 3 and 13.4, with an average of 6.9. We found that tuber acidity, which is almost certainly linked to oxalate content, varied from 4.7 to 7.2 (average–6.3). Starch content averaged only 6.9% in oca tubers, although some accessions had more than 15%.

For cytogenetic characterization, we determined the chromosome number of 149 accessions of cultivated ulluco and 17 of wild ones from Peru, Bolivia, and Ecuador. Of the cultivated ulluco, 144 were found to be diploids ($2n=2x=24$), four triploids ($2n=3x=36$), and one tetraploid ($2n=4x=48$), whereas all the wild ulluco were found to be triploids. The finding of diploid cultivated ulluco and triploid wild ulluco confirmed earlier results of Finnish workers. Our work also confirms the results of Cárdenas and Hawkes, reported 47 years ago, on one sample of cultivated triploid ulluco found near Copacabana, Bolivia, and another one near Bogotá, Colombia. This is the first time, however, that cultivated triploid ulluco has been reported for Peru. The discovery of a tetraploid ulluco in Peru is important; this will throw more light on the evolution of ulluco in the Andes. Furthermore, the ulluco choromosome number was found to be highly correlated with the number of chloroplasts in the guard cells, as diploid ulluco showed 16 ± 1 chloroplasts, and the triploid ones 20 ± 1. This suggests that chloroplast number has a predictive value for ploidy determination in ulluco.

We also determined the chromosome number of 100 accessions of cultivated oca (*Oxalis tuberosa*) and 15 wild accessions of *Oxalis* spp. from Peru. We found all the cultivated oca to be octoploids ($2n=8x=64$), whereas the wild *Oxalis* were diploids ($2n=2x=16$). Therefore, the cultivated oca and wild *Oxalis* share the same basic chromosome number–x=8, not x=11 as suggested by Gibbs and coworkers in 1978. Furthermore, our results confirm the findings of de Azkue and Martínez in 1990 on the ploidy levels of *O. tuberosa* (2n=8x=64).

We also determined the chromosome number of 10 accessions of edible achira (*Canna edulis*) from Peru, and found them to be diploids (2n=2x=18). But eight cultivars of ornamental *Canna* collected in the Andes were triploid (2n=3x=27). These results confirm earlier findings by Darlington and Janaki (1945) and Murherjee and Khoshoo (1971).

Colleagues at the germplasm banks of INIAP (Ecuador), INIA (Peru), and the universities of Cajamarca, Huancayo, Cerro de Pasco, Ayacucho, and Cusco in Peru are testing descriptor lists for ulluco, oca, and mashua. Descriptor lists for achira are being tested in the germplasm banks of INIAP (Ecuador) and the universities of Ayacucho, Cusco, and La Agraria in Peru.

The challenge of using ARTC germplasm

Achira in Vietnam. A survey of *Canna* use in Vietnam indicated that: (1) achira cultivation is important in the mountains of northern Vietnam bordering Laos, where 20,000-30,000 ha are grown; (2) the entire production is used to make transparent noodles in the villages of the Red River Delta around Hanoi; (3) only achira starch possesses as yet unidentified physicochemical properties that give noodles sufficient tensile strength and cooking characteristics of critical importance to Asian consumers; (4) two to four achira genotypes are currently grown; and (5) materials with a higher starch content and less root pulling resistance are needed. Therefore, efforts are under way to improve the use of *Canna* in Vietnam by broadening the crop's genetic base.

Arracacha in Brazil. CIP surveyed the status of arracacha cultivation in Brazil in collaboration with the University of Viçosa, CNPH-EMBRAPA, and the Instituto Agronômico de Campinas. Results were significant. The total cultivated area of arracacha in Brazil is estimated to be about 9,000 ha, of which 3,500 ha are grown in the state of Minas Gerais, 2,800 ha in Paraná, and 850 ha in Santa Catalina. We found minor areas of arracacha cropping in São Paulo, Espírito Santo, Rio Grande do Sul, and Rio de Janeiro. In recent years, arracacha has also spread into the Distrito Federal, Goiás, and Tocantins. Arracacha's popularity is increasing among smallholders because its aromatic storage roots fetch excellent prices (around US$1/kg under farm conditions). Arracacha also employs domestic labor, and the crop fits into rotational potato systems. Arracacha uses the residual nutrients of the potato crop. Productivity ranges from 8 to 23 t/ha. The crop has a narrow genetic base; probably only one genotype has been used traditionally. This survey provided criteria for the selection of CNPH-EMBRAPA elite clones that are superior to traditional Brazilian clones in terms of their short cropping cycle, yield, and pigmentation. Consequently, 35 clones were distributed to the Instituto Agronômico do Paraná (IAPAR), Empresa de Assistência Técnica e Extensão Rural, Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG), the NGO ANGELONI (Anitápolis and Santa Catarina), and to Brazilian farmers.

NARS-CIP collaborative project on conservation of ARTC

In situ conservation. For cultivated plants, we could define this as the continuous management and use of crop genetic resources in farming systems. In traditional farming systems, farmers are usually breeders and conservationists, because they test, select, and maintain landraces in their field plots according to their needs. So we should make use of farmers' abilities and experience to help us maintain crop genetic resources with limited investment, and help their communities to optimize the use of these resources. Therefore, in situ management should complement ex situ conservation.

In cooperation with INIA, the universities of Cusco and Ayacucho, and the NGO CIRNMA, 12 microcenters of conservation for ARTC in Peru have been identified. In cooperation with the Instituto Boliviano de Tecnología Agropecuaria (IBTA), and the NGO Proyecto de Investigaciones Agrarias de la Provincia Bautista Saavedra (PIABS), another seven microcenters of conservation for these crops have been identified in Bolivia. Common staples such as ulluco and oca, as well as rare crops such as *Pachyrhizus* (Figure 13), are maintained and used in these microcenters. We are studying factors that contribute to the maintenance and use of ARTC biodiversity, and the main constraints, in these microcenters. The goal is to develop effective strategies for in situ conservation of ARTC biodiversity.

Ex situ conservation. Scientists from IBTA (Bolivia), INIAP (Ecuador), INIA and the universities of Cajamarca, Cerro de Pasco, San Marcos, Ayacucho, and Cusco in Peru, and CIP established working relations for the collection and conservation of ARTC germplasm in each Andean country. We also identified potential sites for collecting expeditions in each country. Guidelines for maintaining field and in vitro collections were improved and exchanged.

In addition to the acquisition of ARTC already mentioned, IBTA collected 796 accessions (477 mashua, 257 oca, 60 ulluco, and 2 wild *Oxalis*). The universities of Cerro de Pasco, Cusco, Cajamarca, and Ayacucho in Peru collected 274 oca, 177 ulluco, 98 mashua, 75 yacón, 68 achira, 40 mauka, and 3 maca accessions. INIAP (Ecuador) collected 24 accessions of arracacha and achira. Collections were made in areas where collecting expeditions had not been undertaken previously. This material is being maintained chiefly as field collections by the respective NARS. INIAP (Ecuador) and the universities of San Marcos and Ayacucho in Peru also maintain important in vitro ARTC collections.

Morphological characterization and preliminary evaluation of 816 oca, 294 ulluco, 230 mashua, 97 yacón, 62 achira,

C. ARBIZU

Figure 13. *Pachyrhizus* is a legume with edible roots, which are now eaten in crunchy and sweet snacks.

and 40 mauka accessions were made by the universities of Cusco and Cajamarca in Peru. IBTA (Bolivia) also did this on 76 oca, 15 ulluco, and 6 mashua accessions.

Utilization work supported the selection of new arracacha genotypes to back up the breeding program of CNPH-EMBRAPA (Brazil). CNPH sent 20 advanced genotypes of arracacha to INIAP in Ecuador and 12 to IAPAR and 113 to EPAMIG in Brazil under the umbrella of the ARTC collaborative program coordinated by CIP.

■

1993-94 Research Projects and Partners

This list contains titles of research projects, names of principal research partners and responsible CIP scientists, collaborating institutions, and, when applicable, countries where work is conducted.

Potato collection and characterization. Z. Huamán.

- Biosystematic studies and long-term conservation of wild potato genetic resources. Z. Huamán, C. Ochoa, A. Salas, P. Schmiediche.
- Maintenance, documentation, evaluation, and distribution of cultivated potato genetic resources. Z. Huamán.
- In vitro culture, conservation, cryopreservation, and genetic stability analysis after long-term storage of potato germplasm. A. Golmirzaie, F. Buitrón.
- Maintenance of a backup duplicate set of the in vitro potato collection in Ecuador. R. Castillo, G. García, Z. Huamán, F. Buitrón.
- Maintenance and evaluation of Chilean potato collection and use in genetic improvement of marginal and sustainable agriculture. P. Accatino, A. Contreras, Z. Huamán.

Potato germplasm enhancement and application of molecular technology. K. Watanabe.

- Potato germplasm enhancement with wide range of wild *Solanum* for disease and insect pest resistances. K. Watanabe, M. Orrillo.
- Application of molecular markers in potato germplasm improvement. M. Ghislain, K. Watanabe.
- Utilization of increased genetic variability in the potato breeding project. M. Huarte, E. Camadro, K. Watanabe.
- Genetic engineering for developing potato varieties resistant to diseases and pests. A. Golmirzaie, R. Salinas, A. Panta, J. Benavides, L. Ñopo.
- Use of genetic engineering methods to confer fungal disease resistance. A. Golmirzaie; C. Di Pace, R. Caccia (U. Tuscia).
- In vitro selection of potato mutant tolerant of abiotic stress. F. D'Ambrossio (U. Naples).
- Somatic embryogenesis in potato. A. Golmirzaie, G. Cipriani.
- Development and use of molecular maps for potato genetic improvement via introgression of various wild germplasm. K. Watanabe.
- Introduction of horizontal leaf resistance to late blight (*Phytophthora infestans*) from wild potato species. B. Trognitz.

- Production of potato plants resistant to *Erwinia* through genetic manipulation by *Agrobacterium.* P. Oliger, P. Accatino, A. Golmirzaie.
- Design and improvement of lytic peptide constructs for enhanced resistance of transgenic potatoes to bacterial and fungal diseases. A. Golmirzaie, M. Ghislain, L. Ñopo.

Sweetpotato collection and characterization. F. de la Puente, Z. Huamán.

- Collection of potato genetic resources and sweetpotato germplasm enhancement. F. de la Puente.
- Characterization of sweetpotato collections in Latin America and the Caribbean. Z. Huamán.
- Evaluation of sweetpotato germplasm collection contract. Song Bo Fu, S. Jialan.
- Maintenance, evaluation, documentation, and distribution of sweetpotato genetic resources. Z. Huamán.
- In vitro culture, conservation, cryopreservation, and genetic stability analysis after long-term storage of sweetpotato germplasm. A. Golmirzaie, R. Salinas.
- Maintenance of a backup duplicate set of the in vitro sweetpotato germplasm collection in Venezuela. N. Angulo, L. Villegas, A. Golmirzaie, R. Salinas.
- Collection, characterization, and maintenance of sweetpotato germplasm in different regions of Argentina. I.L. Gnoatto (INTA).
- Interdisciplinary collection of *I. batatas* germplasm and associated indigenous knowledge in Irian Jaya (Indonesia): An exploratory study. G. Prain, J. Schneider, Il Gin Mok.
- Collection, characterization, and evaluation of native sweetpotato germplasm in Bangladesh. T.R. Dayal, M.D. Upadhya, M.A. Mannan, N.M. Rashid, A. Quasem.
- Collecting *Ipomoea batatas* germplasm and associated indigenous knowledge in Irian Jaya (Indonesia), and its in situ and ex situ maintenance, characterization, and utilization. G. Prain, Z. Huamán.

Sweetpotato germplasm and molecular techniques. E. Carey.

- Ploidy manipulation for exploitation and enhancement of sweetpotato germplasm. G. Orjeda, E. Carey.
- Development of improved sweetpotato germplasm for warm and cool tropics of Southeast Asia. (GAAS) China. Song Bo Fu, F. Zu-Zia.
- Development of sweetpotato germplasm resistance to diseases and physiological stresses in Southeast Asia. Il Gin Mok.
- Genetic engineering methods for development of sweetpotato varieties resistant to diseases and pests. A. Golmirzaie, M. Ghislain, A. Panta.
- Application of molecular markers in sweetpotato germplasm improvement. M. Ghislain, K. Watanabe.
- Sweetpotato populations for highlands and semiarid tropics. E. Carey.
- Adaptation and utilization of sweetpotato populations in breeding. D. Zhang, H. Mendoza.
- Sweetpotato populations for hot, humid environments. E. Carey.

Andean root and tuber crop collection and characterization. M. Hermann.

- Germplasm exploration, conservation, and utilization of several underutilized Andean tuber crops. M. Hermann, C. Arbizu.
- Biodiversity of Andean roots and tubers: Conservation, evaluation, and

utilization. C. Arbizu, Z. Huamán, M. Holle.
- In vitro culture, conservation, cryopreservation, and distribution of Andean root and tuber crops. A. Golmirzaie, F. Buitrón.
- Study of ARTC diversity. M. Hermann.
- Arracacha germplasm utilization in Brazil. M. Hermann.

PROGRAM 3

Disease Management

Progress in Disease Management

CIP has distributed a new population (called "B") with durable horizontal resistance to potato late blight to 12 NARS. A previously developed population ("A"), which is difficult to work with because of the presence of R genes, has produced additional potato varieties and selections with resistance and high yield in the 25 countries where they are planted in more than 300,000 ha.

CIP shed further light on the variation of *Pseudomonas solanacearum* (which causes bacterial wilt), and this allowed us to formulate a precise strategy for developing resistance. The level of resistance has increased, but susceptibility to latent infection persists. We are making progress with combined resistance to wilt, root-knot nematode, and viruses. We have made promising selections in Brazil, China, Mauritius, and the Philippines.

The first potato variety with immunity to viruses X and Y from germplasm held at CIP was named Batoví in Uruguay. We have used triplex resistance to develop populations that, because they result in a 96% transmission of resistance to their progenies, have made screening unnecessary. Polish collaborators have achieved a combination of resistances to five viruses. Combining resistance to the early blight fungus (*Alternaria solani*) and resistance to three viruses has resulted from collaboration with Brazilian breeders.

Pathological studies on Andean root and tuber crops (ARTC)–maca, mashua, oca, and ulluco–have revealed 35 diseases of storage organs and foliage. An illustrated bulletin is being published.

A new mosaic-causing potato virus–"SB-26"–has been isolated from Arequipa in southern Peru; it is isometric, but not related to other known isometric potato viruses. We detected a similar virus in imported potatoes in quarantine. Saq'o disease in native Bolivian potatoes is graft transmissible, and no vector is apparent, so etiological studies continue.

Potato yellow vein, transmitted by whiteflies, is spreading rapidly in Colombia and Ecuador. Closterovirus-like particles have been observed.

Seven clones that have demonstrated high resistance to PLRV for three years and are agronomically good are available pathogen-tested.

We have compared several known and other partially characterized viruses of sweetpotato for aphid transmissibility using a monoclonal antibody. Among the viruses being identified, C-3 is closterovirus-like and C-4 a luteovirus. Because mixed virus infections have been shown to cause the more severe diseases of sweetpotato, we are seeking combined resistance.

CIP developed screening techniques for bacterial and fungal diseases of sweetpotato storage roots, and found resistance to Java black rot caused by *Diplodia gossypina*. We made progress on the etiology of sweetpotato chlorotic leaf distortion and studies on inheritance of resistance showed a potential for developing resistance. We studied sweetpotato foliar scab caused by *Elsinoe batatas* in Southeast Asia at several sites on numerous clones: preliminary results suggest that general resistance is available.

The detection of potato virus T (PVT) that infects true potato seed (TPS) has proven to be unreliable by serological means, whereas a probe used by radioactive labeling has proven to be quite effective. To simplify the detection of the only two disease agents transmitted by TPS—PVT and PSTVd—a chimeric clone combining their two probes was developed, and it was effective.

We showed the transmission of PSTVd by the aphid *Myzus persicae* when PLRV is also present; the mechanism appears to be the transencapsidation of PSTVd into PLRV.

We found a strain of APLV in 27% of ulluco accessions in Colombian, Ecuadorian, and Peruvian germplasm. Nearly all were infected with a virus. We found a strain of papaya mosaic virus in oca. Detection of ARTC viruses by DAS-ELISA was the most effective technique.

Control of Potato Late Blight

Late blight (LB) is the most severe disease of potato and the greatest limitation to potato production. It is caused by the fungus *Phytophthora infestans*, of which a more aggressive population is completing a worldwide migration begun in 1977. This migration includes the second sexual compatibility type, previously restricted to Mexico, that permits more rapid genetic recombination of this pathogen and its maintenance in soil as resting sexual oospores. CIP, in collaboration with institutions of both developing and developed countries, has assembled a unique genetic base of resistance and collective knowledge about integrated control. We have begun to make significant progress in controlling LB. So far, more than 80 cultivars with moderate resistance have become varieties in 25 developing countries, covering more than 300,000 ha.

A global Potato Late Blight Workshop to promote international cooperation to overcome the threat of the more aggressive late blight populations that are spreading worldwide was held February 20-23, 1994, in Toluca, Mexico. This workshop was sponsored by the International Cooperative Program for Potato Late Blight (PICTIPAPA), with support from the Danish and Irish governments, and Fondo Terra (created by the Mexican foundation PULSAR/INTEGER), under the auspices of the Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), CIP, and SEDAGRO (State of Mexico). As a result, the structure and priorities of PICTIPAPA were redefined and the organization revitalized.

Integrated control of potato late blight

The screening at Rionegro, Colombia, of the eleventh and last generation of late blight breeding population A (which contains both horizontal and race-specific resistance) has raised to about 300 the number of clones being distributed worldwide to NARS. So far, 21 varieties have been released in Latin America and the Caribbean (LAC) and sub-Saharan Africa (SSA), with the last two in Peru: Amarilis-INIA (CIP 384866.5) and K'Ori-INIA (CIP 377744.1).

To counter the worldwide migration of new aggressive strains of the LB fungus

P. infestans, CIP is distributing its newly developed population B, which, because it is non-race-specific, lends itself to rapid selection and development of varieties. More than 169,000 genotypes segregating for horizontal resistance to LB have been sent to 12 countries in three CIP regions: LAC–Argentina, Bolivia, Brazil, Colombia, Mexico, and Peru; SSA–Burundi, Kenya, and Uganda; and East and Southeast Asia and the Pacific–China, the Philippines, and South Korea.

To further develop population B, we tested duplicate sets of clones at both Toluca (Mexico) and Rionegro (Colombia). We also grew clonal generations in La Molina and Cajamarca, Peru.

We thus selected superior clones for crossing. We identified additional R-gene-free resistant clones by progeny tests and will add them to the breeding gene pool.

The use of population A materials in breeding work in the Philippines led to the development of both table and processing potatoes that required only three instead of 14 fungicide sprays to control LB and produce high yields (23 t/ha).

PROINPA staff in Bolivia received population A segregating materials (TPS) in 1989. These and their own subsequent progenies resulted in the selection of six superior cultivars by 1993, after testing in all important potato-producing regions of Bolivia (both at experiment stations and in farmers' fields). With only one or two fungicide applications, they yielded more than 50% higher than the commonly grown varieties. Further testing has led to the selection of two agronomically superior cultivars that are being multiplied for release as varieties.

Epidemiology of horizontal resistance

Methodological studies to evaluate resistance to LB in the field at CIP's Santa Catalina Experiment Station near Quito, Ecuador, demonstrated that the preliminary one-plant plots produced unreliable data, whereas one-row or three-row plots provided similar area under the disease progress curve (AUDPC) results in a four-cultivar study.

By using diploid *Solanum phureja* as a source of horizontal resistance, we recognized three components of resistance: infection frequency, latent period, and lesion size. Of these, latent period has not been considered important in previous studies with other *Solanum* species.

Because precision in the evaluation of disease severity is essential to epidemiological studies and resistance evaluation, we compared CIP's recommended logarithmic evaluation scale with percent infection, and found the latter to have superior precision.

In order to begin potato genotype by environment interaction studies to better understand the potential performance of resistance worldwide, we established a set of standard clones in collaboration with leading LB researchers in Europe, North America, and South America. These clones are being multiplied at selected locations for subsequent testing.

Selecting resistance to late blight

Collaborator Francisco Flores of INIFAP in Toluca, Mexico, selected 47 clones among 688 of population B planted as having good horizontal resistance. He screened 21 families of new crosses, and selected 112 among 1,920 for their resistance and agronomic quality.

In South China, the recently selected resistant clones CFK 69.1 and I-1085 were grown in a combined area of about 2,000 ha, and they will soon officially receive varietal names. Potato scientists from the major potato-producing provinces were trained in the use of population B progenitors, and breeding programs for horizontal resistance have begun.

CIP's regional breeder in Nairobi, Kenya, reported that clones with moderate horizontal resistance to late blight, good agronomic characters, and suitable postharvest quality have been selected in Ethiopia, Kenya, Tanzania, and Zimbabwe. At Tigoni, Kenya, clone CIP 387792.5 yielded 60.8 t/ha, 141% more than variety Kenya Dhamana, which is also LB (and bacterial wilt) resistant. At Uyole, Tanzania, CIP clone KP 90010.1 yielded 56.7 t/ha, 70% more than check variety Kikondo. These clones are entering seed schemes and should soon be released as varieties.

Clone 575049 was released in Venezuela as Caribay, a variety described as yielding 30-40 t/ha with only one fungicide application for LB control, instead of the 6 to 12 used for other varieties.

Integrated Control of Potato Bacterial Wilt

Bacterial wilt (BW) caused by *Pseudomonas solanacearum* is the most important bacterial disease in developing countries. Its integrated control requires resistance, disease-free seed production, and crop rotation accompanied by sanitation and other cultural controls according to location. By knowing the genetic variation of the bacterium, we can develop appropriate control strategies.

Variation of *P. solanacearum* The division of biovar (Bv) 2 of *P. solanacearum* into two variants, Bv 2-A/race 3 adapted to cool temperatures and the lowland Bv 2-T, was described in *CIP in 1992, Program Report.* Bv 2-T had been found in the Amazon basin within Peru. Among the accessions of CIP's worldwide collection of isolates of this bacterium, some Bv 2-T isolates originated in Brazil. We plotted on a map the frequency of presence of different biovars among 36 received from colleagues in Brazil (Figure 1). All Brazilian isolates were from elevations below 1,500 m, and all came from the southeast except for a tomato isolate of Bv 3 in Amazonas State. A similar isolate was from São Paulo State. The remaining 34 isolates were from the southeastern states. Bv 2-T isolates came from lands recently placed in potato cultivation and from two solanaceous weeds, in the warmer potato-growing states in or close to the "cerrado" brushland of eastern Brazil. Bv 1 (solanaceous race 1) also occurred in these warmer areas. Bv 2-A/race 3 was from only the cooler states farthest south. In Brazil, as in Peru, there is a relationship between temperature and distribution, with Bv 2-A occurring only in cooler lands. The Amazon basin and "cerrado" are thus regions of greater diversity for *P. solanacearum.*

Seven isolates from Brazil (3 Bv 1, 3 Bv 2-A, and 1 Bv 2-T) and one Bv 2-T from Nigeria were inoculated (using 1 x 10^8 cfu/ml of each bacterium) to amaranth (*Amaranthus edulis*), blue gum (*Eucalyptus globulus*), tomato (*Lycopersicon esculentum* cv. Marglobe), wild tobacco (*Nicotiana occidentalis*), and peasant's tobacco (*N. rustica*), and incubated at 26-32°C. Bv 1 infected amaranth, blue gum, and tomato; Bv 2-A infected only tomato; and only the Nigerian Bv 2-T was pathogenic to blue gum and peasant's tobacco (Table 1).

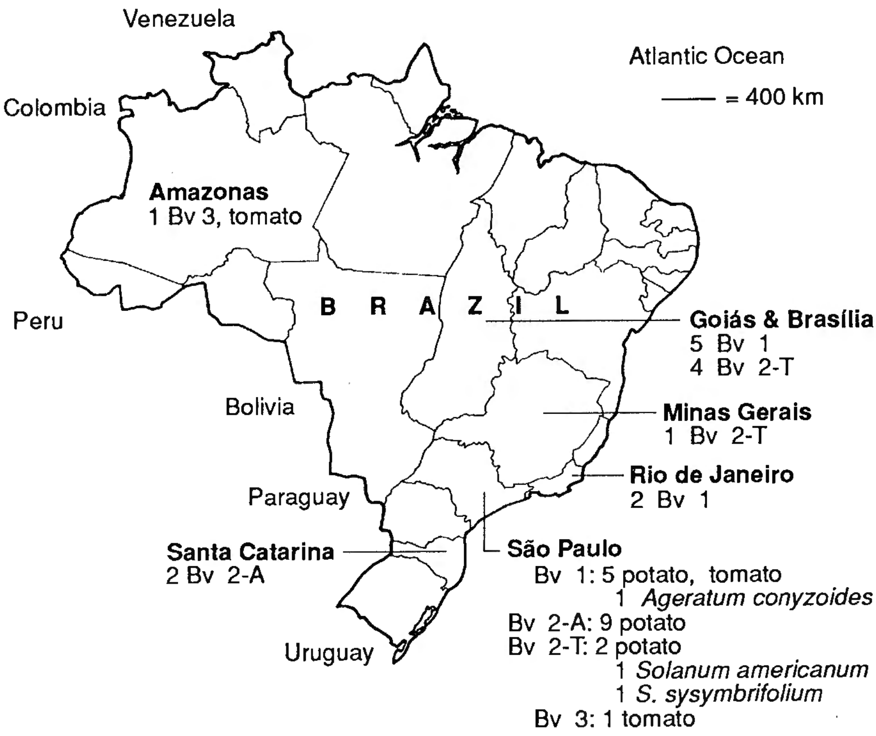

Figure 1. Geographical distribution of biovars 1, 2-A, and 2-T of *Pseudomonas solanacearum* from Brazil. When a host is not shown for Bv 2-A, it is potato.

Table 1. Average bacterial wilt incidence in different plant species grown at 26-32°C and inoculated with 1 x 108 cfu/ml of three strains of biovar (Bv) 1, three of Bv 2-A, and one of Bv 2-T from Brazil, and one strain of Bv 2-T from Nigeria.

Plant species	Bv 1	Bv 2-A	Bv 2-T
		(%)	
Amaranth (*A. edulis*)	12.5^a	0.0	0.0
Blue gum (*E. globulus*)	20.0	0.0	2.5^b
Tomato (*L. esculentum*)	7.5	25.0	0.0
Wild tobacco (*N. occidentalis*)	0.0	0.0	0.0
Peasant's tobacco (*N. rustica*)	0.0	0.0	2.5

a. Incidence as percentage wilt (average of 60 plants).

b. Of the two Bv 2-T isolates, only the Nigerian one was pathogenic to blue gum.

We tested cimarron tobacco (*N. glutinosa*), native to South America, as a potential new indicator. We inoculated it with 12 Bv 1, 8 Bv 2-A, and 9 Bv 2-T; it was susceptible to all 29 isolates. Therefore, this species may be a universal host.

Cultural practices for control of bacterial wilt

We investigated the use of crop rotation and incorporation of organic and inorganic soil amendments for the control of BW in each of two subsequent years to establish a high level of soil infestation (more than 90% wilting) in a field at CIP's San Ramón station. Treatments were:

- T1—Incorporation of coffee hulls (5 t/ha) and sugar cane bagasse (5 t/ha), with subsequent fallow, followed by rotation with sweetpotato and then maize.

- T2–Incorporation of coffee hulls and fallow, followed by rotation with maize during two seasons.
- T3–Incorporation of coffee hulls and dolomitic lime (2 t/ha), followed by rotation with beans and then sweetpotato.
- T4–Continuous potato. Each treatment was followed by a fourth-season potato test crop to record wilt incidence. The field design was an RCBD with three replications of 6.0 x 4.5 m.

Sixty days after planting the potato test crop, the continuous potato check had 88% wilt, whereas T3 had 15% wilt, T2 28%, and T1 30%; all three were significantly superior to the check, but without significant differences among them.

Breeding for resistance to bacterial wilt

To evaluate 39 progenies of crosses for resistance to BW (race 1) and viruses X and Y, we planted them at San Ramón; 56% had useful levels of resistance. The progenitors with a high percentage of resistant genotypes were BWH 87.452, BWH 87.289, and BWH 87.271. The best progenies were BWH 87.452 x XY.13, BWH 87.289 x XY.16, and BWH87.289 x XY.13, with 82%, 81%, and 80% resistant genotypes, respectively. Their tubers, however, had latent infection under these tropical conditions.

At San Juan (Cajamarca), we evaluated 362 clones previously selected as resistant to race 3 in Huaraz, and selected 25 (7%). BWL89.244, H29.62.8, and BWL89.193 had the highest yields, but their tubers had latent infection.

Fifteen selections made–using CIP segregating populations–by the Department of Agriculture of the Philippines for resistance to BW were tested in the greenhouse at La Molina with strains of races 1 and 3 by inoculating 40 stem cuttings for each combination. The most resistant to both races were 385313.4, 385080.9, and 381064.3.

At La Molina, we evaluated 44 progenies bred for resistance to BW, root-knot nematode (RKN), and viruses X and Y for resistance to PVX + PVY under greenhouse conditions. Resistant seedlings were transplanted to the field. We selected about 550 clones because of their agronomic characteristics (such as earliness and yield), and will evaluate them for resistance to RKN under field conditions in Ica (coastal valley near Lima). We evaluated the reaction of 50 families, developed from crosses between RKN-resistant and heat-tolerant materials; 12.3% of them were resistant or moderately resistant to RKN.

In another test, we evaluated 552 tetraploid clones with immunity to PVX and PVY and tolerance of PLRV for their reaction to RKN; 78 were resistant and 60 moderately resistant. The best were clones N-93-319, N-93-511, N-93-772, and N-93-215.

Detection and diagnosis of *P. solanacearum*

Work performed for CIP by Andrea Robinson-Smith of the Rothamsted Experimental Station (RES) as part of an ODA holdback project involving several crops resulted in the production of monoclonal and polyclonal antisera for *P. solanacearum* for use in NARS of Africa and Asia. The antisera all performed best at a concentration of 1 x 10^8 bacteria per ml. The RES monoclonal PS-144 worked well for numerous isolates of diverse origin at a dilution of 1:1,000, whereas monoclonal HP 53 of the Chinese Academy of Agricultural Sciences (CAAS) did not work beyond a 1:50 dilution and it cross-reacted to related bacterial species. The RES polyclonal PS-278 was effective at 1:1,024,000; one from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) at 1:4,000; and one from CAAS at 1:25. They all cross-reacted with closely related species to some extent. Antisera were tested by two methods that would permit field testing. The rapid immunofilter paper assay (RIPA) was more sensitive than dip-stick ELISA.

Evaluation for resistance to bacterial wilt

In Peru, personnel from the Instituto Nacional de Investigación Agraria (INIA) evaluated 38 clones for resistance to BW in Cajamarca; 10 were moderately resistant. Of these, the highest yielding clones not showing latent infection were H89-30-27, H89-58-05, and H89-14-23, with 1.11, 1.06, and 0.88 kg/plant, respectively. In Frías (Piura), the two most resistant among 23 selections were 720118 (Cruza 148) and 720118.1 (37-35A, the induced mutant produced in Italy to eliminate tuber flesh pigmentation). Their yields were similar, and superior to that of check variety Molinera.

Tests by staff of the Centro Nacional de Pesquisa de Hortaliças (CNPH) in Brasília, Brazil, for race 1 of *P. solanacearum* employed data of the AUDPC and multivariate analysis of the principal component to discern small differences in resistance among clones. Of 18 clones selected as resistant over several years, two (390057.32 and 388594.8) were similar in resistance to the best identified so far, varieties Cruza (CIP Mex 720118) and Achat.

Of 28 CIP clones selected in 1993 and retested in 1994, five were equal to or better than the resistant checks Achat and Cruza. Another five clones developed locally had the same performance. Figure 2 compares the resistance level of these 10 clones to that of susceptible common varieties Granola and Baronesa. These resistant clones (Table 2) will be multiplied disease-free in vitro for further testing in Paraná State, where race 3 occurs.

In Mindanao, Philippines, through collaboration between CIP and the Department of Agriculture, we evaluated tuber families for resistance to BW and yield. The best clones were BP87060.2, BP88148.3, 388015.5, BP88120.2, BP88013.2, 388015.3, and BP88026.1. Retesting previous selections led to the selection of clones 800941, BP86152.7, 384008.5, 377835.3, and 379695.4. In a yield test, nine clones yielded more than 30 t/ha, whereas variety Granola yielded only 11.8 t/ha.

In work at CAAS in China, five clones were reevaluated and proven resistant to BW and late blight, and shown to be good yielders: 898006 (Mira x MS42.3), 897003 (76-5-156 x AVRDC 1287.19), BP88098.7 (BR-63.5 x 676098), BP88176.1 (P-7 x BWB), and BP88096.1 (BR63.5 x 104-12-LB). Another four were resistant to BW: 893005 (Zigan x AVRDC 1287.19), 895010 (Mira x AVRDC 1287.19), BP88125.22 (CEW69.1 x BWB), and 388163.18 (Atzimba x 843629). So far, seven of these have been distributed virus-free for further selection and breeding in several institutions.

Work at the Mauritius Sugar Industry Research Institute (MSIRI)-Reduit Experimental Station with segregating populations developed by CIP regional staff in Kenya for tropical adaptation resulted in evaluations with TPS during

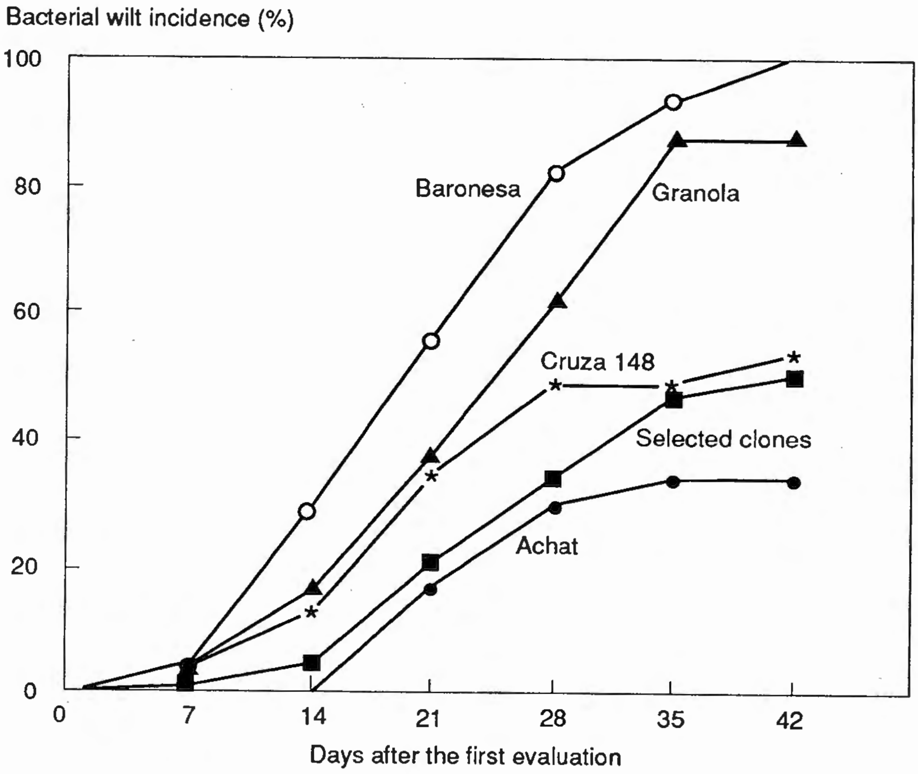

Figure 2. Bacterial wilt progress curves on potato cultivars and selected clones in a comparative trial in a field infested with race 1 of *Pseudomonas solanacearum* at CNPH, Brasília, Brazil (1994).

Table 2. CIP and Centro Nacional de Pesquisa de Hortaliças (CNPH) hybrid clones selected for resistance to race 1 of *Pseudomonas solanacearum* at CNPH, Brasília, Brazil.

Clone	Pedigree	Origin
390756.6	CEW-69.1- x BK (BWL-88R)	CIP
386095.21	BW2TD.8 x 377964.5	CIP
386097.2	BW2TD.1 x 378676.4	CIP
388104.2	BR63.76 x XY.9	CIP
388285.12	MS35.22 x XY.9	CIP
309.95 x 386095.19/7	309.95 x 386095.19	CNPH
7B.16	—	CNPH
7B.24	—	CNPH
Cruza 148 x 386095.19/3	Cruza 148 x 386095.19	CNPH
Monte Bonito x 386095.19/3	Monte Bonito x 386095.19	CNPH

three consecutive years. Seventeen clones were selected and grown with Spunta as a check. None yielded less than Spunta, whereas five yielded 40% more. These clones were resistant to late blight and BW (race 1).

Combining Resistances to Potato Viruses and Fungi

Most viruses cause chronic reductions in yield of infested plants, and many readily spread within a field and through tuber seed to the next generation. Therefore, CIP believes that breeding for resistance to important viruses (which, fortunately, can now be readily done for some) and to a fungal disease that may limit production in a given situation can improve the lot of many farmers.

Breeding for immunity to PVX and PVY

One of the CIP virus resistance progenitors—7XY.1—was released as variety Batoví in Uruguay. In addition to its PVX and PVY resistance, it resists common scab caused by *Streptomyces scabies*, and it appears to have some resistance to PLRV.

Seven duplex PVX- and PVY-immune clones (XXxx YYyy) were selected for high yield and good tuber characteristics during summer, winter, and spring growing seasons at La Molina, with the best yielder producing 1.54 kg/plant. A cross of a duplex for PVY resistance with PLRV-resistant Serrana yielded 1.58 kg/plant.

Selected triplex PVY-immune progenitors (YYYy) that are now available increase the frequency of transmission of immunity to progenies to 96%. Breeding continues to further raise the frequency of immunity genes in progenitors to triplex and quadruplex for both PVX and PVY, so that such parents will eventually transmit these resistances to practically all progenies. Thus, screening for resistance in progenies will not be necessary.

Resistance to potato leafroll virus (PLRV)

As a result of the contract with the Potato Research Institute at Mlochow, Poland, CIP and Polish breeders jointly selected three tetraploid clones that were highly resistant to PLRV and other viruses and had good agronomic characteristics. These were sent to CIP-Lima for use as parents. To further combine resistances to PLRV, PVX, PVY, PVS, and PVM, 92 clones in three diploid families were evaluated for all of these viruses, and 12 were resistant (although resistance to PLRV needs confirmation).

Breeding for resistance to early blight

We evaluated second-generation clones previously screened for resistance to PVX and PVY for resistance to early blight at San Ramón during the dry season. Of 296 clones, 127 were selected. The best were (EB87.001 x XY.4).37, (Maine 47 x XY.13).34, and (XY.9 x Maine 47).58. Of these 127 clones, three were selected for early blight resistance, earliness, and processing quality: (EB87.001 x Yy.4).15, (Chiquita x XY.20).42, and (EB87.001 x XY.4).103.

Collaboration since 1989 with CNPH of Brasília, Brazil, includes evaluation for early blight resistance in the field, and tests for resistance to PLRV and immunity to PVX and PVY. In addition to screening families bred by CIP, CNPH is making crosses between selections. CIP 1992 bred families have resulted in 15 clones being selected for combined resistance plus agronomic and culinary quality (Table 3).

Control of Field and Storage Diseases of Potato and Andean Root and Tuber Crops

Development of potato resistance to *Erwinia* spp.

We generated 15 families bred for resistance; Table 4 shows the distribution

Table 3. Selected true potato seed genotypes (with resistance to early blight and viruses, vegetative cycles of 85-105 days, and shallow tuber eyes), their tuber shape, periderm, pulp color, and frying qualities, Brasília, Brazil, June 1994.

CIP no.	Pedigree	Shape	Periderm	Pulp[a]	Frying[b]
388958.04	XY.10 x NDD-277.2	Long	Yellow	W	2.8
388962.13	XY.5 x NDD-277-2	Long	Russet	LY	2.6
390216.02	Chiquita x XY.16	Long	Russet	LY	2.2
390224.06	Maine-28 x XY.9	Long	Yellow	LY	2.2
390638.09	Chiquita x XY.14	Long	Yellow	Y	3.2
390640.05	Chiquita x XY.4	Oval	Russet	Y	5.0
390640.06	Chiquita x XY.4	Long	Russet	LY	2.4
390640.09	Chiquita x XY.4	Long	Russet	LY	2.0
390640.10	Chiquita x XY.4	Long	Yellow	Y	3.0
390640.18	Chiquita x XY.4	Long	Russet	DY	3.5
390641.01	Chiquita x XY.9	Round	Yellow	LY	3.2
390641.04	Chiquita x XY.9	Long	Russet	Y	3.3
390641.10	Chiquita x XY.9	Long	Russet	LY	3.4
390649.01	Maine-50 x XY.14	Long	Yellow	LY	1.0
390652.03	XY.10 x Chiquita	Long	Yellow	DY	3.4

a. Pulp color: Y = yellow, LY = light yellow, W = white, DY = dark yellow.

b. French fries: <2 = color too light, 2-3 = ideal color, >3 = color too dark.

Table 4. Percentages of highly resistant (HR), resistant (R), moderately resistant (MR), and susceptible (S) clones from 15 families assayed by the injection method, and average tuber rot per family (diameter in mm).

Pedigree	Percentage by resistance category				Average rot
	HR	R	MR	S	(mm)
ERW 91-017 (ERW 293 x ERW 88-021.5)	0	22	66	12	4.94
ERW 91-027 (ERW 88-065.5 x ERW 293)	0	22	45	33	5.56
ERW 91-031 (ERW 88-070.1 x ERW 293)	6	3	31	60	6.20
ERW 91-032 (ERW 88-070.1 x ERW 351.3)	0	14	28	58	5.96
ERW 91-034 (ERW 88-070.1 x OCH 6400.4)	7	10	3	80	7.68
ERW 91-026 (ERW 88-065.4 x OCH 6400.4)	0	8	41	51	5.33
ERW 91-047 (OCH 6400.4 x ERW 399)	0	9	51	40	6.06
ERW 91-030 (ERW 88-065.5 x OCH 6400.4)	0	8	30	62	6.69
ERW 91-048 (OCH 6400.4 x ERW 88-021.5)	4	0	24	72	7.18
ERW 91-029 (ERW 88-065.5 x OCH 6175.2)	3	6	32	59	6.85
ERW 91-033 (ERW 88-070.1 x OCH 6175.2)	7	7	52	34	6.90
ERW 91-039 (OCH 6175.2 x ERW 399)	0	2	20	78	8.21
ERW 91-016 (ERW 293 x ERW 399)	0	0	62	38	6.21
ERW 91-023 (ERW 351.3 x ERW 399)	0	2	16	82	10.19
ERW 91-041 (OCH 6175.2 x ERW 88-021.5)	0	0	26	74	7.59
Desirée, MR variety					10.76

of frequencies of the different levels of soft rot resistance obtained. Families ERW 91-17 and ERW 91-27 that had clone ERW 293 as one of their progenitors showed 22% resistant genotypes (<4.0 mm rot diameter). Other families that produced 17% resistant genotypes were ERW 91-33 and ERW 91-34. For the first time, we produced eight families from *tuberosum* x *andigena* crosses to improve agronomic characters and provide earliness to the *adg* populations (Table 5). Family ERW 91-050 (XY 13 x ERW 293) produced 9% resistant genotypes.

We also made tests to determine genotypes that combine resistance to both soft rot and blackleg in these selections. From 347 selections with various degrees of resistance to soft rot, we selected 51 genotypes with potential blackleg resistance. Of these, 26 had no blackleg symptoms and 25 showed up to 20% of the stem cuttings with blackleg, whereas check variety Desirée had significantly higher soft rot and 100% blackleg. The best seven, with 0-3 mm diameter of average soft rot versus 11 mm for check Desirée, were ERW 91-42.23, ERW 91-45.15, ERW 91-42.01, ERW 91-45.07, ERW 91-02.04, ERW 91-33.29, and ERW 91-43.09.

Although we have selected many clones with resistance to soft rot using the injection method, which is a very severe test, they have a strong *S. tuberosum* ssp. *andigena* background. We have begun crossing these clones with *tuberosum* to improve agronomic characters and provide earliness and broader adaptation. Because this project was rated lowest in priority setting and funding ended in 1993, TPS of these last crosses was turned over to Argentina's INTA-Balcarce experiment station potato program as a result of an agreement in which INTA researchers will continue to develop these populations.

Solanum brevidens-derived resistance has been investigated at SCRI, Scotland (CIP research contract), and found to be operative even under anaerobic conditions among the sexual progenies of a cross between an *S. brevidens* x *S.t. tuberosum* somatic hybrid and a potato cultivar (Katahdin). This has been of value in identifying the mechanism concerned. Both tuber and stem resistances were related to the level of cell-wall pectin esterification. Pectin esterification level and resistance were significantly greater in

Table 5. Percentages of resistant (R), moderately resistant (MR), and susceptible (S) clones in eight families of *tuberosum* x *andigena* crosses, and average tuber rot per family (diameter in mm).

Pedigree	Percentage by resistance category			Average rot
	R	MR	S	(mm)
ERW 91-050 (XY-13 x ERW 293)	9	40	51	6.92
ERW 91-053 (XY-14 x OCH 6175.2)	0	90	10	5.55
ERW 91-054 (XY-14 x OCH 6400.4)	0	22	78	7.57
ERW 91-056 (XY-4 x OCH 6175.2)	2	24	74	8.65
ERW 91-057 (XY-9 x ERW 88-065.05)	2	18	80	8.78
ERW 91-055 (XY-4 x ERW 88-065.04)	0	19	81	8.87
ERW 91-052 (XY-14 x ERW 88-065.04)	0	6	94	9.79
ERW 91-051 (XY-13 x OCH 6175.2)	2	11	87	9.84
Desirée, MR variety				11.25

resistant sibling clone 4680 than in susceptible sibling clone 4708 and three cultivars, including the parental Katahdin. Whereas clone 4680 stems failed to rot when inoculated, tubers of all genotypes rotted, although clone 4680 tubers rotted the slowest. This resistance should be of value because under natural conditions infection is begun by a small inoculum load and prolonged or uninterrupted anaerobiosis is unlikely to occur. Under these conditions, growth of the bacteria would be slowed or even arrested in tubers with a high pectin esterification level by the activity of O_2-dependent resistance, resulting in field resistance.

We improved inoculation methods for the selection of resistance to Erwinia soft rot through a collaborative project with eight European institutions. Standard procedures were published in the European Association for Potato Research (EAPR) 1993 Proceedings of the Triennial Meeting held in Paris.

Diseases of ARTC
In 1993-1994, 35 pathogenic fungi and bacteria of maca, mashua, oca, and ulluco were isolated from diseased storage organs and foliage (Figure 3). We have demonstrated these to be pathogenic in inoculation studies, and have carefully identified them according to genus and species. A bulletin describing these diseases and illustrating them with color photographs is almost ready for publication.

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Figure 3. Gall produced by a smut fungus infection on maca (*Lepidium meyenii*).

Detection and Control of Potato Viruses

Identification and characterization of previously unreported viruses or virus diseases

An isometric virus code-named SB-26 (c. 28 nm diam.), widespread in potatoes in Arequipa, Peru, was shown to cause mosaic symptoms in cv. Tomasa Condemayta. Its host range was restricted to family Solanaceae and it can be transmitted by the leafhopper *Russelliana solanicola* T. (family Psyllidae). It is not serologically related to any known isometric potato virus. Another isometric virus (SB-23), serologically related to Sowbane mosaic tymovirus, was found in some plants of cv. Puebla from Mexico sent to CIP for cleanup. It only produces faint mosaic symptoms and is readily detected by sap inoculation to *Chenopodium quinoa*.

A disease called saq'o was studied in native cultivars Runa and Waych'a in Bolivia. It is characterized in cv. Runa by chlorosis of the leaves, anthocianescence in the lower 3/4 of the plant foliage, mild mosaic, reduced plant vigor, an average of 5 stems in contrast to 1.5 in healthy plants, and absence of flowering. In cv. Waych'a, chlorosis is less pronounced than in Runa. Tubers from affected Runa plants show 4-5 sprouts with excessive branching. The agent causing saq'o can be transmitted by grafting and no vector has been associated with the disease. Etiological studies are not yet conclusive. A PLRV isolate apparently showing infectivity different from other PLRV strains has been found in approximately 21% of cv. Runa plants tested. A previously unreported isometric virus has also been found in one plant of cv. Waych'a and mycoplasma-like organisms (MLOs) have been shown by polymerase chain reaction (PCR) in two infected plants of cv. Runa.

Potato yellow vein disease occurring in Ecuador and Colombia has spread alarmingly in recent years. The agent is transmitted by the whitefly *Trialeurodes vaporariorum* (Figure 4). A viral etiology has not been demonstrated conclusively. Purification attempts have revealed elongated particles resembling those of closteroviruses. PCR analysis using universal primers for closteroviruses has allowed us to amplify a DNA fragment of approximately 350 base pairs (bp).

Variability and detection of potato viruses

Through collaborative research with both SCRI, in Scotland, and PROINPA, in Bolivia, we studied the variability of potato leafroll luteovirus (PLRV) and potato mop-top furovirus (PMTV) in the Andean region. In potato plants with typical PMTV symptoms, the virus was not reliably detected in serological tests, although coat protein gene and amino acid sequence analysis of several isolates revealed little sequence variation. Poor detection might be caused by erratic distribution of PMTV in naturally infected plants, or very low virus concentration in some cultivars. Its

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Figure 4. An undescribed potyvirus in *Tropaeolum tuberosum* Ruiz y Pavón causing yellow vein banding.

detection by reverse transcription (RT)-PCR, however, was reliable and, although not recommended for large-scale screening, it may be a useful diagnostic tool in some circumstances. We found evidence for the existence of a new furovirus in Cusco, Peru, when *Spongospora subterranea* (the vector of PMTV) spore balls scraped from tubers from plants with symptoms were used to infect bait plants of *Nicotiana debneyi*. This new furovirus is not transmitted mechanically to potato or to indicator hosts of PMTV.

We studied variability of PLRV in relation to sensitivity and reliability of serological detection. A panel of 10 monoclonal antibodies (MAbs) was produced for an Andean isolate of PLRV that causes "enanismo amarillo" symptoms in native Andean cultivars. Six of the MAbs were specific for PLRV and four were found to cross-react with other luteoviruses, including groundnut rosette assistor, barley yellow dwarf virus RPV strain, and chickpea luteovirus. Three MAbs showed differences in reactivity among 10 isolates of PLRV tested. Amino acid sequence analysis of these isolates, however, showed little sequence variation. It seems unlikely that the differences detected by the MAbs can be explained by the few amino acid differences in the coat protein of PLRV. It is possible that the MAbs detected a change caused by the minor coat protein gene (read-through protein), which is known to remain attached to some virus particles. MAbs have been produced in large amounts and we are evaluating MAbs-based detection.

Virus resistance studies

We placed major emphasis on determining the mechanisms and stability of the resistance operating in already selected PLRV-resistant genotypes. We tested the seven selected clones, which we have evaluated for seven years for yield and resistance to viruses in alternating winter and summer seasons in Ica, Peru, to determine the type of resistance to PLRV (Table 6). We are evaluating these clones for resistance to virus multiplication and they are available in the pathogen-tested list for distribution.

Because natural virus infection of accessions in the germplasm collection held at CIP facilitates the evaluation for virus resistance, we decided to accelerate this evaluation before taking steps to clean the collection. We determined sources of virus (PLRV, PVX, PVY, PVS,

Table 6. Type of virus resistance in selected potato clones.

Clone	Progenitors	PLRV resistance		Reaction[c] to:	
		Antixenosis[a]	Res. to infection[b]	PVX	PVY
86008	B71.240.2 x 7XY.1	—	MR	H	I
86060	B71.240.2 x 7XY.1	—	R	H	I
87059	Pirola x I-1039	—	S	H	I
88076	Serrana x 84.011	—	R	I	I
88052	7XY.1 x Katahdin	?	R	I	I
88108	Y2 x Katahdin	?	MR	H	I
88146	BR-63.65 x 7XY.1	—	R	H	I

a. Determined by comparing reduction of numbers of aphids after a period of time with a susceptible control (DTO-33); — = no antixenosis exhibited, ? = inconclusive results.

b. MR = moderate resistance, R = high resistance, S = susceptible.

c. H = hypersensitivity, I = immunity.

and APMV) resistance genes among 46 wild species tested and in more than 3,000 accessions of the potato germplasm collection. We are evaluating resistant accessions to determine the type of resistance involved for each virus.

Identification and Control of Sweetpotato Viruses

Identification and characterization of viruses

Because the commercially available monoclonal antibody (MAb) PTY 1 recognizes a cryptotope conserved on aphid-transmissible potyviruses, we used it to determine the relationship among different potyviruses in sweetpotato and to gather evidence on their vector (Table 7). PTY 1 did not react with sweetpotato chlorotic fleck virus (SPCFV), sweetpotato leaf speckling virus (SPLSV), C-3, and C-6, suggesting that their vectors are not aphid species. The observed weak reaction of sweetpotato latent virus (SPLV) with this MAb could explain the aphid transmission of some strains of SPLV reported in Japan and China. The C-3 virus previously reported as a possible bacilliform virus was shown to be a clostero-like virus when it was purified following the protocol reported for sweetpotato sunken vein virus (SPSVV). We observed open, helical elongated particles typical of closteroviruses.

SPLSV, also called C-4 in previous reports, was confirmed as a luteovirus. Complementary DNA obtained from SPLSV-RNA by RT-PCR was cloned and sequenced at SCRI in Scotland. We established relationships between the coat protein gene of SPLSV and other luteoviruses by sequence comparisons. The highest sequence homology was found between SPLSV and PLRV. In spite of this similarity, there is neither serological cross-reaction nor host range congruence between these two viruses.

In Africa, we are studying the importance of virus diseases in sweetpotato through an ODA holdback

Table 7. Reaction of the MAb PTY 1 to different viruses in NCM-ELISA.

Virus[a]	Group	Vector	Sap extracted in:		
			A[b]	B	C
APMV	Comovirus	*Diabrotica* sp.?	—[c]	—	—
PVX	Potexvirus	Fungus	—	—	—
PVY	Potyvirus	Aphids	4+	3+	1+
SPFMV(RC)	Potyvirus	Aphids	4+	2+	1+
SPLV	Potyvirus	Aphids?	+/-	—	—
SPMMV	Potyvirus	Whitefly	—	—	—
SPCFV	Potyvirus?	Unknown	—	—	—
SPLSV	Luteovirus	Aphids	—	—	—
C-3	?	Unknown	—	—	—
C-6	Potyvirus	Unknown	—	—	—
14R	Tobamovirus	Unknown	—	—	—

a. APMV = Andean potato mottle virus; PVX = potato virus X; PVY = potato virus Y; SPFMV(RC) = sweetpotato feathery mottle virus (RC strain); SPLV = sweetpotato latent virus; SPMMV = sweetpotato mild mottle virus; SPCFV = sweetpotato chlorotic fleck virus (or C-2); SPLSV = sweetpotato leaf speckling virus (or C-4); C-3 and C-6 = new flexuous sweetpotato viruses.

b. A = carbonate buffer, pH 9.6; B = tris buffer saline (TBS); C = TBS containing 0.2% Na_2SO_3.

c. Reaction intensity in NCM-ELISA test: 1 = minimum, 4 = maximum, — = no reaction.

project. As in other parts of the world, sweetpotato feathery mottle virus (SPFMV) is the virus most frequently found in diseased plants; however, these plants mainly show symptoms of sweetpotato virus disease complex (SPVDC) caused by the apparent synergism of SPFMV and a whitefly-borne virus, probably a closterovirus. Studies on the etiology of SPVDC are in progress.

Virus resistance studies

SPFMV alone does not usually cause severe yield reduction in sweetpotato; mixed infections of SPFMV with other viruses are the main cause of crop degeneration. Therefore, we developed a strategy to find sources of resistance to several viruses in one genotype. Accessions from the germplasm collection and pathogen-tested list at CIP having high levels of resistance to SPFMV were sequentially tested for resistance to sweetpotato mild mottle virus (SPMMV), SPLV, and SPCFV by grafting *Ipomoea nil* infected with the challenging viruses onto sweetpotato plants. We detected infection of plants under evaluation by symptom development, NCM-ELISA, and back-testing by grafting healthy *I. setosa* plants onto previously graft-inoculated sweetpotato plants (Table 8). It is interesting to note that accessions

Table 8. Reaction of accessions resistant to sweetpotato feathery mottle virus (SPFMV) from CIP-held germplasm collection to SPMMV, SPLV, and SPCFV.

CIP number	Accession	Virus[a]					
		SPMMV		SPLV		SPCFV	
		I. batatas	*I. setosa*[b]	*I. batatas*	*I. setosa*	*I. batatas*	*I. setosa*
420018	ST-3	+	+	-	-	-	-
420019	S-12	+	+	-	-	-	-
420020	S-20	+	+	+	+	-	-
420021	ARB 231	+	+	-	-	-	-
420022	ARB 426	+	+	+	+	-	-
420023	DLP 298	-	+	+	+	+	+
420024	DLP 886	+	+	-	-	-	-
420025	DLP 1912	+	+	-	-	-	-
420026	DLP 1913	-	+	-	-	-	-
420027	DLP 1914	-	-	-	-	-	-
420028	DLP 2247	-	-	+	+	-	-
420029	RCB 73-IN	+	+	+	+	-	-
420030	PMH	-	+	+	+	-	+
	ARB 261	-	-	+	+	-	-
	ARB 403	-	-	-	-	-	-
	DLP 2364	-	-	-	-	-	-
	DLP 279	-	-	-	-	-	-
	RCB IT 16	-	-	-	-	-	-
	RCB H 452	-	-	-	-	+	+
	RCB 3018 H	+	+	-	-	-	+

a. SPMMV = sweetpotato mild mottle virus, SPLV = sweetpotato latent virus, SPCFV = sweetpotato chlorotic fleck virus.

b. Healthy *I. setosa* scions were grafted onto sweetpotato plants previously graft-inoculated with viruses.

DLP 1914, ARB 403, DLP 2364, DLP 279, and RCB IT 16 are resistant to the four viruses tested (SPFMV, SPMMV, SPLV, and SPCFV).

Control of Bacterial and Fungal Diseases of Sweetpotato

Screening for disease resistance

To determine the best way to screen for *Erwinia chrysanthemi* bacterial root rot, we tested three inoculation methods to infect storage roots: microinjection, pipette tip injection, and pipette tip injection plus a vaseline seal, with concentrations of 1×10^5 to 1×10^7 cfu/ml. This last method produced the highest infection, with no significant difference at 1×10^6 and 1×10^7.

We tested *Diplodia gossypina* that causes Java black rot disease against two groups of sweetpotato clones. We found marked differences when high relative humidity (RH) was maintained during the three days following inoculation.

Sweetpotato showed variability in resistance to *D. gossypina*. The pathogenicity of this fungus also varied according to the level of moisture during storage. When 197 accessions were screened using low RH during incubation, 20% resulted susceptible, 7.5% highly susceptible, and 72.5% resistant. But with a high RH incubation for a group of 120 entries, only one (DLP 2689) resulted resistant.

Scab in Asia

Through an agreement between the Natural Resources Institute in the United Kingdom and SAPPRAD, we are conducting collaborative research on sweetpotato scab (caused by *Elsinoe batatas)* in Southeast Asia, where it is a serious problem. Results of multilocational trials with numerous clones indicate considerable variation in resistance among sweetpotato cultivars; therefore, general resistance may be available.

Molecular Approaches for Detection and Control of Pathogens

Detection of viruses and viroids by nucleic acid spot hybridization (NASH)

Detection of potato virus T (PVT) by serological means is unreliable because of the low concentration of the virus in plant tissues, the instability of the polyclonal antibody, and the susceptibility of NCM-ELISA to producing nonspecific reactions when true potato seed (TPS) is tested. We therefore sought molecular approaches to overcome these disadvantages. We used a cDNA (1,100 bp) developed some years ago to prepare a specific ^{32}P-labeled probe. This probe (pPVT1) was able to detect as little as 32 picograms (pg) of virus and 3-5 pg of viral RNA, and allowed us to detect the virus in a single infected TPS.

In order to reduce work in preparing samples for detection of both TPS-borne agents (PVT and PSTVd), the pPVT1 was linked to the PSTVd cDNA to create a chimeric clone. The chimeric clone detected PVT in infected leaf sap up to a dilution of 1/192 and PSTVd up to 1/3,072. In tuber sprouts, PVT can be detected at a maximum dilution of 1/384 and PSTVd at 1/1,536, whereas in TPS, PVT can be detected up to a dilution of 1/96 and PSTVd at 1/768.

We completed work to characterize PSTVd in avocados as requested by the Servicio Nacional de Sanidad Agraria (SENASA), Ministry of Agriculture, Peru.

We found PSTVd in avocados in several Peruvian provinces, but it seems to be especially important in Moquegua, the most important avocado production area.

PLRV-assisted aphid transmission of PSTVd

CIP confirmed in several experiments the transmission of PSTVd by aphids (*Myzus persicae* Sulz.) when the source of inoculum also contained PLRV. Other experiments indicated that like PLRV, PSTVd is also persistent in the aphid and that transmissibility of PSTVd or PLRV is not lost after several passages of viruliferous aphids on cabbage plants. A comparison of PLRV purified from doubly infected plants (PLRV and PSTVd) and PLRV purified from a mixture with PSTVd indicated that PSTVd is closely associated with PLRV particles from doubly infected plants. These results suggest that PSTVd is transencapsidated in PLRV particles during replication, although they do not rule out completely the possibility that PSTVd is attached to the outside of PLRV particles. We will conduct more work to elucidate the mechanism of transmission.

Studies on antiviral compounds of natural origin

We began studies on antiviral compounds from plants using the previously reported viral inhibitor MAP (*Mirabilis* antiviral protein). MAP has been reported as a protein capable of temporarily blocking protein synthesis and therefore virus replication in the infected cells. We have conducted some experiments to confirm the reported effect of MAP, extend information to potato viruses (PVX and PVY), and evaluate the potential practical use of *Mirabilis jalapa* to control virus spread in potatoes.

In a typical experiment, we applied *M. jalapa* extracts (from leaves and roots) manually onto the leaves of *Gomphrena globosa* (a local lesion host for PVX) 24 hours before rubbing them with PVXcp-infectious sap. *M. jalapa* extracts reduced virus infection to 1% of the incidence in the untreated control. Similar experiments, but replacing *G. globosa* with a susceptible potato clone (DTO-33), showed that systemic infection with PVX and PVY was 100% inhibited, whereas the untreated controls became 80-100% infected. The residual effect of the antiviral compound present in *M. jalapa* indicated a high stability and persistence of the virus inhibitory effect. Twenty-four days after treatment, about 50% of the inhibitory effect was still present (Table 9).

Table 9. Residual effect of *Mirabilis jalapa* extracts on PVXcp in *Gomphrena globosa* plants.

Day of inoculation[a]	No. of lesions[b]/plant		Inhibition
	Treatment	Control	
	M. jalapa + PVX	PVX	(%)
1	0.5	35.5	98.6
2	0.5	31.0	98.4
3	2.0	73.0	97.0
4	5.5	78.5	93.0
5	8.0	103.5	92.3
6	20.0	117.5	83.0
7	29.5	121.0	76.0
8	9.5	121.0	92.2
9	8.0	120.0	93.4
10	20.0	120.0	83.4
12	16.0	125.0	87.2
14	70.0	170.0	58.8
15	13.0	140.0	90.7
16	59.0	140.0	57.9
18	53.0	120.0	53.8
21	32.0	120.0	73.3
23	67.0	150.0	55.3
24	80.0	150.0	46.7

a. Day of treatment with *M. jalapa* = day 0.

b. Average calculated on 2 plants, 2 leaves/plant.

Virology of Andean Root and Tuber Crops

Identification of viruses

Studies on viruses of ARTC aim to identify, characterize, and detect viruses. Recently, we identified an isometric virus from *Ullucus tuberosus* (ulluco) as a strain of APLV, and it was detected in 27% of ulluco accessions from germplasm originating in Colombia, Ecuador, and Peru. We found another isometric virus in ulluco from Peru, although its relationship to other isometric viruses has not yet been determined. General surveys on ulluco from three locations in Peru showed that 98% of the samples were infected with viruses.

In *Oxalis tuberosa* (oca), we characterized a strain of papaya mosaic virus. This virus was found in 20% of the field samples tested. In *Tropaeolum tuberosum* (mashua), we determined a high incidence of yet unidentified viruses. Table 10 summarizes the viruses affecting ARTC. We are characterizing several other viruses and have not included them in the table.

We have developed serological methods for the detection of ARTC viruses. Because DAS-ELISA was consistently more sensitive than NCM-ELISA and indirect ELISA, we are presently using this form of ELISA. We have distributed antisera kits to ARTC programs in Ecuador, Bolivia, Peru, and Colombia for use in the production of healthy planting materials.

Training

A workshop on the use of R-gene-free horizontal resistance to *P. infestans* was conducted in Kunming, China (24 participants from several potato-growing provinces), and Montevideo, Uruguay (15 participants from five countries). We provided in-service training to 14 NARS staff during visits by CIP-Lima staff to Costa Rica, Guatemala, and Panama. Collaboration with PRECODEPA in Mexico provided training in a Workshop on Management of Germplasm for Resistance to Late Blight for 26 participants from Costa Rica, Cuba, El Salvador, Honduras, Mexico, Nicaragua, and Panama (August 21-27, 1994). At the CIP station in Rionegro, Colombia, training was given to NARS scientists from PRACIPA and PROCIPA

Table 10. Groups of viruses affecting Andean root and tuber crops.

Virus group	Virus	Symptoms[a]	Particle size (nm)	Natural transmission
Potyvirus	UMV	M	750	Aphids
	AP-1	M, Df	15 x 750	Aphids
Comovirus	UVC	M, Mm	28	Mechanical (beetles)
Potexvirus	PapMV/U	M, Df	550	Mechanical
	PapMV/O		550	Mechanical
Tobamovirus	TMV/U	M, B	250-350	Mechanical
Tymovirus	APLV/U	SS	29	Mechanical (beetles?)
Nepovirus	PBRV/A	SCR	25	Nematodes?
	AVA	M	26	Nematodes?
	UVB	SS	28	Nematodes?
Unknown	AVB-O	SS	26	Unknown

a. SS = symptomless systemic infection, M = mosaic, Mm = mild mottle, Df = leaf deformation, B = blistering, SCR = systemic chlorotic rings.

participating in a planning meeting on late blight.

CIP and the Institut des Sciences Agronomiques du Burundi (ISABU) provided a Workshop on Management of Bacterial Wilt in the PRAPACE countries in Bujumbura, Burundi (February 22-26, 1993). Both BW and Erwinia diseases were covered in the Workshop on Bacterial Diseases of Potato organized by PROCIPA, CNPH-EMBRAPA, and CIP in Brasília, Brazil (March 15-18, 1993). An International Workshop on Integrated Management of Bacterial Wilt of Potato took place in New Delhi and Shimla, India (October 11-16, 1993). It was organized by the Indian Council of Agricultural Research (ICAR) and CIP regions–South and West Asia and East and Southeast Asia and the Pacific. Training on diagnosis of BW in the field and laboratory was given to staff of the Servicio Agrícola y Ganadero (Chile) to undertake a BID-financed survey (September 20-October 1, 1993).

Víctor Alvarez of Bolivia (September 20-October 17, 1992), Paulina Tolosa and Ernesto Vega of Chile (October 5-17, 1992), and Alicia Albornoz of Cuba (November 15-30, 1993) received individual training at CIP on bacterial wilt.

Ivette Acuña of Chile, who received training on Erwinia diseases in 1992, received an intensive follow-up session during a visit by Liliam Gutarra of CIP-Lima to Osorno (August 8-27, 1993). G.P. Henz of Brazil received training in Lima, November 2-12, 1993.

A course on Techniques for the Detection of Phytopathogenic Viruses was held in Lima for participants from Ecuador, Chile, and Peru (August 2-13, 1993). A two-week practical course on Potato Virology was held in Paraguay (September 27-October 6, 1993) for 18 participants. A two-week course on Basic Techniques in Virology was conducted in Lima in February 1994 for 14 participants from Peru, Chile, the USA, and Italy. In June-July 1994, two courses were held in Lima: Advanced Virology (June 27-July 26), with seven participants from Peru, Chile, India, Venezuela, the USA, and Syria; and Seed Production, involving tissue culture, rapid multiplication, and serological techniques (June 27-July 11), with five participants from Italy, Mexico, Peru, and Syria.

Personnel from the Virology Department have also been asked to participate in and help conduct several courses organized in Peru by national entities (such as SENASA and INIA). We provided on-the-job training to several NARS staff from Peru and other countries.

■

1993-94 Research Projects and Partners

This list contains titles of research projects, names of principal research partners and responsible CIP scientists, collaborating institutions, and, when applicable, countries where work is conducted.

Control of potato late blight (*Phytophthora infestans*). G. Forbes.

- Breeding and selection for horizontal resistance to late blight in potato. J. Landeo, G. Forbes, M. Gastelo, H. Pinedo.
- Integrated management and control of potato late blight. Bolivia. N. Estrada,

E. Fernández-Northcote, J. Gabriel (PROINPA).

- Development of fundamental information for late blight work. Netherlands. L. Turkensteen (IPO).
- Evaluation of genetic material from CIP and ICA for resistance to late blight in Rionegro, Colombia. J.L. Zapata, G. Forbes.
- Epidemiological and biological studies related to efficiency of selection for horizontal resistance to late blight and its durability. G. Forbes, J. Landeo, H. Pinedo.
- Relationship between late blight attack and production in potato. R. Morales, J. Revelo (INIAP); G. Forbes.
- Selection of adapted potato cultivars with emphasis on late blight resistant germplasm in South China. Wang Jun, Li Baoquing (YNU); Song Bo Fu.
- Selection of resistance to late blight of potato. Mexico. F. Flores (INIFAP); J. Landeo, G. Forbes.
- Combating a genetically distinct migrating population of *P. infestans* with plant resistance. Bolivia, Ecuador, Peru. G. Forbes, F. Muñoz, E. Fernández-Northcote, H. Pinedo, W. Fry.

Integrated control of potato bacterial wilt. E.R. French.

- Ecology, taxonomy, and strategy to control *Pseudomonas solanacearum.* E. French, P. Aley, U. Nydegger.
- Improvement in the integrated control of bacterial wilt disease caused by *P. solanacearum.* United Kingdom. A. Robinson (ODA), E. French.
- Management of bacterial wilt. Kenya, Burundi. S. Ajanga (KARI), A. Rubigiri (ISABU), D.E. Berríos.
- Breeding for resistance to bacterial wilt. R. Anguiz, P. Aley, E. Guevara, E. French, H. Mendoza, K. Watanabe.
- Effect of plant extracts on *Meloidogyne incognita.* R. Anguiz, M. Canto.
- Evaluation for resistance to bacterial wilt races 1 and 3. Brazil. C.A. Lopes, J.A. Buso (EMBRAPA); E. French, R. Anguiz, P. Aley.
- Screening potato germplasm for resistance to *P. solanacearum* in Southeast Asia. DA Philippines. F. Saldivar, A. Tumapon, L. Duna, E. Maape; E. Chujoy.
- Control of bacterial wilt of potatoes in China. He Liyuan (CAAS); Song Bo Fu, E. French.
- Evaluation of clones for resistance to bacterial wilt. Colombia. J.L. Zapata, O. Hidalgo.

Combining resistances to potato viruses and fungi. H. Mendoza.

- Genetic studies and breeding for virus and viroid resistance. H. Mendoza, L.F. Salazar.
- Breeding for early blight resistance. R. Anguiz, H. Mendoza, E. French.
- Breeding potatoes resistant to the potato leafroll virus, PLRV. Poland. M. Dziewonska (IZ, IPR).
- Evaluation of potato germplasm for resistance to viruses and early blight. Brazil. J.A. Buso, S. Brune, A. Dusi, P. Melo, A.C. Torres (EMBRAPA); R. Anguiz, H. Mendoza, U. Jayasinghe.
- Evaluation of advanced potato breeding material in Andean countries. R. Pineda, E. Hernández (CORPOICA); M. Sola, J. Revelo (INIAP); R. León, E. Ortega (FONAIAP); R. Egúsquiza (INIA); V. Huanco (INIA); O. Hidalgo.
- Evaluation of advanced potato breeding material in southern South America. M. Huarte (INTA); A. Buso (EMBRAPA); A. López (MA Paraguay); F. Vilar (CIAAB); H. Mendoza, F. Ezeta.

- Utilization of *Solanum tuberosum* ssp. *andigena* germplasm in potato improvement and adaptation. USA. R.L. Plaisted, H.D. Thurston, W. Tingey, B. Brodie, E. Ewing (Cornell U); P. Gregory.
- Potato breeding for disease resistance and desirable agronomic characteristics in East Africa. J. Higiro (ISABU); B. Lemaga (IAR); D. Maingi (KARI); P. Tegera (ISAR); D. Akimanzi (MOA); N. Bouwe (INERA); H.M. Kidane-Mariam.
- Germplasm evaluation with emphasis on virus resistance. Tunisia. M. Fahem (CPRA), C. Martin.
- Evaluation of advanced potato genetic materials in Egypt. L. Amrity (MA), A. El Abassey (Ainshames Faculty of Agric.), R. El-Bedewy, C. Martin.
- Evaluation of advanced potato genetic materials for Cameroon and countries with similar agroecological conditions. GTZ. National breeders of West and Central Africa, H. Mendoza.
- Selection of advanced virus-resistant potato materials with adaptation to North Africa and the Middle East. P. Rousselle (INRA), H. Mendoza.
- Evaluation of potato germplasm for earliness and resistance to PVY, PVX, PLRV, and *Alternaria solani.* Uruguay. J. Vilaró, C. Crisci (INIA); H. Mendoza.
- Evaluation of advanced potato breeding materials in Central America and Caribbean. PRECODEPA. NARS breeders, J. Landeo, F. Ezeta.

Control of field and storage diseases of Andean roots and tubers including potato. T. Icochea.

- Control of tuber and soil-borne diseases of potatoes. L. de Lindo, H. Torres, E. French.
- Erwinia disease in different phases of the Tunisian potato seed program. M. Mahjoub, M. Romdhani (ESH); C. Martin.
- The importance of Erwinia diseases during the different phases of Tunisia's potato seed multiplication program. Ministry of Foreign Relations (France) and ESH. S. Priou, R. Cortbaoui, E. French.
- Elimination of viruses and determination of the effect of viruses and other pathogens prevalent in promising ulluco and oca cultivars. G. López (UNCP).
- Identification and characterization of bacteria and fungi pathogenic to Andean root and tuber crops. T. Icochea, H. Torres, P. Aley, W. Pérez.

Detection and control of potato viruses. L.F. Salazar.

- Antiserum production and improvement of serological techniques for virus detection. C. Delgado, V. Flores, L.F. Salazar.
- Production of antisera and standardization of virus and viroid testing procedures for potato. S.M.P. Khurana, J.S. Grewal (CPRI); M. Upadhya.
- Variability and mechanism of resistance to potato leafroll virus (PLRV). L. Salazar.
- Characteristics of the transmission of potato viruses and viroids through TPS. P. Malagamba, N. Maza, C. Barrera, L.F. Salazar.
- Development and utilization of virus detection techniques. Zhang Heling (U Inner Mongolia), Song Bo Fu.
- Characterization of new virus and virus-like diseases and confirmation of immunity to PVX and PVY. E. Fernández-Northcote, A. Gandarillas, V. Alvarez (PROINPA); L.F. Salazar.

- Epidemiology of PVY in potato seed fields and their environments. C. Cherif, M. Boudhir, K. Mnari (INRAT); C. Martin.
- Studies on the potato diseases Saq'o and Kully Onqoy. PROINPA. L.F. Salazar, E. Fernández-Northcote.

Identification and control of sweetpotato viruses. L.F. Salazar.

- Identification and characterization of sweetpotato viruses, and search for resistance. S. Fuentes, L.F. Salazar.
- In vitro eradication of potato and sweetpotato viruses and viroids. A. Golmirzaie, L.F. Salazar.
- Virus diseases of sweetpotatoes: Genetic resistance. G. Loebenstein, H.J. Vetten (Volcani Center); L.F. Salazar.
- The influence of viruses on sweetpotato yields in Uganda: Assessment of the potential to use clean planting material to increase yields. R. Gibson, R. Mwanga (ODA); E. Carey.

Control of bacterial and fungal diseases of sweetpotato. T. Icochea.

- Etiology of sweetpotato chlorotic leaf distortion. C.A. Clark, R.A. Valverde, D.R. La Bonte (LSU).
- Morphological and pathogenic characterization of *Elsinoe* (*Sphaceloma*) *batatas*: Causal agent of sweetpotato scab. J. Lenné (NRI), E.T. Rasco, E. French.

Molecular approaches for detection and control of pathogens. M. Querci.

- Molecular analysis of genetic resistance to viruses and development of molecular probes. M. Querci.
- Molecular analysis of genetic resistance of sweetpotato to viruses and development of molecular probes. M. Querci, L.F. Salazar.

Virology of Andean roots and tubers. L.F. Salazar.

- Virology of Andean tuber and root crops. UNMSM. R. Estrada, L.F. Salazar, M. Hermann.
- Cleanup, management, and conservation in vitro of germplasm of *Ullucus tuberosus, Oxalis tuberosa, Tropaeolum tuberosum,* and *Solanum andigena.* C. Granados (U Tacna).
- Virus elimination from native potato cultivars. R. Mejía (INIA).
- Identification and characterization of viruses in Andean roots and tubers. F. Barrantes (UNSCH), L.F. Salazar, C. Lizárraga.
- Select, divulge, and implement specific methods of virus detection for Andean roots and tubers. Collaborators from U Ayacucho, UNCP, INIA, CICA, PROINPA, CORPOICA, INIAP; L.F. Salazar.
- Determine the effects of viruses in cultivars of Andean roots and tubers. Collaborators from UNCP, CICA, PROINPA, ICA, INIA; L.F. Salazar.

PROGRAM 4

Integrated Pest Management

During 1993-1994, the Integrated Pest Management Program did a significant amount of work to integrate previously developed IPM components into IPM programs, and tested these programs under experimental and farmers' conditions. Pest species include the Andean potato weevil, three species of potato tuber moth, the potato leafminer fly, and the Asian sweetpotato weevil. Countries involved are Bolivia, Peru, the Dominican Republic, Cuba, and Tunisia. At the same time, we continued to develop new IPM components, particularly for breeding for pest resistance in both potato and sweetpotato plants. We also studied the role of parasitoids in the population dynamics of leafminer flies and potato tuber moth, and the effects of local cultural practices on African sweetpotato weevil infestations under mounds (piecemeal harvest) and in furrow cropping in Uganda. In Southeast Asia, we assessed the importance of the sweetpotato weevil, developed interactions with NARS, and evaluated the potential of the farmer field school model for CIP's IPM programs for sweetpotato in the region. The first pilot IPM field schools were organized recently in Vietnam.

We contrasted previously developed individual IPM components with conditions of the integration plots and pilot areas and adjusted them accordingly. This work involved research on potato tuber moth pheromones, trapping of leafminer flies, mass trapping of the Asian sweetpotato weevil using pheromones, and crop rotation schemes for management of the potato cyst nematode and potato rosary nematode.

All of this work corresponds to CIP's IPM research strategy (Figure 1). The goal is to continue to develop technologies that farmers can apply to reduce pest damage that limits crop productivity, without the use of costly and dangerous pesticides.

We conducted intensive training activities and produced diffusion materials to help implement IPM in pilot areas as well as on a large scale. The extension work itself was under the responsibility of NARS and NGOs. Significant roles were played by the Institut National de la Recherche Agronomique de Tunisie (INRAT), Tunisia; Instituto de Investigaciones de Viandas Tropicales (INIVIT), Cuba; Programa de Manejo Integrado de Plagas (MIP), Dominican Republic; CARE-Peru and the Centro de Investigación, Educación y Desarrollo (CIED), Peru; and Programa de Investigación de la Papa (PROINPA), Bolivia.

Management of the Potato Tuber Moth

The potato tuber moth (PTM) is the most injurious pest of potatoes in fields and stores in warm, dry areas of the world, such as North Africa and the Middle East, Mexico, Central America, and the inter-Andean valleys of South America.

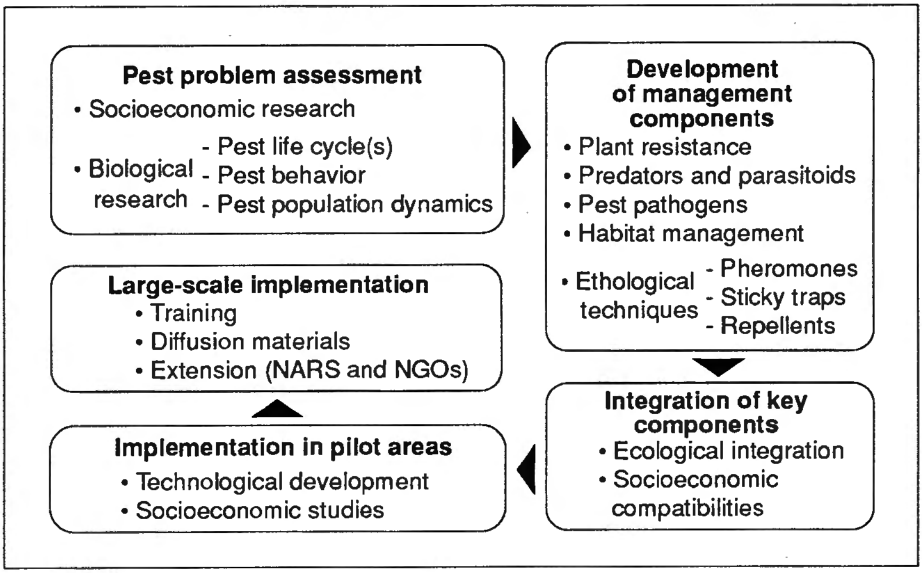


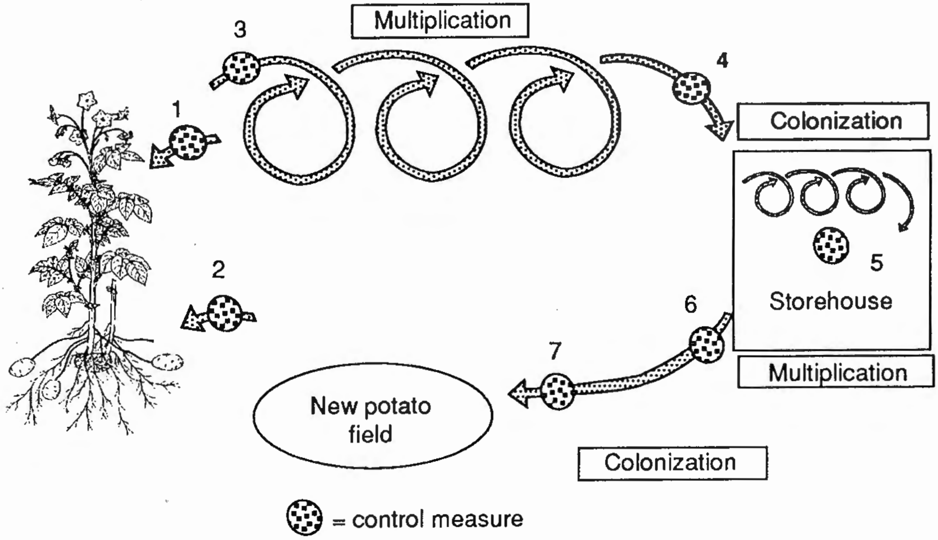
Figure 1. CIP's IPM research and implementation strategy.

Species involved are the common PTM, *Phthorimaea operculella*, of worldwide distribution; the Andean PTM, *Symmetrischema tangolias (plaesiosema)*, in the mid-elevation Andean region; and *Tecia solanivora*, a Central American species that has spread to Venezuela and Colombia in recent years. There is still another species, *Scrobipalpuloides (=Scrobipalpula) absoluta*, whose damage is restricted to the aerial part of the plant.

Work in the Middle East and North Africa

The IPM developmental phase for management of this pest varied according to locality, species of PTM, and progress in previous work. In Tunisia, where the IPM program for PTM is already well developed, most work related to monitoring PTM field populations using pheromone traps to measure the efficiency of cultural practices (hilling and irrigation). Sprays were phased out under field conditions. The PTM problem is restricted to nonrefrigerated store conditions. Here, highly toxic compounds have been replaced with the bioinsecticides *Bacillus thuringiensis* or PTM granulosis virus, which are not toxic to humans. INRAT is multiplying this virus and distributing it to farmers. The experience in Tunisia could soon be replicated in Egypt, where the government and farmers have expressed their interest in establishing IPM programs for PTM in order to reduce the current intensive use of pesticides. Figure 2 depicts CIP's IPM program for PTM.

We have evaluated specific IPM components in different places. In Morocco, the Complex Horticole of the Institut Agronomique et Veterinaire Hassan II has found that appropriate hilling is a key component in PTM management in that country. In Yemen, we are evaluating PTM parasitoids, including some native species. In the



Components

1. Resistant cultivars (not in commercial use yet).
2. Irrigation and hilling.
3. Pheromones and selective insecticides.
4. Sorting prior to storage.
5. Baculovirus or *Bacillus thuringiensis,* repellent plants.
6. Trapping in store (pheromone or light traps).
7. Trapping in the field (pheromone traps).

Figure 2. Potato tuber moth: population dynamics and management.

Dominican Republic (Valley of Constanza), the adoption of pheromone traps led to better timing for spraying, which resulted in 50% fewer sprays in the field. In stores, preliminary trials were conducted with the granulosis virus instead of the highly toxic insecticides currently used.

Work in the Andean region

In the Andean region, the situation was more complex because of the simultaneous presence of the common PTM and the Central American PTM species in Venezuela and Colombia; and the common PTM and Andean PTM species in Peru and Bolivia (Tarija). Research concentrated on the life cycle and behavior of the Central American species in Venezuela (FONAIAP) and Colombia (ICA and CORPOICA), the use of traps with specific pheromones, and the determination of susceptibility of this species to the granulosis virus used against the common PTM species. Based on these findings, we established pilot areas in Mérida (Venezuela) and in Pamplona, Rionegro, and Tunja (Colombia). In all these places, researchers are evaluating under local conditions the various IPM components developed by CIP. During the first two growing seasons, use of the IPM program in Pamplona resulted in a 50% reduction in the use of pesticides compared with farmers' practices.

In Peru and Bolivia, part of our research was related to the Andean PTM species. In this case, no sex pheromone is available yet. Research on the isolation, identification, and synthesis of a specific pheromone is being conducted by the Research Institute for Plant Protection (IPO-DLO), Netherlands. The first samples with a synthetic compound demonstrated a strong attractant effect. For effectiveness of the granulosis virus, the Andean PTM species was more than 1,000 times less susceptible than the common PTM (Figure 3). Furthermore, the larvae did not develop the disease; they were killed by toxicosis as neonate larvae. For this reason, we cannot use this species for multiplication of the granulosis virus.

We have established pilot areas for management of the common PTM and Andean PTM species in southern Peru (Urquillos, Cusco), in the central Sierra (Huancayo), and in the north (Cajamarca). PROINPA, in Bolivia, has established a pilot area in Mizque. There, infestations of tubers under the IPM program, after three months of storage, were below 10%, whereas damage averaged 40% in the traditional system.

Biological control

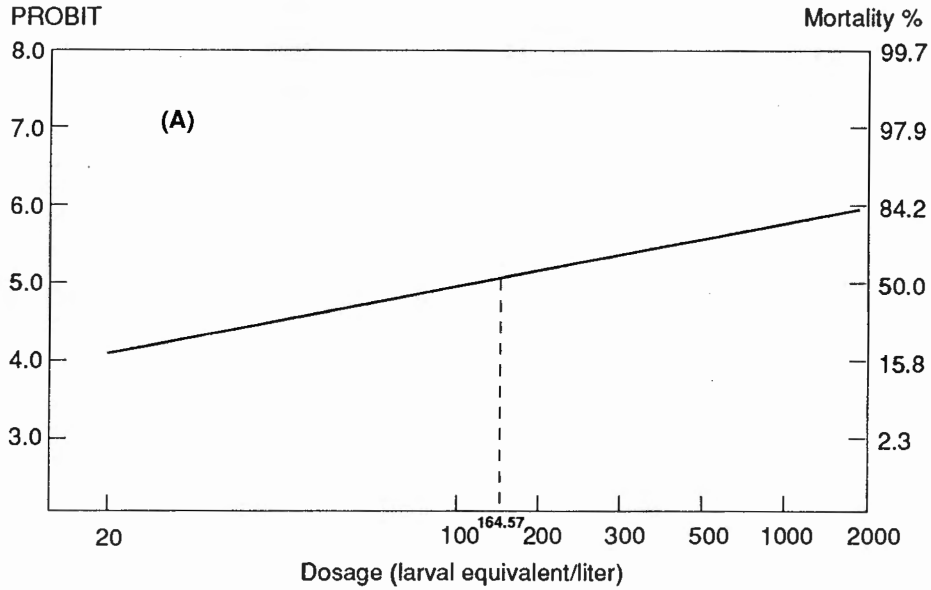
The granulosis virus plays a key role in the management of PTM in stores. CIP has developed a simple technique for multiplication and formulation of the virus. The dust formulation (20 infected larvae/kg) is used at 5 kg/ton of stored potatoes. The virus is being produced in Peru (CIP and NGOs), Bolivia (PROINPA—40,000 infected larvae per season), Egypt, and Tunisia (INRAT). Several other countries and institutions have expressed an interest in having their own production units. Meanwhile, samples are being shipped for testing purposes when requested.

CIP also developed a simple method to multiply the egg-larval polyembryonic parasitic wasp *Copidosoma koehleri*. This species has been reared and released in Peru, Bolivia, Colombia, Tunisia, Yemen, India, and other countries, in most cases successfully. Tunisia and Yemen reared the parasitic wasps *Diadgema molliplum*, *Chelonus phthorimaea*, and *Orgilus lepidus*, besides *C. koehleri*. Some refinements are still needed to improve the production and define the ecological conditions that would ensure the successful introduction or release of *C. koehleri*. Recent tests have demonstrated that, for laboratory multiplication of parasites, fresh eggs (1-2 days old) are more productive. Laboratory-reared wasps had a limited searching capacity; 80% of total parasitism was produced within 10 cm of the release point and the remaining 20% up to 30 cm. Under store conditions, parasitism was low and limited to the superficial layers of potatoes.

Periodic field sampling in the central Coast of Peru showed that the predominant parasitoid was *Dolichogenidea (=Apanteles) gelechiidivoris*, with 26-41% parasitism in farmers' fields (with application of insecticides) and 57% parasitism in an isolated field without the use of insecticides. Species of *Temelucha* and *Pristomerus* were present only in the nontreated field with 13% parasitism.

Plant resistance

Conventionally, plant resistance is considered a key component of any IPM program. For PTM management, however, resistant plants are not yet part of our program. But a great deal of breeding work is going on, both



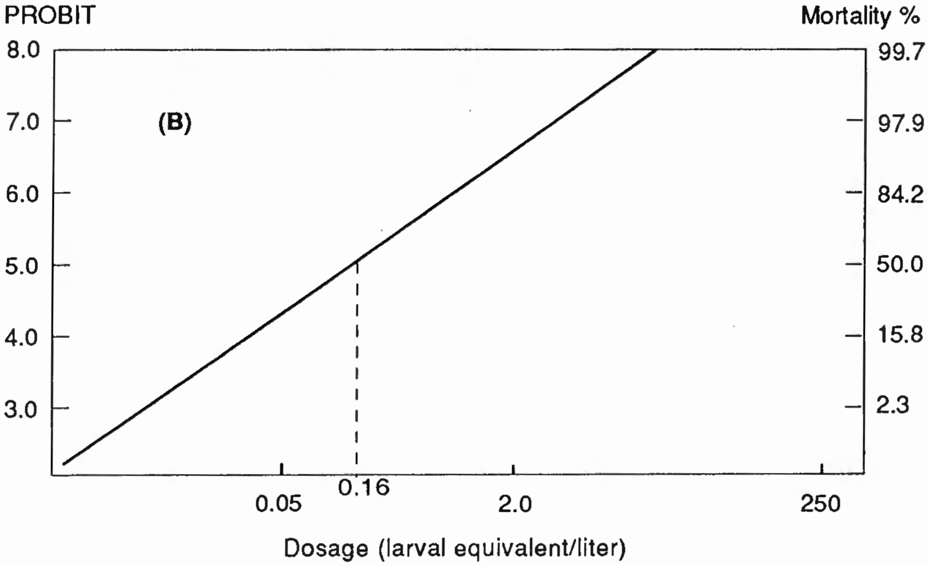


Figure 3. Dosage/mortality regression line of granulosis virus on (A) *Symmetrischema tangolias* and (B) *Phthorimaea operculella*.

conventional and with genetic engineering, to obtain potato plants that are resistant to the pest and at the same time high yielding and acceptable to farmers and consumers.

To find sources of resistance, we screened 764 accessions of the wild potato collection using the open-container, free-choice infestation method, and recorded 33 accessions as resistant. Likewise, 283 clones of cultivated potatoes undergoing the same test resulted in 6 clones with moderate resistance. Finally, 966 clones derived from 16 families with resistant parentals, glandular trichomes, and TS-5 (TPS parentals) resulted in 23 resistant and 38 moderately resistant clones. Another group of 46 clones previously selected from the TPS breeding lines rendered 4 resistant clones.

The evaluation of transgenic potato plants containing the Bt CryA(b) toxin gene continued with tests under laboratory, greenhouse, and controlled field conditions. We did this work in collaboration with Plant Genetic Systems (PGS), Belgium. Forty-one transgenic lines of Sangema and Cruza-148 tested against PTM under greenhouse conditions showed 100% and 74% resistance, respectively. We evaluated under controlled field conditions 14 transgenic lines of LT-8 and Sangema clones that showed high resistance to PTM in greenhouse tests. Yields were similar to those of the nontransformed plants (Table 1).

Studies on PTM-plant interactions showed that, under field conditions, tall, erect plants are less infested (15% infestation) than shorter, decumbent plants (100% infestation). For piles of clean stored tubers, infestation starts on the outer layers and progresses inward as new moth generations emerge.

Table 1. Transgenic potato plants containing the *Bacillus thuringiensis* insecticidal crystal protein (CryA(b)), toxic to potato tuber moth (PTM).

Clone	Line	PTM mortality (%)	Yield (g/plant)
LT-8	Control	0	318
	DST 36-8	100	346
	DST 36-4	100	323
	DST 34-2	100	318
	DST 34-1	100	314
	DST 36-1	100	304
Sangema	Control	0	169
	DST 39-2	100	205
	DST 39-3	100	141

Management of the Andean Potato Weevil

The Andean potato weevil, *Premnotrypes* ssp., is the most serious pest of potatoes at high altitudes (above 2,800 m) in the Andean region (Bolivia, Peru, Ecuador, Colombia, and Venezuela). In this region, land divided into small units has made impractical the ancient system of communal rotations that so efficiently controlled this and other pests. Under recent conditions, 15-40% of tubers are commonly infested at harvest despite the use of insecticides. Fields are sometimes abandoned because of high infestations.

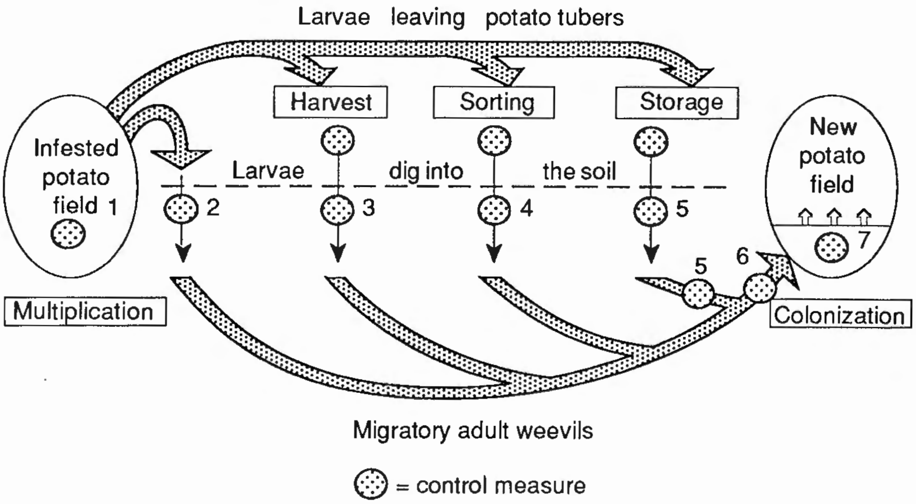
Three main weevil species that share similar biological and ecological characteristics have been identified: *P. vorax*, occurring in northern Peru, Ecuador, Colombia, and Venezuela; *P. suturicallus* in central Peru; and *P. latithorax*, in southern Peru and Bolivia. Two other species of different genera, *Rhigopsidius tucumanus* and *Phyrdenus muriceus*, are largely restricted to Bolivia and are being studied by PROINPA. Weevils that infest other Andean tubers such as oca (*Oxalis tuberosa*), ulluco (*Ullucus tuberosus*), and mashua

(*Tropaeolum tuberosum*) have also been considered pests of potato. However, our recent tests indicate that these weevil species do not infest potatoes.

The first pilot area for management of the Andean weevil (see scheme of IPM program in Figure 4) was established in Chinchero, Cusco, where damage averaged 44% infested tubers in 1990. We have used this successful experience as a model for establishing new pilot areas: one, in the community of Aymara, Huancayo (central Peru), with an average damage of 25% despite the use of insecticides; and one in Chilinpampa, Cajamarca (northern Peru), with an average damage of 60% with no use of insecticides (Figure 5). Each site has a different weevil species, and different socioeconomic conditions. The management programs, however, are basically similar, with minor adjustments to new conditions. In Chinchero, weevil damage decreased, from 14% in 1992 to 8.5% at the end of 1994. In Chilinpampa, adoption of the IPM program reduced damage from 60% in 1992 to 17% two years later, without the use of insecticides.

We are evaluating two other sities for establishment of pilot areas: Vereda Sote, Tunja, in Colombia, and Mérida in Venezuela.

In order to improve the efficiency of IPM components in the pilot areas, we conducted additional investigations on insect behavior and seasonal occurrence at the new sites (Figure 6). We tested all the other components—winter plowing and the use of chickens as predators, hand-picking of adult weevils, the use of



Components

1. Winter plowing.
2. Elimination of volunteer plants.
3. Use sheets or turn over soil in winter.
4. Use sheets or turn over soil in winter.
5. Fungus treatment of soil or trenches around store.
6. Trenches around new field.
7. Border barriers.

Figure 4. Andean potato weevil: population dynamics and management.

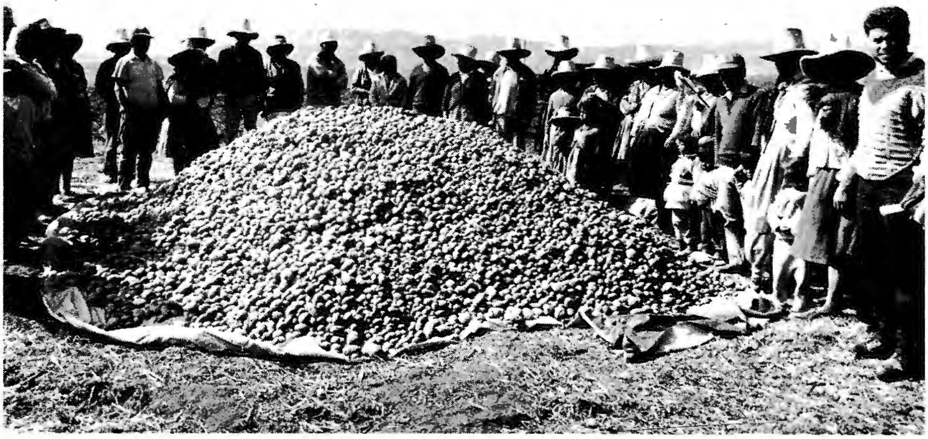


Figure 5. Use of blankets (to prevent weevils in harvested tubers from returning to the soil) during the sweetpotato harvest, an IPM component for management of the Andean weevil in the community of Chilinpampa, Cajamarca, Peru.

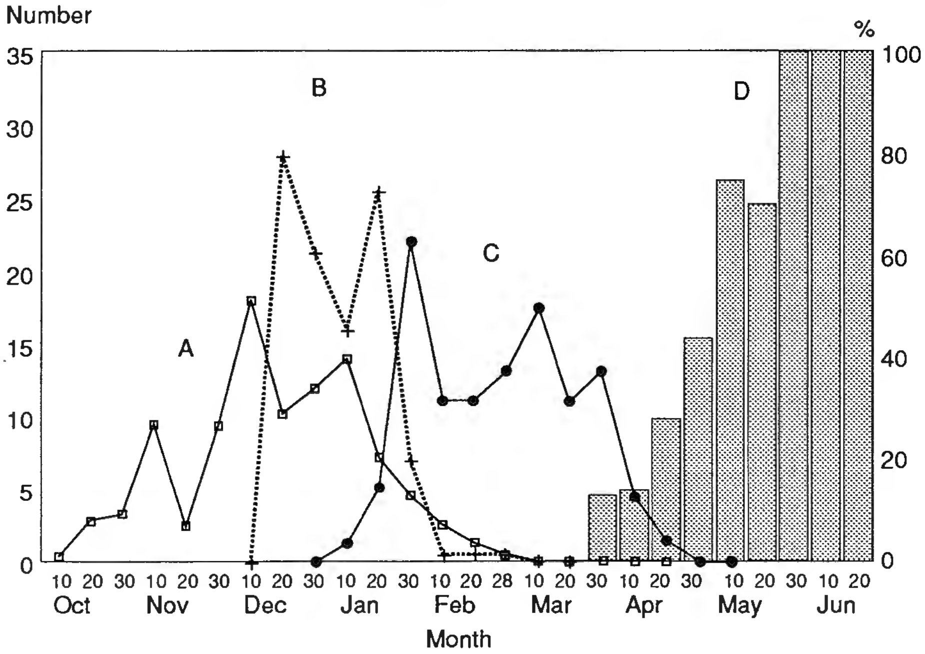


Figure 6. Aspects of insect behavior and seasonal occurrence of Andean potato weevil: (A) emergence of overwintering weevils from rustic stores, (B) immigration of adults into a new field, (C) oviposition sequence, (D) infestation of potato tubers in the field, Chinchero, Cusco, Peru, 1992-1993.

sheets at harvest and sorting, the use of the parasitic fungus *Beauveria brongniartii* in stores, and field barriers—and evaluated their acceptance by farmers.

PROINPA, in Bolivia, worked on chemical components for the management of *Rhigopsidius tucumanus.* This work included deinfestation of seed tubers with aluminum phosphide (treatments killed 90% of the insects but were toxic to tubers, thus reducing sprouting) and soil treatments with carbofuran and isazofos that were effective.

The strategy for making the IPM program self-sustained in Huatata, Chinchero, is based on the direct involvement of farmers, the municipality of Chinchero, the Instituto Nacional de Investigación Agraria (INIA), the University of Cusco, and the NGO ARARIWA in short courses and field days. In these activities, farmers participating in the IPM program played active roles and transferred their knowledge and experience to other farmers. The municipality of Chinchero has taken on the responsibility of producing the fungus *B. brongniartii.* The municipality recently obtained a loan to construct a larger producing unit that will meet the demand for the fungus beyond community boundaries.

The success of this program (as well as the IPM program for PTM) has generated interest in other institutions to participate in its diffusion, such as the NGOs Jorge Basadre in Cajamarca, TALPUY in Huancayo, and CARE. CARE, with USAID funding, is developing a program that covers 3,500 farmer families over a period of three years (Figure 7). CARE technical staff have been trained and provided with all the necessary diffusion materials for their work. CIP provides technical supervision.

M. MEJIA

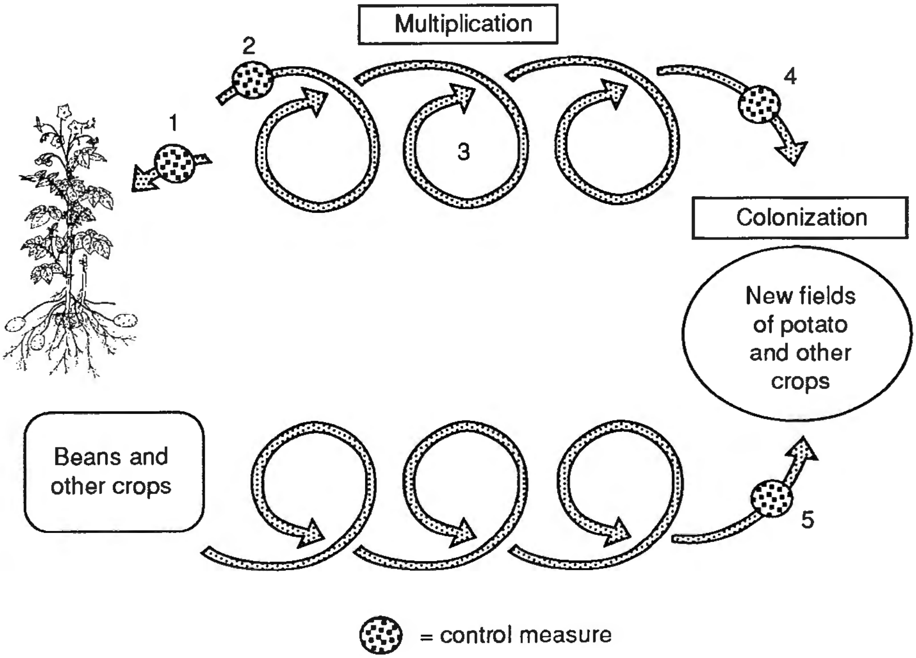
Figure 7. CARE (an international development NGO) works to diffuse IPM technology developed by CIP in the community of Barro Negro, Otuzo, La Libertad, Peru.

For individual IPM components, all conventional components are present in the IPM program except plant resistance. All native cultivars were susceptible to the weevil; however, in screening tests for resistance using the germplasm bank, some accessions showed moderate resistance. The adoption of these or other improved resistant materials by farmers who have cultivated traditional potato varieties for centuries is doubtful. These farmers plant several native cultivars, not only for their use in traditional cooking but also to reduce the risk of production losses caused by unfavorable biological and climatic conditions. For these reasons, plant resistance is not yet a part of APW management.

Management of the Leafminer Fly

The leafminer fly, *Liriomyza huidobrensis*, is a polyphagous insect that becomes a serious pest in areas where insecticides are used intensively and where particularly susceptible cultivars are planted. These conditions occur in coastal Peru and Chile and in certain areas of Brazil, Central America, Kenya, and other countries. In Peru's Cañete Valley, this pest reduced yield 45-62%, as an average for six cultivars.

The management strategy for this pest (Figure 8) differs from that of the potato tuber moth and Andean potato weevil



Components
1. Resistant or tolerant plants.
2. Sticky yellow traps.
3. Increase of natural enemies.
4. Selective insecticides.
5. Avoid other crops nearby that host leafminer fly.

Figure 8. Leafminer fly: population dynamics and management.

already mentioned. It is based on the use of resistant or tolerant cultivars and habitat management to favor the increase of natural enemies, which are normally quite effective in balanced agroecosystems. The use of sticky yellow traps to capture adult flies reduces the rate of increase of the pest. The use of selective insecticides (insect growth regulators) when necessary is a final step.

CIP has evaluated several mechanisms of potato plant resistance against this pest, including hypertrophic growth of the leaf tissue surrounding the incrusted eggs (so that eggs are exposed to desiccation and predatory action); hypersensitivity, in which eggs are surrounded by necrotic tissue so that newborn larvae cannot survive; leaf tolerance of mining damage, in which the leaf remains turgent (clones ES93053 and C89.294) whereas it dries out in a susceptible plant; and a less understood mechanism apparently related to glandular trichomes. Plants with high trichome densities had 60-90 fewer eggs compared with susceptible cultivars (there was no evidence of a trichome trapping effect). Some materials have antixenotic and larval antibiotic effects.

Field tests with 314 clones derived from resistant parents resulted in 3 resistant and 145 moderately resistant clones, all with yields higher than 1,000 g/plant. Similar yields were obtained with 40 tolerant clones despite their relatively high foliar infestation.

Some advanced clones currently being tested have good levels of resistance to and tolerance of LMF and good agronomic characteristics. The most advanced materials have been evaluated with the participation of farmers (to test for agronomic traits) and consumers (to test for use in cooking, such as boiled potatoes, French fries, and chips) (Table 2).

Table 2. Performance of seven best potato clones resistant to leafminer fly selected by farmers for agronomic characters, Tambo Valley, Arequipa, Peru, 1994.

Pedigree	Tuber characters[a]			Plant yield (kg)	Dry matter (%)
	Shape	Unif.	Ranking		
282LM87B	9	9	9	1.20	23
136LM86B	7	9	8	0.80	28
Revolución[b]	6	9	7	0.75	23
66LM86B	8	9	8	0.70	20
320LM86B	8	8	8	0.70	22
92LM87B	7	8	7	0.70	22
153LM87B	7	8	8	0.65	21
220LM87B	8	8	8	0.65	22

a. On a scale of 1 to 9, where 1 = poor, 9 = best.

b. Susceptible Peruvian cultivar (sprayed for LMF control).

Intensive research on LMF population dynamics, including the influence of climatic conditions and the role of natural enemies (the sequence of endo- and ectoparasitoids), is under way. There is evidence of diapause in the endoparasitoids *Halticoptera arduine* (3.5 to 8 months), *Chrysocharis* sp. (3.5 to 8 months), and *Ganaspidium* sp. (5.5 to 8 months) collected in winter and autumn. *H. arduine* represented 91% of the diapausing parasitoids in the Cañete Valley and 62% in La Molina, Peru. The factors that induce and terminate the diapause are not known. Several species of weeds that host LMF may also be considered natural reservoirs of the parasitoids. It is interesting to note that the relative abundance of parasitoids varied with weed species. Pteromalids were more numerous in *Stachys arvensis*, Eulophids in *Solanum americatum*, Cynipids in *Galinsoga parviflora*, and Braconids in *Malva parviflora*. We sampled a total of 25 different species of weeds. In a study on the capacity of parasitoids to survive after insecticide sprays, we found that *Diglyphus* sp., an ectoparasitoid, was able to survive cyromazine (an insect growth regulator) treatments.

Sticky yellow traps had a wide acceptance by farmers, probably because they see the flies trapped on the surface (Figure 9). We are studying the real value of the traps. In experimental plots, six traps (0.5 x 0.5 m, replaced twice) captured 2.5 million flies and 154,000 parasitoids in 1,100 m^2 during the cropping season.

In experimental plots using a susceptible cultivar (Revolución), a selective insecticide (cyromazine), and monitoring of the timing of application, two sprayed plots yielded 1.1 kg/plant and the control plot 0.27 kg/plant. The average number of sprays in the Cañete Valley, where the experiment was conducted, was 10.

The first pilot area for LMF management was established in the Tambo Valley (southern Peru), with direct participation of CIED, an NGO. In a two-year period, participating farmers benefited from a reduction in the number of insecticide sprays from six per season to zero to two. Farmers are increasingly asking to be incorporated into the IPM program.

Management of Sweetpotato Weevils

Sweetpotato weevils are the most important sweetpotato pest in the world. Different species prevail in different geographic areas. The South American species, *Euscepes postfasciatus*, occurs in South America and a few other places. The Asian species, *Cylas formicarius*, is present in the Caribbean, southern United States, and Asia. African species *Cylas puncticollis* and *C. brunneus* are restricted to sub-Saharan Africa.

J. ALCAZAR

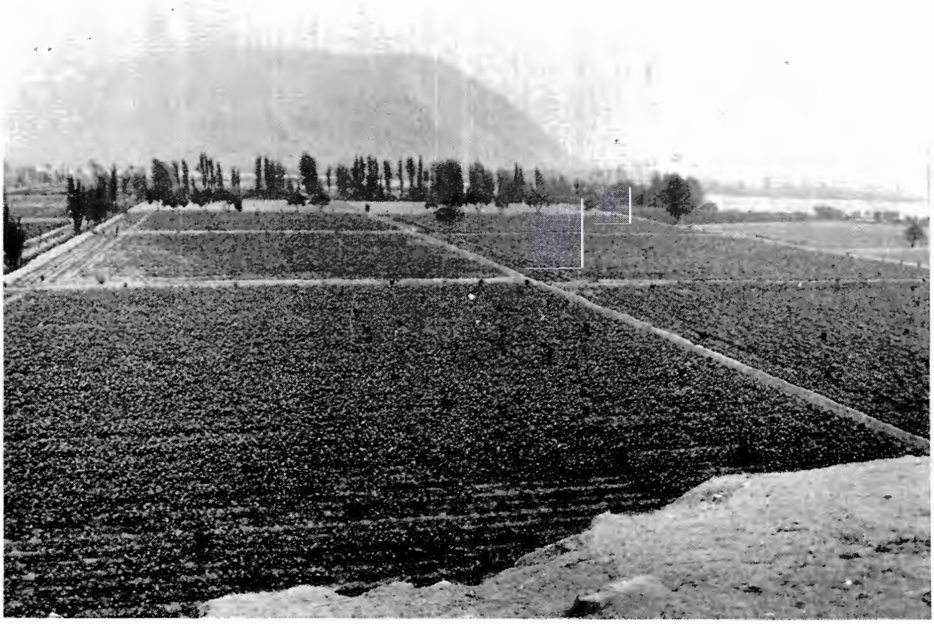


Figure 9. Use of sticky yellow traps in leafminer fly management in the Tambo Valley, Peru, as part of IPM work done by the NGO CIED.

CIP's strategy for managing the Asian species focuses on a series of measures designed to use noninfested sweetpotato cuttings as planting material, reduce the physical and time exposure of the crop to infestation in the field, increase the action of natural enemies (predatory ants and the fungus *Beauveria bassiana*), and reduce the rate of increase of the population by mass trapping of males with sex pheromones. Despite intensive efforts to develop true resistant plants (that is, with antibiosis or antixenosis mechanisms), little has been achieved so far. Therefore, attention is turning to pseudoresistance—escaping weevil damage through deeper formation of storage roots and short-season varieties, which are less time-exposed to weevil infestation (Table 3).

Table 3. Evaluation of two IPM components (clones and harvest timing) for the management of sweetpotato weevil in Horquita and Arimao, Cuba, 1994.

Clone	Infestation (%)		Yield (t/ha)		Harvest timing (days)
	Clone	Check	Clone	Check	
C85-48	4.7	6.9	18.2	13.5	100
C78-354	12.7	27.8	20.1	8.0	120
Yabú	14.4	23.3	13.1	6.1	150

The Cuban experience

CIP is developing this program in close coordination with INIVIT, the Cuban research institution in charge of tropical staple food crops in that country, and MIP, the Dominican institution working on IPM. Pilot areas are located in Arimao, Cienfuegos Province, Cuba, and in La Vega, Dominican Republic.

Until 1990, Cuban farmers used 12-14 sprays to control the sweetpotato weevil. In 1991-1992, when insecticides from the Soviet Union were no longer available, weevil damage increased to 40-50% of production. But after two years of using IPM, with financial support from the Organization of Petroleum Exporting Countries (OPEC) Fund for International Development, damage dropped to 12% (1-18%) in the pilot and surrounding areas, without the use of insecticides.

Although the adult weevil is able to fly long distances, studies in Cuba indicate that planting infested sweetpotato cuttings results in the insect spreading to new fields in the form of egg-larvae infested vines and free adult weevils. Research on oviposition preference shows that about 60% of the eggs are deposited in the basal 10 cm of the vine, 30% between 10 and 30 cm, and 10% 30-40 cm from the base in plants 100 days old used to produce cuttings for planting new fields. Therefore, the basal part of the vine (40 cm) should not be used as planting material. Cuttings selected for planting are submerged in a water suspension of the fungus *B. bassiana* prior to planting. Any adult weevils present in the cuttings become infected by the fungus and die in two to three days.

INIVIT has investigated the use of the predatory ants *Pheidole megacephala* and *Tetramorium guineense*. After studying the biology and behavior of the ants, including their efficiency as predators, researchers developed a technique to transfer the ants from their natural or artificial reservoirs to sweetpotato fields. Experiments in farmers' fields colonized with 100 nests/ha showed reduced weevil damage at harvest of 2.5% (with *P. megacephala*) and 3.5% (with *T. guineense*). Damage in the control fields with insecticide treatments was 6-10%. Experiments have demonstrated the compatibility of the predatory ants with *Beauveria bassiana* and *Bacillus thuringiensis*.

Sex pheromones

The attractant effect of the Asian sweetpotato weevil sex pheromone has become an important component in management of the pest. The sex pheromones were initially used to monitor the weevil population. Investigations in Cuba and the Dominican Republic have demonstrated their efficiency in reducing pest populations when a trapping or killing device is used. If no trapping device is used, males attracted to the lure are killed by spraying insecticides or a suspension of *B. bassiana* around the sex pheromone unit. Research findings from field trials indicated that 16 traps/ha is recommended, the normal dosage of 1 mg of active ingredient/septum can be reduced to 0.1 mg with negligible loss of efficiency, and that traps should be installed as early as possible, no later than 30 days after planting. In Uganda, preliminary tests with a synthetic compound (decyl (E)-2-butenoate) identified by the NRI chemical ecology group showed that this compound attracted males of one of the African sweetpotato weevils, *Cylas puncticollis*. This suggests that this compound may be part of the sex pheromone.

Use of *Beauveria bassiana*

Research conducted in Cuba demonstrated that the entomopathogenic fungus *Beauveria bassiana* can play an important role in controlling sweetpotato weevil. Cuban farmers spray the fungus spore suspension around pheromone traps instead of insecticides. It is well established that soil moisture is important for the survival of the fungus, but the effectiveness of broadcast applications cannot be considered consistent yet. In fact, preliminary field trials in Uganda were not successful. We still need to characterize the conditions that favor the development and effectiveness of the fungus in the field.

Cultural practices

The influence of rainfall and soil moisture on the level of sweetpotato infestation has been well established in experiments in Cuba, the Dominican Republic, and Uganda. In Cuba, infestation during the dry season was 4-5 times higher than during the rainy season or when irrigation was available. Weevil infestation is favored by soil cracking, which becomes more severe 80-90 days after planting, at the time of storage-root bulking. Proper hilling and irrigation were found to be effective at that time in avoiding direct access of the weevil to the sweetpotato through soil cracks. In Uganda, we are conducting tests to verify the effect of hilling and filling of soil cracks under conditions of planting in mounds and piecemeal harvesting.

Plant resistance

Sweetpotatoes with weevil resistance are a desirable IPM component, but significant levels of resistance have so far been elusive. Research conducted at Mississippi State University under a CIP contract has reported some progress in increasing resistance levels through selection and intermating. Selected clones are producing a higher percentage of uninjured roots than cv. Regal, which had the highest level of resistance available at the beginning of this research. The identification of new sources of resistance might result in more rapid gains in producing stable weevil resistance. In Cuba, seven selected clones with some resistance are being used in polycrosses and backcrosses for combining resistance with good yield. Because breeding for true resistance is a long-term and complicated process, the Cuban breeding program is considering two other approaches: deep storage-root formation to avoid or reduce the possibilities of weevils contacting the roots, and short-season cultivars to reduce the time of sweetpotato exposure to weevil infestation. Under the same conditions, a short-season (80 days) clone had only 50% of the infestation reported for an intermediate (110 days) clone. Long-season clones (more than 130 days) were 3.5 times more infested than short-season clones.

For another sweetpotato pest, the biology, natural enemies, and economic importance of the sweetpotato butterfly, *Acraea acerata*, are being studied in Uganda.

Management of Potato Cyst Nematodes

Potato cyst nematodes (PCN), *Globodera pallida* and *G. rostochiensis*, are a serious soil pest of potatoes in the Andean region (where they are native), in temperate regions, and in a few other highland locations. Although PCN reduces yield by about 30%, farmers usually overlook its occurrence because of its minute size and the lack of specific aboveground symptoms. Research on this pest focuses on two aspects: breeding and evaluation of resistant clones, and field management trials (mostly rotations) for nematodes.

Although there are different races of *G. pallida*, the most common are P4A, P5A, and P6A, whose interactions with the potato plant vary to such an extent that a plant resistant to one race may be susceptible to another. For this reason, the three main races were used in resistance evaluation tests with the pot test in the screenhouse and the petri dish test in the laboratory. Further testing took place under natural nematode infestations in the field.

From crosses made in 1992, 400 genotypes were tested for the first time in pots. Results indicated that 36% were resistant to P4A, 26.5% to P5A, 9.3% to P6A, and 2.8% were simultaneously resistant to the three races. We subjected 314 previously selected clones to the petri dish test. From 95.7% to 98.1% of the clones were resistant to individual races, and 71% were resistant to the three races.

Field testing included 77 genotypes that were evaluated for a second year. Of these, 45 inhibited the development of female nematodes. From these, 19 were selected for agronomic characteristics, including yields higher than those of cv. María Huanca, a resistant cultivar released in 1989. Seven other genotypes were selected as tolerant.

Another group of clones (85) was field tested; 73% confirmed their resistance and 10 were selected for high yield. Seven were considered tolerant.

Studies in Bolivia by PROINPA confirmed the presence of both *G. rostochiensis* and *G. pallida*, which caused yield losses of up to 58% in infested areas. Previously selected native potato cultivars confirmed their resistance to mixed populations of *Globodera*. Some clones were also resistant to *Naccobus aberrans*. Selected clones fron PROINPA and CIP breeding programs showed resistance, good yield, and good quality. Clones G87523.8, G87540.1, G87368.1, G87323.4, 91-168.2, 91-168.5, 90-128.21, and 90-96.8 were selected for use in PCN management trials in farmers' fields.

Management of the Potato Rosary Nematode

The potato rosary nematode (PRN), also called the false root-knot nematode (FRKN), *Naccobus aberrans*, is a severe pest in the Andean plateaus of Peru and Bolivia, where losses vary from 11% to

62%. The presence of many cultivated and noncultivated plant hosts (69 species, 17 families) limits alternatives for rotations and reduces their efficiency. Therefore, management of this nematode mainly focuses on the use of resistant cultivars and soil amendments with organic matter, and the potential use of "trap plants" (*Distichus umilis*, *Bromus unioloides*, *Triticosecale* cv. Renacer, and *Hordeum vulgare* cvs. Lucha and IBTA-BO).

Resistant genotypes from CIP and PROINPA with high levels of resistance and high yield potential were selected after testing under field conditions for more than three years. Superior clones that are ready to be included in the management of this nematode in farmers' fields are 90-225-15, 90-234-1, N8805.25, N8802.38A, G87432.3, G84371.27, and G85479.5. Percentage of root nodulation in these clones was minimal. In Bolivia, native cultivars (Gendarme, Sakampayas, Palis, and others) and clone 84-75-16 confirmed their resistance in Cochabamba field tests. Tests in Chuquisaca, however, have shown the occurrence of a more aggressive population of this nematode, which is able to overcome available resistance.

Soil amendments with sheep and cow manure at the rates of 10-15 t/ha reduced nodules to 5-18%, whereas the control plots had an average of 40% nodulation. Meanwhile, yields increased 28-45%. In Bolivia, similar results were obtained with chicken manure (7 t/ha). These results have been consistent during the past two to three years and should be taken into consideration for management of this nematode.

The third-year evaluation of crop rotations (of a five-year program with 25 different crop sequences) showed that the most economical sequences, so far, are potato-horsebean-potato and potato-barley-potato. In Bolivia, the use of *Vicia faba* and *Lupinus mutabilis* as rotation crops or green manure and early plowing (one month before planting) reduced the nematode population and increased potato yields.

Finally, because nematode-infested seed tubers are the main source of spreading the pest, we conducted trials to deinfest tubers. Thermotherapy (water at 49-50°C for 15 minutes) killed 93-100% of the nematodes. Immersion of tubers (10 min) in pesticide dilutions (fenamiphos, ethoprop, and carbofuran) was also effective.

Management of the Root-Knot Nematode in Sweetpotato

In many areas of the world, the root-knot nematode (RKN), *Meloidogyne incognita*, causes significant yield reductions in sweetpotato. This nematode is polyphagous and infests many other cultivated and noncultivated plants. Research in previous years has shown the occurrence of many sources of resistance among germplasm accessions, particularly from China, Peru, and Japan. Therefore, management of this pest is based on the use of resistant cultivars.

Clone ME12 was introduced in La Convención Valley, Cusco, Peru, as an alternative to native cultivars that were susceptible to nematodes and low yielding, and had a long growing period (which exposed them more to weevil infestations). The clone had a wide acceptance by farmers; as a result, the University of Cusco, a collaborator in the program, released the clone as a new cultivar (Alto Urubamba). A program for multiplying planting material in the area was supported by a United Nations

Development Programme (UNDP) project. We are currently testing ten new clones with advantageous traits for the region.

CIP evaluated 16,251 seedlings representing 208 families of selected materials resistant to salinity and tropical conditions for their resistance to the root-knot nematode. Some 360 genotypes (2.2%) were selected as highly resistant, 3,242 (20%) as resistant, and 603 (3.7%) as moderately resistant. These results indicate a high frequency of nematode resistance genes in the tested material. We evaluated the selected genotypes (highly resistant, resistant, and moderately resistant) under field conditions for yield and other agronomic characteristics, and selected 374 clones.

We conducted tests to characterize some clones of the pathogen-tested list for their susceptibility to RKN. Of 174 clones evaluated, 15.5% were resistant and 12.6% moderately resistant.

Training and Diffusion of IPM Technology

In order to assure that the technology developed through research reaches farmers' fields, training and other diffusion activities must be taken seriously. CIP does not pretend to replace the national extension system but to help extension workers in NARS and NGOs to do their work for the benefit of IPM technology. The conventional approach of industrial countries—scientists produce scientific articles based on their research, and extension workers use the technical information and produce extension bulletins and other materials to train farmers on adoption of IPM—does not usually work in the area of CIP's influence.

CIP's IPM program is involved in three activities related to the diffusion of IPM technology: training, preparation of IPM diffusion materials, and, to some extent, consulting.

Training

In order to establish IPM pilot areas, participating farmers need to be trained on the biology of the pest(s) and the rationale of measures considered in the program. During the execution of the program, field days are occasions for strengthening farmers' knowledge and stimulating their contributions to improving the program. Farmers in pilot programs also participate in presenting their experiences to other farmers. In addition, workshops are organized once a year to evaluate the operations and other aspects of the pilot program and to make necessary adjustments for the next year.

Training for the large-scale establishment of IPM includes short courses, workshops, talks, and field days for NARS specialists, NGO technicians, and farmer-leaders, nationally and internationally. In most cases, non-CIP local staff share the training responsibility. In some cases, such as those of INIVIT (Cuba), MIP (Dominican Republic), and CIED (Peru), staff who had participated in international workshops took full responsibility for training in their areas of influence (Table 4).

Preparation of diffusion materials

The most efficient way to reach farmers with the right message is to produce adequate training materials for extension workers (manuals, bulletins, charts, posters, slide sets, video cassettes, etc.) (Table 5). The form and content of these materials are validated previously under farmers' conditions before proceeding to large-scale production. These validated

Table 4. Training activities on IPM conducted in 1993-1994.

Country	Institution[a]	Workshops	Short courses	Field days	Talks
Dom. Rep.	MIP	—	—	430 (13)[b]	269 (13)
Cuba	INIVIT	—	105 (6)	1,126 (51)	5,163 (143)
Colombia	CORPOICA-CIP	—	—	582 (48)	1,587 (62)
Uganda	CIP	—	25 (1)	—	—
Peru					
Puno	INIA-CIP	—	127 (1)	—	—
Ayacucho	INIA-CIP	—	121 (1)	—	—
Apurímac	INIA-CIP	—	141 (1)	—	—
Huánuco	INIA-CIP	—	120 (1)	—	—
Cajamarca	INIA-CIP	—	726 (10)	119 (1)	450 (16)
Cusco	INIA-CIP	—	257 (3)	327 (2)	827 (14)
Huancayo	INIA-CIP	—	548 (6)	375 (3)	611 (6)
Lima	INIA-CIP	30 (2)	—	—	—
Tambo	CIED-CIP	—	—	300 (2)	—
Cañete	VG-CIP	—	70 (1)	—	—
Regional					
Lima, Peru	CIP	15 (1)	—	—	—
Kenya	MENA	12 (1)	—	—	—

a. MIP = Manejo Integrado de Plagas, INIVIT = Instituto Nacional de Investigación en Viandas Tropicales, CORPOICA = Corporación del Instituto Colombiano Agropecuario, INIA = Instituto Nacional de Investigación Agraria, CIED = Centro de Investigación, Educación y Desarrollo, VG = Valle Grande (NGO), MENA = Middle East and North Africa.

b. Numbers in parentheses refer to number of indicated events.

Table 5. Preparation and production of IPM diffusion materials.

Posters:	Life cycles[a]	Management
	APW	APW (2 versions)
	A-PTM	SPW
	SPW	
	CA-PTM	
	LMF	
Folder pages:	Life cycles	Management
	APW	APW
	PTM	PTM
Bulletins:	IPM of Andean potato weevil, IPM of potato tuber moth, mass rearing of *Copidosoma koehleri*	
Charts:	Life cycles of *Premnotrypes* spp., *Symmetrischema plaesiosema*, *Phthorimaea operculella*, *Tecia solanivora*	
Entomological boxes and cases:	Andean potato weevil (life cycle), potato tuber moth (life cycle)	
Slide sets:	Andean potato weevil (life cycle), potato tuber moth (life cycle)	
Video cassettes:	Andean potato weevil (life cycle), potato tuber moth (life cycle)	

a. APW = Andean potato weevil, A-PTM = Andean potato tuber moth, SPW = sweetpotato weevil, CA-PTM = Central American potato tuber moth, LMF = leafminer fly, PTM = potato tuber moth.

materials make training easy and pleasant for most NARS and NGO extension workers. Farmers themselves often act as successful extension workers with these training aids. The British Embassy in Peru has partially financed the preparation and production of many training materials on IPM.

Consulting

CIP'S IPM staff has acted as technical consultants for NARS and NGOs involved in the establishment of IPM for potato and sweetpotato. This activity mainly focuses on general aspects of the IPM implementation programs that are going to be under the responsibility of a NARS or an NGO. Eventually, we may consider specific technical aspects, such as the production of potato tuber moth granulosis virus or *Beauveria brongniartii*, the parasitic fungus of the Andean potato weevil.

■

1993-94 Research Projects and Partners

This list contains titles of research projects, names of principal research partners and responsible CIP scientists, collaborating institutions, and, when applicable, countries where work is conducted.

Potatoes with resistance to major insect and mite pests. A. Golmirzaie, M. Palacios.

- Breeding for resistance to insect pests. A. Golmirzaie, J. Tenorio, M. Palacios.
- Breeding for glandular trichomes. A. Golmirzaie, J. Tenorio, M. Palacios.
- Field evaluation of insect-resistant clones. M. Palacios, J. Tenorio.
- Evaluation of transgenic potatoes with insect resistance. PGS (Belgium). A. Golmirzaie, F. Cisneros, J. Benavides, V. Cañedo.

Integrated methods for control of potato tuber moth (PTM), leafminer fly, and other potato pests. F. Cisneros, M. Palacios.

- Development of IPM components for PTM and other foliage insect pests. M. Palacios, F. Cisneros.
- IPM for potato pests in Bangladesh. G.P. Das.
- Integrated methods for the control of PTM in North Africa and the Middle East. A. Lagnaoui.
- Integrated methods for the control of PTM in Colombia and Venezuela. P. Corzo (Colombia); L. Niño (Venezuela); M. Palacios, F. Ezeta.
- Integrated methods for the control of PTM in the Dominican Republic. P. Alvarez, V. Escarraman; M. Palacios, J. Alcázar.
- Integrated methods for the control of PTM in Bolivia. R. Andrew (PROINPA), J. Alcázar.
- Integrated methods for the control of PTM in Kenya. KARI, N. Smit.
- Evaluation of components for the integrated management of pests other than PTM. J. Herrera (UNA).

Integrated methods for the control of sweetpotato weevils. A. Braun, J. Alcázar.

- Development of IPM components for sweetpotato weevils. A. Braun, J. Alcázar.
- Host-plant resistance for sweetpotato weevil. P. Thompson (Miss SU).
- IPM for sweetpotato pests in the Caribbean (Dominican Republic and

Cuba). OPEC. P. Alvarez (Dom. Rep., MIP); A. Morales, N. Masa (Cuba, INIVIT); J. Alcázar, M. Palacios.

- IPM for sweetpotato pests in Bangladesh. G.P. Das (BARI).
- IPM for sweetpotato pests in East and Southeast Asia and the Pacific. A. Braun, E. Chujoy.
- IPM for sweetpotato pests in Kenya, Burundi, and Uganda. N. Smit.
- Integrated methods for the control of sweetpotato weevil in India. K.S. Pillai (CTCRI), M. Upadhya.
- Use of pheromones and entomopathogenic nematodes for control of sweetpotato weevil. R. Jansson (U Fla), F. Cisneros.

Integrated methods for the control of sweetpotato nematodes. P. Jatala, F. Cisneros, A. González.

- Integrated management of important nematodes of sweetpotato. P. Jatala, E. Guevara, A. González.
- Utilization of root-knot-nematode-resistant clones in Peru. P. Jatala.

Integrated methods for the control of Andean potato weevils. F. Cisneros, J. Alcázar.

- Development of IPM components for Andean potato weevils. J. Alcázar, F. Cisneros.
- Mass production and use of parasitic fungi for the control of Andean potato weevils and other pests. H. Torres, J. Alcázar.
- Integrated methods for the control of Andean potato weevil in Peru and Colombia. IDRC. J. Alcázar, M. Palacios, F. Cisneros.
- Integrated methods for the control of Andean potato weevil in Bolivia. R. Andrew (PROINPA), J. Alcázar.
- Integrated methods for the control of Andean potato weevil in Ecuador. P. Gallegos (INIAP), V. Lindao (FUNDAGRO), J. Alcázar.

Integrated methods for the control of potato cyst nematode (PCN) and false root-knot nematode (FRKN). J. Franco, M. Canto, A. González, A. Matos.

- Management of PCN in Peru: Cajamarca, Cusco, Puno. M. Canto, A. González, M.A. Pacheco (INIA), J. Arcos (INIA), J. Franco.
- Management of FRKN in Peru (Puno). J. Franco, J. Arcos.
- Breeding, screening, and selection for resistance to PCN. J. Landeo, A. Matos, M. Canto, J. Franco.
- Integrated management of PCN in Bolivia. J. Franco, R. Montesinos (PROINPA).
- Integrated management of FRKN in Bolivia. J. Franco, R. Montesinos (PROINPA).

PROGRAM 5

Propagation, Crop Management

Propagation of Healthy Clonal Potato Planting Materials in Diverse Agricultural Systems

Through special projects, CIP continued to assist seed production in Cameroon, Bolivia, and Ecuador, with economic assistance from the Swiss Technical Cooperation Agency in the latter two countries. Two other similar special projects in Burundi and Uganda ended after several years of successful cooperation.

In Bolivia, PROINPA has organized a prebasic seed production system, based on the production of pathogen-tested in vitro plantlets at three research stations of the Instituto Boliviano de Tecnología Agropecuaria (IBTA). PROINPA's pathology and nematology departments are establishing phytosanitary control in the system. Rustic beds to produce basic seed were promoted among farmers to handle small and affordable amounts of tuber seed. The current system also includes cleanup and promotion of new, advanced cultivars and research on optimization of production factors to improve multiplication rates.

A collaborative project between CIP and the Institute of Horticultural Development, Knoxfield, Victoria, Australia, seeks to produce pathogen-tested potato and sweetpotato germplasm for East and Southeast Asian and Pacific (ESEAP) countries. The project has supplied basic seed tubers of 42 potato clones to potential collaborators throughout the ESEAP region. These clones were supplied as sets of seed tubers to the Philippines, Indonesia, Bangladesh, Vietnam, Vanuatu, Western Samoa, and Fiji.

The project supplied 53 pathogen-tested sweetpotato clones to regional tissue culture laboratories in Papua New Guinea, Fiji, and Western Samoa.

In Burundi, CIP and collaborators tested an integrated approach for the production of prebasic tubers and are now using it on seed farms of the Institut des Sciences Agronomiques du Burundi (ISABU). In order to reduce possible latent infection from *Pseudomonas solanacearum*, the model basic seed scheme being used is the key element in the integrated approach. Researchers proposed a flush-out scheme based on initial in vitro micropropagation of pathogen-tested plantlets in screenhouses.

In Colombia and Venezuela, we have obtained better knowledge on seed quality, prebasic and basic seed techniques, and actual seed production. Several private companies that participate in seed production in those countries are now using these techniques and results. Information on sanitary conditions for seed production, especially in Venezuela, is facilitating increased production, thereby reducing seed imports.

For basic seed production in Peru, the total production of potato basic seed in research stations of the Instituto Nacional de Investigación Agraria (INIA) increased by 65%, and adjusted the quantities of varieties according to regional needs. The quality of seed sold also improved. The introduction of adequate agronomic technologies for seed has increased the production of seed-sized tubers in INIA's production centers for potato basic seed.

A pilot project for seed production in low-cost greenhouses (LCG) in Puno Department has made it possible to train farmers in the use of this low-cost technology. Productivity has improved and average yield obtained by farmers per LCG increased from 32 to 71 kg of high-quality potato seed. Production improved mostly because farmers were trained. Farmers are adopting this technique to produce potato seed with security in a high-risk environment.

In Uganda, four local varieties (Sangema, Rutuku, Malirahinda, and Rosita) were cleaned and their basic seed produced for distribution. Two additional cultivars—CEW 69.1 (CIP-575049) and Cruza-148 (CIP-720118)—have been included in the seed program because of demand by farmers, in places where late blight and bacterial wilt are the main problems. True potato seed (TPS) is at the threshold of adoption. A group of farmers in Kabale district has already demonstrated the commercial viability of this technology. The Sugar Cane Corporation in Lugazi has tested TPS technology successfully on a large scale to produce low-cost quality seed for its own fields, for planting between the rows of young sugar cane.

The Uganda special project also successfully adapted established technologies for basic seed production to local conditions. At the Kalengyere Research Station in Kabale (2,600 m), high-quality seed can be produced in one aphid-free cool season by using conventional clonal propagation and rapid multiplication techniques (such as rooted stem cuttings), which have proven to be successful. We organized four in-country training courses on different aspects of potato improvement for the benefit of researchers, extensionists, and farmers.

In the Philippines, CIP continued on-farm evaluations of potato stem and sprout cuttings as alternate planting materials. We used apical stem cuttings tested in lowlands as planting materials for clonal testing. The apical stem cuttings produced tuber yields comparable to those of tuber seed in lowlands. Trials with sprout cuttings indicated diversity in tuber yield among clones. Farmers selected clones 385130.5 and 385130.11. The latter clone was found suitable for lowlands when hilled up 15 days after transplanting, with mulch removed before hilling up and later remulched. In the highlands, 54 out of 58 clones were selected; several outyielded the local checks grown from tuber seed.

Sexual Potato Propagation

CIP evaluated 60 progenies from a TPS population mated with virus-resistant clones in Peru for agronomic and reproductive characters in warm tropical environments. We selected some families for further evaluation by CIP regional scientists. Many clones, which can be used as female or male for TPS production, have been identified and added to our pathogen-tested list because of their high general combining ability for agronomic and TPS characters, and adaptation to warm tropical climates. Screening of advanced TPS progenies in Peru resulted in the identification of two additional promising TPS male parents—TS-9 and TS-5. We identified nine superior TPS hybrids with adaptation to tropical conditions (Chiquita x TS-4, MF-I x TS-9, MF-II x TS-9, LT-9 x TS-5, Serrana x TS-5, TS-7 x TPS-67, LT-9 x TPS-113, LT-8 x TS-9, and HPS-25/67). Five hybrids showed superior adaptation to highland conditions (Yungay x 104.12LB, variety Chacasina, Ccompis x 4.1DI, F-6 x Ccompis, Yungay x Ccompis, and F-7 x 4.1DI). TPS hybrid families LT-8 x TS-9, LT-9 x TS-9, LT-9 x TPS-113, HPS-I/67, and MF-II x TS-10 were selected for superior processing quality of tubers. Trials on production of TPS from advanced hybrids identified three superior cross combinations for TPS yield per plant under short-day warm environments—TS-12 x TPS-67 (15.4 g/plant), Chiquita x TS12 (11.1 g/plant), and TS-8 x TPS-113 (8.2 g/plant).

Selection of improved TPS parental materials in India has produced a number of hybrid families with a wide range of adaptability for CIP's South and West Asia (SWA) region (Table 1). Progress made through breeding in this region is evidenced by the selection of adapted parental materials (male and female) that produce widely adaptable hybrid TPS families. Five superior clones (MF-I, MF-II, TPS-7, TPS-13, and TPS-67) out of the selected parental lines were supplied to the Central Potato Research Institute (CPRI), other governmental agencies, and NGOs for hybrid TPS production. We selected potato clones with reasonably long tuber dormancy, high dry matter, and low reducing sugars. Two TPS hybrids—HPS-II/67 and HPS-7/13—were introduced for advanced trials at All-India Coordinated Centers. We have selected clones with profuse flowering under natural short-day photoperiod from the *tuberosum* group of potato. We will use these clones to breed this flowering character in promising potato clones having high yields and desirable horticultural traits. In addition, 419 accessions were selected from 57 different cross combinations.

We compared three methods for bulk extraction of potato pollen for efficiency and effect of extracted pollen on berry set, seeds per berry, and 100-seed weight. Results indicate that extraction of pollen using a sieve with 24-mesh nylon netting and shaking the predried anthers was the most economical in time, labor, and simplicity of the procedure, which also required inexpensive equipment.

The excellent yields produced by two TPS hybrids selected in India—HPS-II/67 and HPS-7/67—convinced the government to become actively involved in the promotion of TPS in Bangladesh. In collaborative projects with the Tuber

Table 1. Yield data from advanced adaptability trial of F_1C_1 tubers of TPS families in different agroecologies, India, 1993-1994. Crop duration was 90 days, with a split-plot design. Cultivars used were Kufri Chandramukhi (Chhindwara and Hissar), Kufri Bahar (Modipuram), and Kufri Sindhuri (Patna).

TPS family/cultivar	Hissar		Chhindwara		Modipuram		Patna		Average yield (t/ha)
	Total (t/ha)	Mkt.[a] (%)	Total (t/ha)	Mkt. (%)	Total (t/ha)	Mkt. (%)	Total (t/ha)	Mkt. (%)	
HPS-I/13	38.9	95.6	26.2	93.4	38.3	91.8	35.3	87.6	35.5
HPS-II/13	43.7	93.5	39.5	94.5	38.4	90.7	32.0	87.5	36.5
HPS-7/67	41.0	91.6	39.4	95.3	38.2	90.9	30.1	77.8	37.5
Cultivar	29.9	95.4	26.2	95.6	—	—	28.5	82.6	26.5
LSD (P=0.05)	2.3	0.8	2.1	2.6	7.3	2.2	1.5	1.7	5.6

a. Mkt. = marketable.

Crops Research Center (TCRC) and Department of Agricultural Extension in Bangladesh, we conducted 281 farmer trials in 12 different districts. Almost all of the farmers involved expressed continued interest in potato production using TPS.

Breeding of adapted TPS parental materials in Kenya has produced several dozen hybrids and open-pollinated (OP) progenies that have been advanced for large-scale production and testing in Africa. We have identified several progenies that are adaptable and have acceptable yields and overall uniformity for seed tuber production. We will test them further in multilocational trials, mainly in PRAPACE member countries.

Research results indicate that the use of TPS could be an acceptable technology in Tunisia, Syria, and Morocco. There is optimism in Turkey from the preliminary results from TPS use, but future CIP activities will concentrate on adoption, use, and production of TPS by farmers and private companies in Egypt.

The use of TPS continues to increase in the highland regions of southwestern China (Yunnan and Sichuan provinces). Ten clones introduced by CIP were selected for production of TPS hybrids on the basis of yield and disease resistance.

Farmer-led research and evaluation of TPS progenies since 1988 has indicated that for TPS to have an economic impact in Indonesia, we must screen and identify progenies that mature earlier and maintain stable yields across generations. The development of methods that involve farmers in the evaluation of new material is crucial to success.

We have obtained encouraging results in the Philippines, Vietnam, Indonesia, and Sri Lanka after the first year of the project on "Field-testing of true potato seed in the lowland tropics," funded by the Asian Development Bank. Conditions for establishing this project were substantially different in each country. But Indian hybrid TPS of the HPS series, now produced by the country's private sector, has outperformed TPS from all other sources in all participating programs. We have conducted in-country training activities in Vietnam and regional training activities in India.

Research under way at the Department of Vegetable Agronomy and Genetics of the Università Degli Studi di Napoli Federico II, Naples, Italy, on selection of TPS parental lines for the production of improved TPS families has shown that three 4x clones, coming from clonal selections evaluated for their flowering characteristics, have been used to produce hybrid TPS. In addition, some new diploid interspecific 2n pollen-producing hybrid clones have been used as male parents in 4x x 2x crosses for hybrid TPS production.

We have obtained new hybrid combinations by crossing widely cultivated varieties in southern Italy with cultivars and clones already tested for TPS production. We evaluated different hybrid TPS families coming from 4x x 4x and 4x x 2x crosses for ware potato production using seedling tubers and seedling transplants.

CIP investigated alternatives to avoid the high cost of sending samples to the United States to determine total glycoalkaloid (TGA) content in TPS progenies. Important results were obtained from research on sensory and chemical analysis. We standardized the ELISA technique for estimating TGA content and screening all advanced TPS materials. We obtained satisfactory correlations with triangular sensory tests at a relatively low cost. We are in the process of standardizing the HPCL technique to compare its sensitivity with ELISA.

We are obtaining increasing evidence of client confidence in CIP's postharvest handling and seed-quality testing practices, as well as more awareness of the need to use only high-quality TPS for sowing under suboptimal field conditions (Figure 1). Newly harvested TPS of 162 different lots totaling 25.1 kg was conditioned (dried below 4.5% moisture content and packaged) and periodically tested during afterripening (high temperature and low moisture for "breaking" dormancy). When ready for sowing, the lots were returned to CIP's seed specialist for regional research and technology transfer. Also, 83 different TPS lots totaling 32.5 kg were tested for clients in Peru or for CIP scientists.

Results from seed-quality tests accurately and consistently predicted relative field establishment in a large direct-seeding operation under desert conditions in Ica, Peru. TPS handling and testing techniques were adopted by seed producers of the Instituto Nacional de Investigaciones Agropecuarias (INIA) and ESCAgenetics in Chile, and were transferred to NARS in Cuba and Turkey via an information bulletin and individual training.

The ability of CIP's seed-quality laboratory to conduct applied research capable of responding quickly to our clients' urgent needs was demonstrated when the SEINPA program in Peru provided 12.5 kg of a deeply dormant highland TPS progeny (Ccompis OP), of which 2.5 kg was needed by 100 small

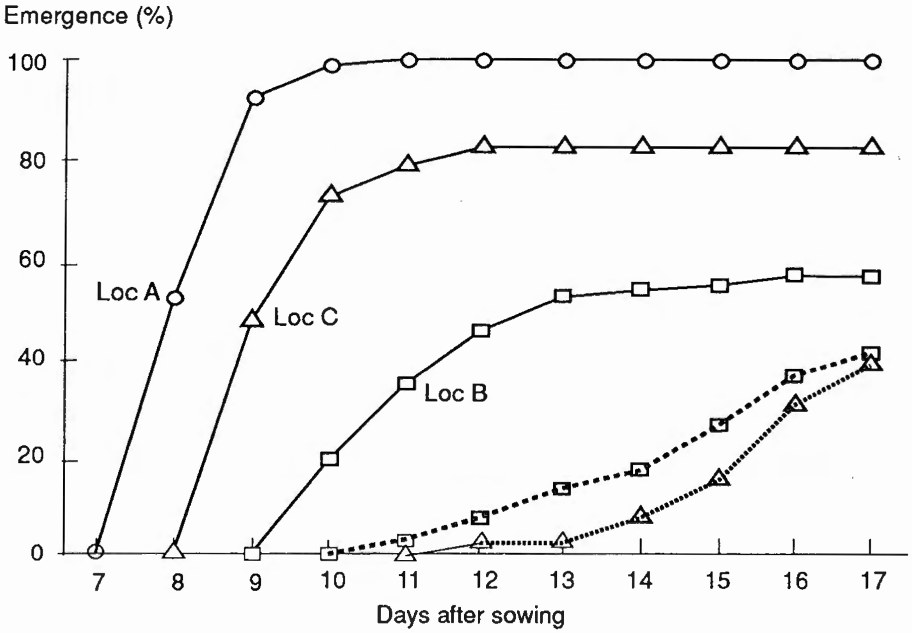


Figure 1. Effects of seed moisture content(—— = 3%, - - - = 5%) after 18 months of storage at 45°C in three seed lots harvested from the bottom (lot A), middle (lot B), and top (lot C) thirds of the mother plant. Seeds stored with 7% SMC did not emerge. Bars indicate significance at $P < 0.05$.

communities in Puno for immediate planting. Research results showed that for this progeny we could accelerate the rate of afterripening by careful low-moisture storage at high temperature (40°C). As a result, we satisfied SEINPA's needs in time. We applied a less aggressive afterripening treatment to the remaining TPS before returning it to SEINPA without cost for distribution to 1,000 farmers.

Propagation of Healthy Clonal Sweetpotato Planting Materials in Diverse Agricultural Systems

The soils of Peru's coastal plain are very low in organic matter content (below 1.5%). Therefore, soils are also extremely poor in available nitrogen. In many field experiments, however, we have obtained yields higher than 25 t/ha without any N fertilizer application, indicating strong fixation of N_2 by *Azospirillum*. We have found a nonsignificant response between varieties.

Field experiments also showed that high yields could be obtained without any application of organic matter. In very sandy soils (new, irrigated sandy soils), however, we have found a highly significant response to organic manure and NPK fertilizer applications.

In order to understand how N affects the complex relationship among the sweetpotato plant, the soil, and the atmosphere, we needed to conduct a systematic study on all phases of the plant's growth cycle. This approach has been useful in identifying physiological processes directly affected by N, and showing how all this affects plant yield. We conducted two field experiments at two locations—La Molina and San Ramón—during the growing season (May-November 1994). Our goals were to determine the rates of growth and assimilation pattern of the sweetpotato plant under different N regimes and environmental conditions, and to better understand the physiological processes that produce N yield responses.

CIP and collaborators developed forage-type sweetpotato "Helena" as a new perennial forage that is an environmentally sustainable, low-input crop with a plant-top yield and nutrient value that surpass those of other forage crops, including alfalfa. The fresh forage and silage provide excellent palatability and digestibility for different kinds of livestock. This cultivar has produced up to 225 t/ha of fresh forage or silage with up to 20-25% protein (dry weight) under a range of environmental conditions.

We screened 254 sweetpotato clones from the pathogen-tested list under extreme water stress conditions in both the winter and summer seasons at Lima, Peru. We planted cuttings in replicated trials under moist field conditions and harvested after 150 days without any additional irrigations. We identified 20 clones for superior drought tolerance, root yield, and acceptable quality (size, color, taste, and dry matter). These clones demonstrated rapid establishment and superior maintenance of top growth under extreme water stress. These characteristics are vital to ensure availability of planting materials during the short rainy periods that occur in the drylands of Africa. One orange-flesh clone (Zapallo), collected in Cajamarca, Peru, was outstanding under both winter and summer conditions; it produced an average of 620 grams of edible sweetpotato roots per plant (Figure 2). The practical applicability of this simple screening procedure has been demonstrated after only the first year of

J ALCAZAR

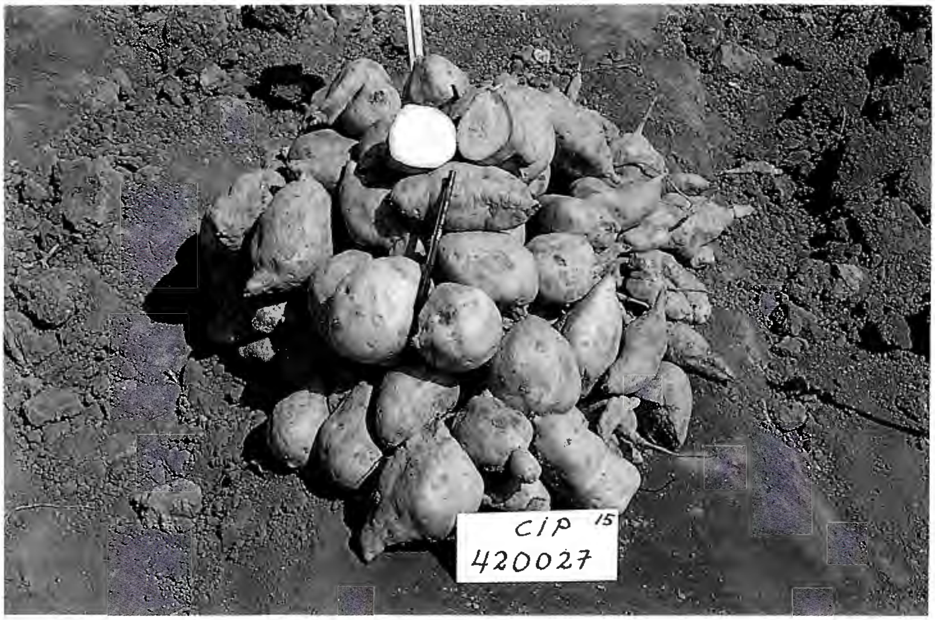


Figure 2. Yield of sweetpotato clone Zapallo in Peru.

research. Clone Zapallo was noted for producing superior yields during three trials in the drylands of Kenya under both irrigated and water-stress conditions.

During 1994, CIP conducted intensive work on genetic evaluation for tolerance of salinity and drought. We have screened about 1,600 sweetpotato clones and 32 hybrid families under summer and winter conditions in the coastal arid-saline fields of Tacna, Peru. Germplasm screened included advanced clones and progenies from hybridization programs. We have now generated 167 stress-resistant clones with good agronomic performance under a restricted irrigation system and salinity levels corresponding to EC 515 mmh/cm. From these improved populations, eight superior early clones were released jointly by the Universidad Nacional de Tacna and CIP. Farmer participation in the selection of these new varieties was an important component of this work.

Maintenance, International Distribution, and Monitoring of Advanced Potato Germplasm

The central pathogen-tested potato collection now consists of 1,242 cultivars maintained in vitro for different purposes. We can safely export these cultivars to germplasm users around the world. Some 86 clones are in the process of cleanup. In 1994, distribution of most of the different types of genetic materials remained at the same level as in previous years. CIP sent clonal material in the form of tubers to 27 countries, in vitro plantlets to 39 countries, tuber families to 9 countries, and true-seed families to 15 countries around the world. We distributed 3,400 samples of clonal material and 300,000 genotypes in the form of families for varietal selection. For research on TPS, CIP-Lima distributed 22 million seeds (18 kg) to 29 countries, 42% more seed than in 1993.

In the Philippines, CIP maintained a total of 269 pathogen-tested clones in vitro for regional distribution. We cleaned the most adapted locally selected clones and sent 91 to Lima for final pathogen-testing. We distributed 29 of the newly cleaned advanced materials locally for testing. Trials to compare the efficiency of PVY eradication showed that thermotherapy at a constant temperature of 36°C plus meristem culture was the most efficient method.

We continued to select for late blight resistance and earliness in the Philippines, and screened a wide range of germplasm. Dalisay (B-71-240.2) and Montañosa (I-1035) kept their moderate resistance in spite of the extent of variation in the races of the fungus. We urgently need to identify new cultivars resistant to late blight.

In Kenya, we continued to produce and distribute improved genetic materials. Following the new CIP policy, a seed unit will be created to produce and distribute elite or prebasic seeds of a few advanced clones (three to six per country) to selected countries (Burundi, Ethiopia, Kenya, Rwanda, and Uganda).

We continued to clean native and advanced clonal material from CIP in Austria and Australia in 1994.

We produced large amounts of TPS for research and commercial uses in India, Chile, and Turkey. In India, we distributed six TPS hybrids (IP 88001, 88002, 88003, 88004, 88005, and 88006) to different research centers for multilocational evaluations. These hybrids have wide adaptability in Asia, Africa (Uganda and Kenya), and Nicaragua. With technical support and a supply of parental lines from CIP-India (SWA region), the State Department of Agriculture of Tripura produced 110 kg of hybrid TPS during 1993-1994. In total, about 140 kg of hybrid TPS was produced in India in 1994.

In Chile, INIA produced 10 kg of seven progenies to meet the needs of large CIP research and development projects on TPS. Production of TPS in the Turkish Potato Program at Izmir was consolidated by improving TPS quality and by producing new progenies from better parental lines.

Maintenance, International Distribution, and Monitoring of Advanced Sweetpotato Germplasm

A total of 372 sweetpotato clones (19% more than in 1993) from diverse sources are now pathogen-tested and available for general distribution from CIP-Lima. We cleaned 70 clones in 1994. From Lima, we sent 1,240 samples of in vitro clones to 24 countries and 26,000 genotypes in the form of true-seed families to 13 developing countries. The number of in vitro clones increased by 107% in relation to 1993.

In 1993-1994, the Universidad Nacional Agraria La Molina, together with CIP, released forage variety Helena, selected from the germplasm collection maintained by CIP.

In Kenya, genetic materials received from CIP-Lima (183 clones and 23 true-seed families), CIP-Indonesia (12 true-seed families), and Uganda (64 true-seed families) were cleaned by the Kenyan Plant Quarantine Station (PQS) and tested under local conditions. In vitro clones were sent to Zaire. Currently, PQS-Kenya and CIP sub-Saharan Africa (SSA) regional facilities keep 126 in vitro clones for regional evaluation. Some of these clones are also maintained under greenhouse conditions to produce exportable material.

In the Philippines, we maintain 82 in vitro pathogen-tested cultivars for regional distribution to the Philippines, Bangladesh, India, Indonesia, Vietnam, and South Korea. In 1993-1994, we tested 43 of these clones in the highlands of the Philippines for adaptation and possible use in processing. Sweetpotato accessions differed in response to propagation through single-node cuttings; yields varied between 4.3 and 31.8 t/ha, with clone L9 yielding the highest. Rooted single-node cuttings outyielded normal vine cuttings.

Abiotic Stresses and Crop Management

CIP continued collaboration with NARS in the SSA region to evaluate superior potato clones. Most national programs emphasized the identification of clones possessing resistance to and tolerance of late blight, higher yield, and overall adaptation to local environments.

Burundi. We evaluated 19 clones in a replicated trial at the Gisozi station. Trial results indicated that at least two clones–CIP-382210.2 (19.5 t/ha) and CIP-387197.23 (18.8 t/ha)–yielded more than check cultivar Ndinamagara (16.6 t/ha), which showed the same degree of resistance to late blight.

Ethiopia. We conducted a national varietal evaluation trial with seven advanced clones and two checks. Results indicated that two clones–CIP-384298.56 and CIP-384321.16–performed uniformly at the four sites, and outperformed the checks in yield and uniformity in production under the diverse locations. We are also evaluating clones to develop varieties for lowlands in order to expand potato production in Ethiopia.

Kenya. CIP and collaborators conducted extensive evaluations and screening at the National Potato Research Center (NPRC) of the Kenyan Agricultural Research Institute (KARI). The evaluation scheme consisted of 350 clones in several cycles of selection at different stages. Scoring for late blight began with the appearance of the first symptoms and continued on a weekly basis until full maturity. Few clones performed consistently. We will include the top five clones in on-farm trials and five in national performance trials (NPT) in 1995. In the final evaluation of clones in the NPT trial at the NPRC, farmers from the surrounding area also participated, and the farmers and researchers generally agreed in their preference ranking of the clones.

Tanzania. The Uyole Agricultural Research Center in the southern highlands of Tanzania has evaluated germplasm supplied by CIP and has selected a few clones to advance to multilocational trials in the 1994-1995 season.

Zambia. The Zamseed Company of Zambia has selected promising clones from 45 clones received from CIP in 1990. These will be evaluated in the formal national advanced trial system in 1995 before final release of selected clones as varieties.

The national potato programs of Malawi, Mauritius, Zaire, and Zimbabwe are evaluating in different stages germplasm supplied by CIP.

We have conducted studies on gene expression during cold acclimation in potato in a contract project with the Department of Vegetable Agronomy and Genetics of the Università Degli Studi di Napoli Federico II, Naples, Italy, to identify a gene or genes responsible for cold-hardening ability of *Solanum commersonii.* One partial and one full-length cDNA clone coding for the enzyme AG stearyl-ACP desaturase have been isolated from an *S. commersonii* cDNA library. Sequence analysis of the two clones has revealed high homology to other published sequences.

CIP continued to develop frost-tolerant potato cultivars for the Andean highlands in 1993-1994. We evaluated more than 40,000 clones produced at PROINPA (and received from CIP) at -3°C to -5°C under natural conditions and in a growth chamber. We selected 1.3% of this material for future field evaluations.

We conducted field tests in Bolivia in the departments of Cochabamba (PROINPA), Oruro (Universidad Técnica, UTO), and La Paz (ORSTOM group). All clones tested (about 200) underwent frost stress for several hours at temperatures of -2°C to -4°C. We selected 10 advanced clones for their frost tolerance, with average yields of 1-1.5 kg/plant versus 0.5 kg/plant for the local cultivars. These clones also carry resistance to nematodes, wart, and late blight. Evaluations of their culinary qualities with participation by local farmers have led to the identification of five clones with potential as future cultivars.

Development of drought-tolerant potato cultivars in Bolivia is a collaborative activity with PROINPA. Because the activities only started recently, our efforts have focused on obtaining hybrid seeds from crosses between wild species *S. weberbauerii, S. megistacrolobum, S. infundibuliforme, S. leptophies,* and *S. berthaultii* and cultivated species *S. phureja, S. goniocalyx, S. andigena,* and *S. x ajanhuiri.* We have obtained about 2,000 seeds of 22 families, which we will test in the greenhouse during the next season. Material obtained last year was sowed in trays in the greenhouse and was exposed to drought stress when seedlings were about 10 cm in height. We selected 143 clones from 20 families for their drought tolerance.

We began a preliminary trial to study the morphological and physiological factors involved in drought tolerance. We studied tetraploid clones reported as drought tolerant from the Peruvian national program such as Chaska and Yungay, in addition to clone 84-48-7 (Colombian), and compared them with Waych'a (*S. andigena*), Alpha (*S. tuberosum*), and *S. berthaultii.*

CIP continued research on the adaptation of potatoes to arid and saline soil conditions in southern coastal Peru as a collaborative activity with the Universidad Nacional de Tacna. This work resulted in the release of two early maturing stress-resistant clones as varieties Tacna and Costanera. In addition to their stress tolerance, these varieties have high tuber-processing quality and resistance to PVY, PVX, and PLRV.

Under advanced selection, three clones–CIP-388615.22, CIP-392781.1, and CIP-392780.1–were selected for release as varieties after on-farm trials and confirmation of resistance to PVX, PVY, PLRV, and root-knot nematodes.

In the project on technical assistance to Uganda's National Potato Research and Development Program, which ended in 1994, we made several achievements. Clone CIP-575049 (CEW 69.1) was provisionally named Kabanyolo and, along with CIP-720118 (Cruza-148), may be considered for release. Three genotypes were officially released as varieties Victoria (CIP-381381.20), Kisoro (CIP-381379.9), and Kabale

(CIP-384080.5). Resistance to late blight and tolerance of bacterial wilt characterized them. We also selected genotypes with combined resistance to bacterial wilt and late blight, adapted to mid-altitude regions.

Propagation of Andean Root and Tuber Crops and Management of Andean Natural Resources

Production of ulluco seed in peasant communities of the Ecuadorian highlands

Five communities in five provinces of the Ecuadorian highlands participated in work aimed mainly at multiplying ulluco (melloco) (*Ullucus tuberosus*) seed. An additional objective was to validate enhanced production technologies through active farmer participation and thus achieve "training by doing."

We selected six clones for good yield and earliness (Table 2). We studied their days to flowering, tuberization, and harvest; pest and disease resistance; and their seed production by community.

As work progressed, farmers showed great interest in the yield of these plants. Their similarity with local varieties made clones ECU-814 and ECU-831 more acceptable. Farmers also expressed satisfaction with the wider range of color, size, shape, and taste of the newly introduced varieties.

Meanwhile, peasant community leaders agreed to continue with seed multiplication of these varieties, subject to continued advice from the Instituto Nacional de Investigaciones Agropecuarias (INIAP).

We used 1,061 kg of seed from six promising clones produced at the Santa Catalina Experiment Station to install multiplication plots in peasant communities, using rapid multiplication techniques developed for potato.

Tuber seed dormancy of oca (*Oxalis tuberosa*) and ulluco could be broken 15 days after treatment with Rindite, bromoethane, 2-chlorethanol, and gibberellic acid, but the treatment with these chemicals did not break seed dormancy when applied to mashua (*Tropaeolum tuberosum*).

Quality seed production in peasant communities for oca, ulluco, and mashua

Some 11 communities from Arequipa, Cusco, and Puno (Table 3) participated in this work conducted by Peru's National Andean Crops Program. The goal was to increase oca, mashua, and ulluco production by using high-quality seed to

Table 2. Yield and earliness of six promising ulluco (melloco) clones, with average yields at 11 locations, Ecuador, 1993.

Clones	Yield (kg/ha)			Days after planting		
	Maximum	Minimum	Average	Maximum	Minimum	Average
ECU-759	32.7	8.9	18.0	256	200	226
ECU-791[a]	40.7	10.0	23.5	253	200	225
ECU-831	49.6	9.6	25.1	258	205	228
ECU-814	42.6	7.6	24.5	252	188	221
ECU-837	30.4	13.9	21.5	251	200	225
ECU-842[a]	33.3	10.8	20.5	253	200	226

a. Low mucilage content.

Table 3. Seed production for oca, ulluco, and mashua by location and participating communities, Peru, 1993.

Department	Experiment station	Communities
Arequipa	San Camilo	Pachaychaca, Echancay
Cusco	Andenes	Patapayoc (Sacsayhuamán), Chiara (Combapata), Ccorimarca (Chinchero), Checacupe (Urcos), Cruz Verde (Arco)
Puno	Illpa	Titilaca (Acora), Potojani (Platería), Corpamaquera (Ilave), Yanaque (Acora)

strengthen farmers' potential to grow these crops (Table 4).

Peru's INIA, with support from CIP, has developed a quality seed production system for Andean tubers. This allows farmers to increase production and profit from wider diversity.

We have increased oca, ulluco, and mashua genetic diversity and now have 100 cultivars of oca, 57 of ulluco, and 18 of mashua.

Basic seed production for Andean roots and tubers using rapid multiplication methods

Low multiplication rates (1:3 to 1:10) with traditional methods to produce seed material led us to try rapid multiplication techniques using sprout cuttings from young, lateral, and adult stems, and stolons, split tubers, and tuberlets at CIP's Huancayo experiment station. Our main objective was to introduce rapid multiplication methods for use in the production of planting material of ulluco, oca, and mashua.

We can attain efficient surface disinfection of seed tubers by soaking for 10 minutes in a solution of alkyldimethylbenzylammonium chloride (Dimanin A) (1 cc per liter of water). A mixture of deltamethrin (1 cc per liter of water), benomyl (1 g per liter of water), and Tween 20-adhesive (0.5 cc per liter of water) is recommended as a fungicidal treatment for 10 minutes at 24 hours after the Dimanin treatment.

Table 4. Production (kg) of three types of oca, ulluco, and mashua seed in Puno, Peru, 1993-1994.

Locality	Crop	Genetic nucleus	Basic seed	Community seed	Total
Puno	Oca	307	3,972	4,906	9,185
	Ulluco	1,817	1,587	1,584	4,988
	Mashua	—	480	116	596
Arequipa	Oca	399	474	92	965
	Ulluco	243	293	79	615
	Mashua	80	—	—	80
Cusco	Oca	6,147	2,842	2,673	11,662
	Ulluco	1,965	2,140	1,644	5,749
	Mashua	325	380	240	945
Total		11,283	12,168	11,334	34,785

■

1993-94 Research Projects and Partners

This list contains titles of research projects, names of principal research partners and responsible CIP scientists, collaborating institutions, and, when applicable, countries where work is conducted.

Propagation of healthy clonal potato planting materials in diverse agricultural systems. O. Hidalgo.

- Potato seed program in Burundi. A. Sanduhija, C. Muvira, Z. Nzogihera, D. Berríos.
- Potato propagation research and production in Cameroon. C. Martin, H. Mendoza.
- Potato seed research and production in Uganda. L. Sikka.
- Strengthening of research and production of prebasic potato seed in Bolivia. A. Devaux (PROINPA).
- Support for seed production to improve potato productivity in Peru. E. Franco (SEINPA).
- Information management systems for potato production and distribution in Ecuador. P. Espinoza, C. Crissman.
- Potato seed in Ecuador. Evaluation of internal demand for seed. Basic seed production. Production and distribution among small farmers. A. Hibon.
- On-farm evaluation of various cuttings as alternative planting materials. Philippines. E. Chujoy.
- Comparison of tuber productivity of four types of seed tubers in Vietnam. E. Chujoy, U. Jayasinghe.
- Research and technical assistance in potato seed production in Colombia and Venezuela. P. Corzo, Y. Rodríguez (CORPOICA); O. Hidalgo, P. Espinoza.
- Production of potato seed by rapid propagation in Paraguay. A. Strohmenger.

Sexual potato propagation. N. Pallais.

- Breeding and selection of appropriate TPS progenies and/or parental lines in eastern and southern Africa. Kenya. H.M. Kidane-Mariam.
- Potato production from TPS in North Africa (Egypt, Tunisia, Morocco). NARS and M. Fahem (CPRA), A. Hilali, R. El-Bedewy, C. Martin.
- Breeding for TPS parental lines and initial evaluation in India. K.C. Thakur, M. Upadhya.
- Evaluation of TPS progenies and research on production of hybrid seed in Indonesia. A.A. Asandhi (LEHRI), A. Chilver.
- Evaluation of advanced TPS families and on-farm trials in India. M.S. Kadian, M. Upadhya, P.C. Panday.
- Studies on TPS production in Bangladesh. H. Rashid (BARI), A. Quasem (TCRC), M. Upadhya.
- Potato production from TPS in Asia. Sri Lanka, Indonesia, Philippines, and Vietnam. ADB. P. Schmiediche.
- Development of TPS progenies for various environments of China. W. Ketong, Song Bo Fu.
- Development of TPS parental lines and progenies in Peru. A. Golmirzaie.
- Screening of advanced TPS progenies and production technology in Peru. P. Malagamba, J. Bryan, R. Cabello.
- Physiological studies on TPS quality, storage, and handling in Peru. N. Pallais.
- Production and utilization of seed tubers derived from TPS in Paraguay.

IAO. T. Mayeregger, A. Strohmenger, J.F. Bareiro.

- Breeding to select TPS progenies in Chile. J. Kalazich, P. Accatino (INIA-PROCIPA).
- Search for horizontal resistance to late blight for the development of cultivars for producing potatoes from TPS. Argentina. M. Huarte.
- Use of TPS for potato production in Central American and Caribbean countries. F. Torres, M. Batista.
- Selection of TPS parental lines. Italy. L. Frusciante, P. Gareffa.

Sweetpotato production through improved planting and management techniques. H. Beaufort-Murphy, P. Malagamba, M. Upadhya.

- An evaluation of tolerance of excess moisture of South China sweetpotato germplasm. X. Chunsheng, L. Meiying, Song Bo Fu.
- Soil management, fertilizers, and mineral nutrition of the sweetpotato under different soil, climate, and farming conditions. Peru. S. Villagarcía.
- Development of propagation and crop management techniques for sweetpotato in Peru. H. Beaufort-Murphy.
- Physiological mechanism for improved tolerance of abiotic stresses in sweetpotato. Peru. N. Pallais.
- Adaptation of sweetpotato to arid and saline soil conditions. Peru. R. Chávez.
- Nitrogen and dry matter portioning during the development of sweetpotato under different N regimens and environments. Peru. M. Villagarcía.

Maintenance, international distribution, and monitoring of performance of advanced potato germplasm. O. Hidalgo.

- Introduction, maintenance, and distribution of advanced potato genetic materials. Kenya. H. Kidane-Mariam.
- TPS production in Turkey for the needs of the Middle East and North Africa. M. Eraslam (AARI), R. Cortbaoui, C. Martin.
- Maintenance, multiplication, and distribution of potato germplasm. Indonesia, Philippines. U. Jayasinghe.
- Production and distribution of hybrid TPS. India. K. Thakur, M. Upadhya.
- Maintenance, multiplication, and distribution of pathogen-tested potato; production of low-virus seed. Peru. J. Bryan, O. Hidalgo.
- TPS production in Chile. J.S. Rojas, J. Kalazich (INIA); P. Accatino.
- Pathogen elimination of selected potato cultivars for worldwide distribution. Austria. J. Bryan, O. Hidalgo, A. Golmirzaie, J. Schmidt.
- Production of pathogen-tested potato and sweetpotato germplasm for East and Southeast Asia and Pacific countries. Australia. P. Schmiediche.

Maintenance, international distribution, and monitoring of performance of advanced sweetpotato germplasm. J. Bryan, O. Hidalgo.

- Introduction, multiplication, and distribution of sweetpotato germplasm. Kenya. H. Kidane-Mariam.
- Maintenance, multiplication, and distribution of sweetpotato germplasm. Indonesia, Philippines. U. Jayasinghe.
- Maintenance, multiplication, and distribution of pathogen-free sweetpotato materials. Peru. J. Bryan, O. Hidalgo.

Abiotic stresses and potato crop management. P. Malagamba.

- Collaboration with national programs in the evaluation and selection of superior clones. Eastern and southern Africa. NARS and H.M. Kidane-Mariam.
- Agronomic research. Uganda. L. Sikka.
- Use of PGR substances for stress protection to improve potato productivity. India. M. Upadhya.
- Soil management, fertilizers, and mineral nutrition of potato under adverse conditions of soil and climate. Peru. S. Villagarcía.
- The use of agronomic practices to reduce temperatures in the potato macroclimate. Dominican Republic. F. Payton.
- Development of frost-tolerant potato cultivars in Bolivia. N. Estrada, A. Devaux.
- Development of drought-tolerant potato cultivars in Bolivia. N. Estrada, A. Devaux.
- Adaptation of potato to arid and saline soil conditions. Peru. R. Chávez.
- Database on crop response to environment. Peru. P. Malagamba, J. Roca.
- Study on the effect of NK fertilizer on the production and processing of potato. S. Villagarcía (SQM-Chile).
- Study of gene expression during cold acclimation. Italy. M. Tucci.
- Genetic basis for improved tolerance of frost and other major abiotic constraints of cool growing areas. Peru. J. Landeo.
- Breeding and selection of potato genetic material for adaptation to suboptimal temperatures. Chile. J. Kalazich (INIA), P. Accatino.

Propagation of Andean root and tuber crops (ARTC) and management of Andean natural resources. M. Holle.

- Production of high-quality seed of *Ullucus tuberosus* (melloco). Ecuador. C. Monteros (INIAP).
- Basic seed production of native potato cultivars. Peru. G. Javier (UNCP).
- Production of certified seed of *Lepidium meyenii* (maca) through clonal selection and progeny tests for the Pasco and Junín regions of Peru. D. Ponce (UNDAC).
- Basic seed production of Andean root and tuber crops. Peru. J.L. Marca.
- Basic seed production of Andean tuber crops in farming communities of Puno and Cusco. Peru. A. Mujica (INIA-PICA).
- Physiological and soil fertility studies on ARTC. Peru. S. Villagarcía.

PROGRAM 6

Postharvest Management, Marketing

Expanding Utilization of Potato in Developing Countries

Introduction

The potato is increasingly becoming an important source of carbohydrates in developing countries, particularly at harvest, when other basic staples are in short supply and potato is comparatively cheap. For the rest of the year, the potato is a high-status, relatively high-priced vegetable. Because potato provides certain amino acids (such as lysine) and vitamins (vitamin C) that are not found in cereals (such as rice or wheat), consumers have sound nutritional reasons for their preferences. Growing urbanization, female participation in the formal workforce, and tourism increase the demand for processed potato products with convenience and gastronomic appeal. In Asia, Africa, and Latin America, however, potato production tends to be highly seasonal, with periods of abundant supply followed by weeks or months of relative scarcity.

Consumers are eager to incorporate more potatoes into their diets if the crop can be made more readily available throughout the year. To help achieve that goal, CIP's postharvest efforts currently focus on three areas of research: ambient-temperature (or rustic) storage for table potatoes; marketing of potatoes and potato products; and breeding for processing. Training activities in the form of courses and materials on methods complement these research efforts.

Storage

In the developing world, farmers store potatoes in many different ways, depending on their scale of farming and the purpose for keeping the tubers. The size, design, and material used for storage also differ. Small farmers tend to keep their produce in the home in small containers, on floors in special structures, or in earthenware pots. These closely guarded stocks serve as seed for the next season and also as ware potato when the need arises. As yields improve and production increases, however, particularly in Asia, even small farmers take an interest in alternative storage practices to help reduce losses and raise incomes.

In areas where cold-storage capacities are low in relation to demand, the limited availability of cold-store space as well as the cost and rental conditions for such facilities prevent many small farmers from availing themselves of such infrastructure. In India, construction of additional cold-storage capacity and the future supply of adequate power to operate these units simply may not be able to keep up with the anticipated increase in potato production by the year 2000. Farmers are therefore left with the following options: sell the bulk of their potatoes at harvest at very low prices; heap tubers in the field for 1-2 months until prices recover; or find alternative storage arrangements to keep their potatoes for later sale.

Option one is often simply not economical. Farmers prefer to leave the crop in the field when producer prices do not cover the cost of harvesting. Heaping can be useful, but is extremely risky. If wet weather develops, such a practice invites disaster; farmers can lose their entire crop, as occurred in certain farming areas in India in 1994. A permanent structure of a rustic nature, cheap to build and maintain, can serve as a storage facility for potato farmers during the glut period. Such a facility can help small growers avoid climatic uncertainties and overcome limited access to cold-storage space. CIP and its collaborators in national programs have experimented with different rustic-storage designs for many years. Recently, CIP postharvest specialists and national program scientists began to test the most promising designs in field experiments under farmer conditions. The purpose of these trials is to evaluate economically and technically the package of improved storage techniques versus traditional practices.

India. Storage research focused on the state of Uttar Pradesh (UP), where more than 6 million tons of potatoes are produced annually in the lowland plains. Nearly all these potatoes are harvested in a period of just 4-6 weeks. Given the resulting drastic drop in potato prices at harvest (Jan.-Feb.), most farmers keep part of the crop in cold stores or under rustic conditions. CIP-supported collaborative storage research seeks to provide farmers with a cheap and simple yet improved method to delay the sale of table potatoes at harvest, when prices are low. The CIP-Central Potato Research Institute (CPRI) research team conceives storage as a "system" and the set of improvements as a "package." In this approach, they view structure, quality and type of potato stored, and storage management as integral components of the overall system.

The CIP-CPRI team tested four storage designs with evaporative cooling during 1994. The first was at the CPRI research station at Modipuram and the other three in neighboring on-farm trials in Meerut district. The team modified the store design of the previous year to improve evaporation of water from the troughs and to obtain uniform movement of air through the potato pile in storage. They fitted the roof of the store at the CPRI farm with a rotary exhaust turbine driven by wind power (Figure 1). The upward draft of moist air caused by the turbine provided a faster, more uniform, and continuous movement of moist air through the potato pile and away from the water trough.

They also modified the storage design by covering the loading door with an enclosure to prevent its heating during periods of higher temperatures and added an improved floor to hold the potatoes in the store using unsplit, small, green bamboo poles tied together to form a mat. They improved water evaporation by constructing a lip, 5 cm higher than the existing lip, on the water trough on the eastern side of the store. The store was constructed so as to catch the westerly winds that prevailed during the postharvest season. The lip on the eastern side prevented the wind from blowing through the bottom of the store, thus increasing the residence time of the wind over the water trough. This gave the water in the trough more time to evaporate and move upward through the potato pile.

Weekly temperature data (Table 1) taken during the storage period from March (entry into storage) to June 1 (removal from storage) indicate a uniform reduction in the difference in temperatures outside versus those inside the CPRI store during the day; these differences became larger from March to

S. ILANGANTILEKE (4)

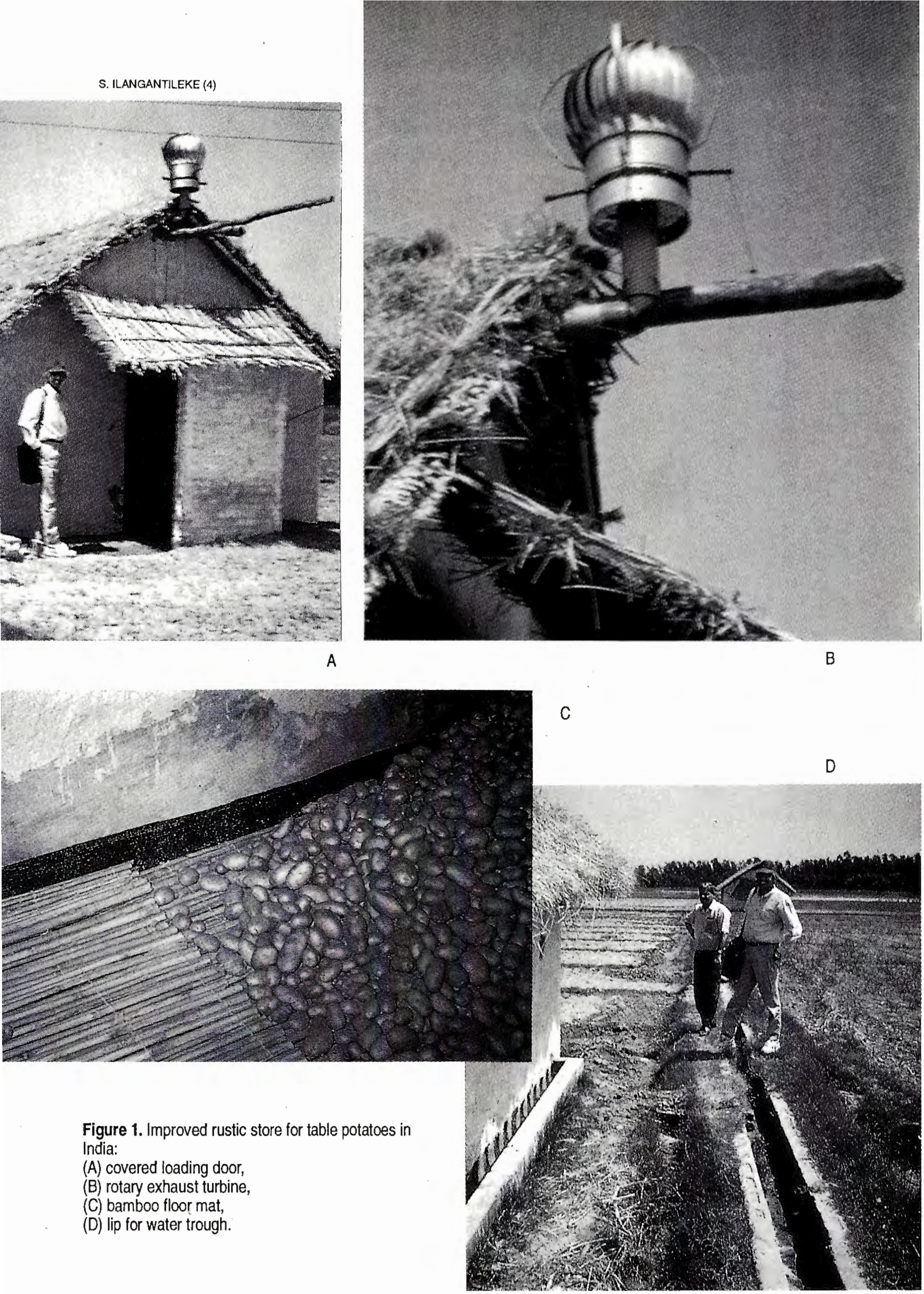


Figure 1. Improved rustic store for table potatoes in India:
(A) covered loading door,
(B) rotary exhaust turbine,
(C) bamboo floor mat,
(D) lip for water trough.

May. For example, in the store with the rotary turbine on the roof, the inside temperature recorded at 2 p.m. was 12-19°C lower than the outside one. The rotary exhaust enhanced evaporative cooling. Together, this combination helped avoid fluctuations in temperatures inside the store; ones observed at 8 a.m. and 2 p.m. were not significantly different.

Table 1. Weekly averages of maximum and minimum temperature in CIP-type evaporative cool store and ambient during March-June, 1994, Uttar Pradesh, India.

Month	Week	Temperature (°C)			
		CIP store		Ambient	
		8:00 a.m.	2:00 p.m.	8:00 a.m.	2:00 p.m.
March	4	21.2	21.2	18.0	35.2
April	1	20.0	20.6	20.0	33.2
	2	18.6	18.6	20.8	36.8
	3	21.3	21.9	23.3	33.2
	4	22.9	23.4	26.3	40.0
May	1	25.2	25.6	26.3	41.5
	2	25.4	25.4	23.9	41.4
	3	24.2	24.9	25.0	43.0
	4	27.7	28.2	29.6	44.1
June	1	28.4	29.5	27.4	45.0

Results from these initial storage experiments in farmers' fields have been mixed, but nonetheless encouraging. Two of the three farmers who stored potatoes in rustic stores made a profit (Table 2). Although the CPRI store in Modipuram had losses, the losses were lower than in stores under farmers' conditions. For a storage period of 70 days, losses for Kufri Chandramukhi (KCM) were 11.8%, and were 12.3% for Kufri Bahar (KB) at Modipuram. Varietal differences no doubt played an important role; KCM and KB are considered to have better keeping quality. KCM was sold after 70 days at Rs. 1.45-1.65/kg and KB at Rs. 1.21-1.26/kg (31.25 rupees = US$1.00).

Among the three farmers who tried out the improved storage design, the farmer with the best results had losses of 13% and 13.7% in storage periods of 84 and 76 days for Kufri Badshah and potatoes produced from true potato seed (TPS), respectively. Timely storage, good store construction and efficient store management (such as regular watering to keep the evaporative cooling process working and attention to market

Table 2. Details of storage studies conducted in CIP-type cool store and ambient, Uttar Pradesh, India, March-June 1994.

Location	Cultivar	Cool store						
		Storage		Disposal		Days of storage	Loss	Price range
		Date	Wt.	Date	Wt.		(%)	(Rs./100 kg)
Machhri unit at CPRS[a]	KCM	31/III	60.0	8/VI	52.9	70	11.8	145-165
	K. Bahar	31/III	39.7	9/VI	34.8	71	12.3	121-126
Village: Lavad	K. Badshah	24/III	50.0	15/VI	43.5	84	13.0	160-180
	TPS	1/IV	70.0	15/VI	60.4	76	13.7	160-180
Village: Bichola	JI-5857	3/IV	43.2	31/V	32.0	59	26.0	65-180
	TPS	3/IV	54.9	1/VI	42.4	60	22.8	65-180
Village: Sivaya	Advanced selection	14/III	50.4	20/V	41.9	67	16.9	n.a.
	TPS	14/III	50.4	20/V	41.9	67	16.9	n.a.

a. The cool store at Machhri was fitted with a wind-powered rotary exhaust turbine.

conditions), good store hygiene, and store location enabled this farmer to minimize his storage losses. He also carefully monitored prices in different markets in India and finally sold his potatoes at prices 30-60% higher than when they were placed in storage. These prices gave him a good profit.

The other two farmers had losses of about 17-26% for storage periods of 67 and 59 days (Table 2). Their higher losses were caused by poor store management and poor quality of potatoes stored. They also sold their potatoes earlier and at lower prices. Nevertheless, one farmer indicated an interest in building a larger rustic store for the 1996 season.

This was the first attempt to take CIP rustic-storage technology to the farm level in South Asia. The findings obtained provide a basis for further improvement of the overall storage system. As part of this effort, CIP postharvest specialists made visits during 1993-1994 to observe storage practices in other parts of India, and in Pakistan. Scientists with Bangladesh's Tropical Crops Research Center (TCRC) began a storage survey in Bangladesh with support from CIP regional staff, and expect to complete it in 1995.

China. Results from a survey on potato storage in Inner Mongolia conducted by Chinese scientists with support from Program 6 revealed that the well-cellar method, now used almost overwhelmingly, is intended to store tubers for table consumption or for seed. Storage temperature is from 0°C to 5°C. Because a large quantity of tubers grown in this region are for industrial use, the Chinese team has indicated a need to develop, with CIP support, an appropriate storage method for potatoes destined for processing (such as chipping).

Egypt. Collaborative research in Egypt focused on the storage behavior of seven potato varieties and three TPS hybrid progenies. Data from the fall season of 1993-1994 indicate that varieties Diamant, Monalisa, and Draga and TPS progenies S x DTO-28, S x LT-7, and Ex-2 showed high yields after storage under rustic conditions. Varieties Ajax and Nicola showed lower yields and therefore require cold storage.

Marketing

Building on earlier case studies of specific countries, recent marketing research at CIP has focused on international trade, the market for processed products, and comparative marketing systems.

In research on trade and processed products, CIP social scientists noted three interrelated trends: (1) a shift in the locus of potato production back to developing countries, as their share of world output passed from 10% to 30% between 1961 and 1993 (Figure 2); (2) the growth in potato trade as a percentage of global output from roughly 1% in 1961 to between 4% and 5% in 1990—FAO data on trade in ware and seed potatoes (Figure 3) were combined with national statistics on trade in processed potato products to arrive at this estimate; and (3) the explosive expansion in demand for processed potato products (such as french fries and chips) in developing countries.

With trade liberalization, improvements in telecommunications and transport, and the international mobility of consumers, traditional limitations to international trade in potatoes—such as bulkiness and perishability—are beginning to disappear. The growth in potato trade involves developing countries in a variety of ways. Developed countries are exporting more potatoes to North Africa (seed) and

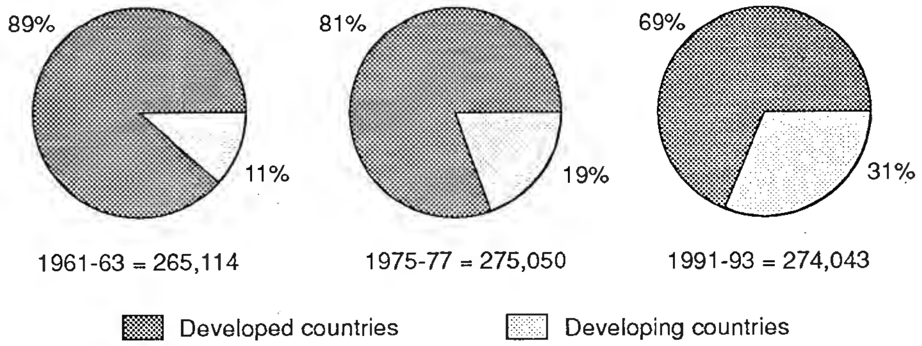


Figure 2. Global potato production (000 t), 1961-1993. (Adapted from FAO, PC-Agrostat, unpublished statistics, 1993.)

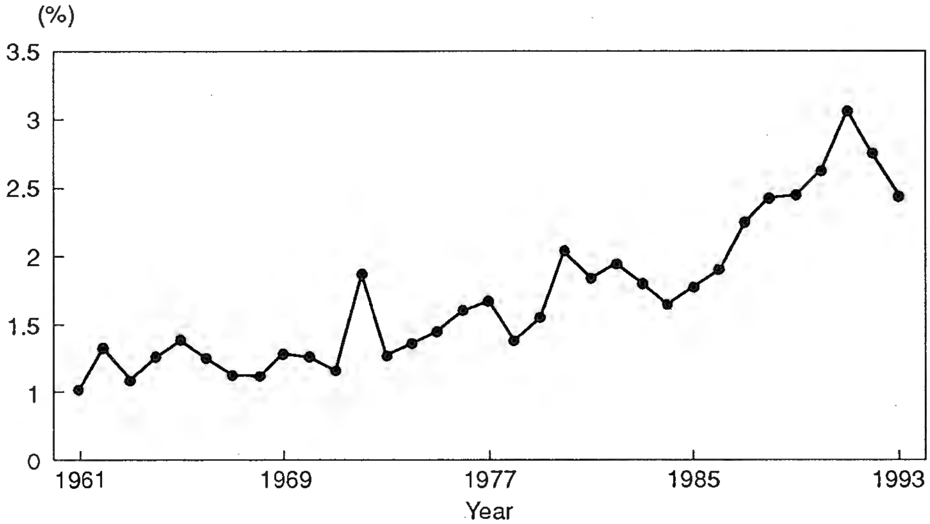


Figure 3. Potato exports as a share (%) of global production, 1961-1993. (Adapted from FAO, PC-Agrostat, unpublished statistics, 1993.)

eastern Asia (processed products). Developing countries around the Mediterranean basin are shipping more table potatoes to Western Europe. Trade among developing countries is also emerging in importance (e.g., Latin America).

Recently completed research comparing marketing systems for potatoes in Africa highlights important differences among the crop's nature, size, and growth prospects in two regional markets north and south of the Sahara. The differences encompass the socioeconomic environment, the orientation of production, the marketing system, and consumer demand (Table 3). As with agroecological production

Table 3. Food systems for potatoes in Africa.

Component	Region	
	North	Sub-Saharan[a]
Socioeconomic environment		
Per capita incomes, (US$), 1991	600-2,000	100-350
Urban population (%)	45-55	12-35
Production		
Ecology	Arid temperate	Humid tropical
Elevation	<500 m	>1,500 m
Marketing		
Percentage sold	Nearly all for sale	Less than 50%
Imports/exports	Imports of seed, exports of table potatoes	Negligible foreign trade
Consumption		
Form	Boiled in stews, french fries	Boiled
Role in diet	Regular complementary vegetable	Luxury item, seasonal staple
Levels	Highest in urban areas	Highest in rural areas

a. Data for South Africa are as follows: per capita income—US$2,560; urban population—60%; rate of growth—0.7%; share of agriculture in gross domestic product—5%.

research, these findings point to the need for more market-specific technological innovations, that is, emphasizing the potential for processing in certain locations (North Africa) and de-emphasizing it elsewhere.

Breeding for processing

A rapidly growing local fast-food industry bolstered by the prospects of joint-ventures with well-known food chains provides increasing evidence of the potential for potato processing in developing countries. The main constraint to accelerated development of processing industries is the nonavailability in both quality and quantity of varieties that serve as suitable raw material for french fries (frozen and fresh) and chips. CIP therefore continues to develop varieties adaptable to tropical growing conditions to meet these processing requirements.

Peru. Lima-based breeders working in Program 6 have obtained advanced clones for processing with high yield and immunity to the most important potato virus diseases (PVY and PVX). Based on trials involving a population of more than 500 clones in La Molina during spring 1993 and in La Molina, San Ramón, Tacna, and Ica during winter 1994, eight clones showed good adaptability and performance for chips and french fries. These clones had high yield, high dry matter (DM) content (ranging from 21% to 24%), and low glucose content (ranging from 0% to 0.5%), with a very good frying color.

CIP staff planted the same population in the highlands (Huancayo, 1994 rainy season), but because of excessive rainfall more than 80% was lost to a severe attack of late blight. However, some clones survived and showed resistance to late blight, with good yield and good processing attributes (Table 4).

CIP breeders planted a population of 10,000 seedlings from 50 TPS progenies obtained from crosses between advanced progenitors for processing and clones resistant to late blight, PVX, PVY, and PLRV at La Molina during winter 1994. The seedlings were previously screened for PVX and PVY. Sixteen progenies showed good yield, uniformity, acceptable DM content, and low reducing-sugar content (Table 5).

At harvest, CIP breeders selected approximately 400 individual clones for agronomic attributes and will evaluate them in 1995 for processing attributes

Table 4. Clones selected for processing at Huancayo, Peru.

Clone	Yield (kg/plant)	DM^a (%)	GL^b (%)	Chip color^c
Costanera	0.90	24.23	0.05	1.5
E86.695	0.70	25.40	0.06	2.0
(LM86.320 x YYbk)62	0.58	23.18	0.09	2.0
(87.055 x XY.20)71	0.94	23.17	0.09	2.0
390652.1	0.81	23.15	0.11	2.0
Kamera	0.75	23.18	0.04	2.0
Zarevo	0.90	23.19	0.06	2.0

a. DM = dry matter content.

b. GL = glucose, acceptable up to 0.10%.

c. On a scale of 1 to 5, where 1 = lightest color and 5 = darkest color; acceptable up to grade 3.

and to confirm their immunity to PVY and PVX. During 1994, these scientists evaluated 130 clones with late blight resistance for processing. Ten clones showed good DM content and acceptable frying color, both for chips and french fries. Researchers planted six advanced processing clones—385499.11 (E86.011), 386611.5 (E86.300), 386612.5 (E86.604), 385500.1 (E86.692), 385500.2 (E86.694), and 385500.3 (E86.694)—cleaned for pathogens at La Molina for multiplication, and will use them later in trials in farmers' fields. These clones are available at CIP for the processing industry for chips and french fries.

Kenya. Potato scientists with the Kenyan Agricultural Research Institute (KARI) worked with CIP breeders based in Nairobi to test varieties grown in various trials, clones, TPS progenies, and other varieties in the seed program for agronomic and postharvest attributes. Lab tests focused on the use of these materials as boiled tubers, chips, and fresh and frozen french fries. KARI staff also organized taste panels to evaluate consumer acceptability. They also tested the acceptability of cooked potatoes after various periods of storage. The goal is to develop efficient screening methods for existing varieties that will reliably predict their acceptability to Kenyan consumers.

Table 5. TPS progenies with processing attributes.

Progeny	Yield (kg/plant)	Dry matter (%)	Glucose (%)
LT-8 x 575049	1.19	21.25	0.10
LT-8 x I-1039	1.18	21.02	0.08
Atlantic x I-1039	1.16	21.86	0.03
Atlantic x TY.3	1.15	21.90	0.04
Delcora x XY.20	1.14	19.75	0.04
E86.300 x DXY.10	1.03	22.01	0.10
Norchip x XY.13	0.99	18.30	0.08
Shepody x XY.13	0.97	18.90	0.12
E86.300 x XY.4	0.97	21.45	0.10
E86.692 x DXY.10	0.97	21.67	0.08
DXY.10 x Atlantic	0.96	20.34	0.05
Ernzteltolz x DXY.15	0.96	21.49	0.10
Shepody x XY.4	0.85	20.38	0.12
Shepody x XY.9	0.85	19.28	0.11
(YY.5 x K223.1)7 x I-1039	0.85	20.15	0.12

KARI scientists worked with CIP staff to conduct field trials involving 25 potato clones in 1994 during the long rains at Mau Norok (2,500 m). Trials also took place at Kabete (1,800 m), with five TPS clones, and at Tigoni (2,100 m), with 12 clones and five varieties. Based on their high yields, disease resistance, and desirable postharvest quality characteristics in previous seasons, clones 381381.13, 381381.20, 384298.59, 382792.5, KP90188.3, 378699.2, and 387699.2 have been advanced to national performance trials.

China. Some 30% of potato production in China goes to processing into flour and starch to make noodles. In northern China, CIP-sponsored research attempted to improve the noodle-making process for potato starch. Innovations included the addition of konjacmannan (*Amorpho phallus konjac*) flour to potato starch, which greatly reduced the amount of alum needed to facilitate the extrusion process used to produce noodles from starch. The addition of the flour also reduced the health risk from the use of alum, and decreased the viscosity of the wet noodles while increasing the tensity of the cooked noodles. These improvements ease the production process, increase profits of processors, and help promote potato cultivation in northern China.

Product Development for Sweetpotato in Developing Countries

Introduction

As economies develop, crop utilization patterns change in response to shifts in market demand for fresh foodstuffs, processed foods, and feeds. This pattern has been particularly pronounced in the case of sweetpotato, as several major producers, most notably China, have witnessed sharp shifts in use patterns for this commodity over the past two decades. These developments represent a series of opportunities and challenges for CIP.

One opportunity concerns the chance to study the nature and pace of, as well as causal factors behind, changing utilization patterns. This should serve to better establish research priorities for sweetpotato use for the countries in question and to anticipate similar scenarios in other countries. Another opportunity concerns the emergence of indigenous technological developments that facilitated these changing use patterns, namely, techniques for possible horizontal transfer. A third opportunity involves simultaneous work on sweetpotato for food or feed or both, depending on the regions and their circumstances, and the need for new innovations to build on existing practices.

Certainly one major challenge to CIP resulting from these developments is the need to adjust research and training activities to maximize the prospects for impact under this dynamic situation. This will require careful priority-setting in terms of technological problems to be addressed, geographic focus, and research methods to be employed. In Program 6, these elements come together in baseline studies aimed at analyzing evolving production/use patterns and market potential for processed sweetpotato products, product development efforts aimed at improving or developing new products made from sweetpotato, and accelerated breeding work to provide a more competitive source of raw material, especially sweetpotato cultivars that have both higher yield and higher DM content. Training efforts in the form of thesis preparation and completion of a training manual on product development complement these research initiatives.

Baseline studies

In an effort to better understand trends in sweetpotato production and use in key countries in Asia, Africa, and Latin America, Program 6 launched a series of baseline studies in collaboration with national research institutions. Two key questions are:

- What have been the major trends in sweetpotato utilization in the country (or region within the country) and what is their relation to production patterns?
- What do these trends imply for sweetpotato postharvest research?

China. As the producer of 85% of the sweetpotatoes in the developing world, China dominates global trends in production and use. Sweetpotatoes are equally important to China itself, as they constitute the fourth largest crop in terms of sown area. They fulfill a vital role in food and feed security in many provinces, especially in the economically poorer and more remote areas that have increasingly become the focus of poverty alleviation efforts. Because Sichuan Province alone produces more sweetpotatoes than the whole of the non-Chinese developing world, is the leading pig-producing province within China, and is a major maize-deficit region, CIP's collaborative efforts have focused on this location to identify use trends, opportunities, and research priorities. To put this province in a national context, recent CIP-supported research by Stanford University's Food Research Institute and Chinese research partners has focused on Zhejiang and Jiangsu provinces, on the rapidly developing eastern seaboard, and Sichuan, isolated in the southwestern interior of the country.

The households sampled in Zhejiang Province in 1991 used more than 60% of sweetpotato production for on-farm pig feed. Only two years later, this had declined to 16%, reflecting the fact that, with rapid development of off-farm employment in new industries, on-farm labor was insufficient for pig-raising activities (pigs per household dropped by 22% over the same period). Sweetpotatoes are now mostly processed (chipped and dried) and sold for feed to households in other areas not yet well linked to the industrial sector of the economy.

In contrast, in the households sampled in three major sweetpotato-producing counties of Sichuan Province, located away from the coastal mainstream of China's economic development, more than 80% of sweetpotato production is still used on-farm as pig feed. Only 6% is consumed fresh on-farm, and another 4% processed into starch and noodles. Sweetpotato tops are also important for feed. The number of pigs per household in Sichuan (more than 10) is large compared with Zhejiang (only 1.8), reflecting the importance of the crop and pig production/utilization systems in Sichuan. Feed grain deficits there cannot be easily countered by imports from other provinces, because of poor and clogged interprovincial transport networks, the remoteness of many of these pig-producing areas within Sichuan, and the seasonal nature of grain deficits, which coincide with peak times of sweetpotato root and vine production.

In the households sampled in the north of Jiangsu, the poorest region of this coastal province, sweetpotatoes were dedicated mainly to processing starch and noodles at the household level (Figure 4).

C. WHEATLEY

Figure 4. Sweetpotato noodle drying, Sichuan Province, China.

Indeed, sweetpotato production was insufficient in many households, and large volumes were purchased from other counties, and even from as far away as Anhui Province. Almost no sweetpotatoes were used for food or feed directly on-farm. Nearly 60% of processed products were marketed outside the county of production, a sign of good market linkages.

In light of these results, Program 6 will focus postharvest research activities in China in Sichuan Province, where sweetpotato production is high and relatively stable. Use is varied. Collaborative research now emphasizes sweetpotato for pig feed, with localized importance given to starch and noodle production (see below). Furthermore, because of shortages of maize for feed and for general food processing, coupled with the total absence of cassava starch in this part of China, sweetpotato starch and flour may have market potential in the food industry beyond that already reached through noodle production. In 1994, for example, the price of sweetpotato starch was competitive with that of maize and other available starches and flours (Table 6). Given this situation, CIP regional staff will join with UPWARD in support of market research to identify the most promising commercial segments for product development research.

Philippines. An economist from the University of the Philippines-Los Baños has conducted a baseline, priority-setting study titled "Prospects of sweetpotato production and processing in the Philippines." It considers crop production and the following sweetpotato-based food and feed products: flour, dehydrated sweetpotato, fermented products, chips for feed, catsup and soy sauce, and snacks (sticks).

Current sweetpotato yields in the Philippines average only 5 t/ha. Research at Visayas State Agricultural College (ViSCA) and elsewhere shows that yield can be increased easily by using new varieties and better production technology, such as fertilizer use. But why has this not happened? Basically because expanded sweetpotato production quickly saturates existing markets, resulting in sharp declines in producer prices. Average elasticities of supply across 12 regions of the country are 0.40-0.65, whereas elasticities of demand vary from 0.20 to 0.30. A 10% increase in production quickly results in a 50% drop in fresh-root prices. This removes incentives for farmers to invest in new production technologies for the crop.

If farmers use high-yielding varieties along with good production technology, they can still obtain good incomes from sweetpotato production, based on increased yields. Net returns on a yield of 20 t/ha and price of P 1.25/kg (24 Philippine pesos = US$1.00) are 98% (296% if the price is P 2.50/kg). In comparison, the rate of return (ROR) for maize is only 25-50% using high technology, or 4-28% using traditional technology (based on 1989-1990 data), because of the high cash cost of the inputs needed. Net social profit ranges

Table 6. Prices of starches and flours available in Chengdu and Suining markets, Sichuan, China, 1993-1994.

Starch or flour	Wholesale price (Y/kg)[a]
Sweetpotato starch	1.7
Maize starch	2.1
Rice flour	2.5
Bean starch	2.2
Cassava starch	n.a.[b]

a. Y 8.7 = US$1.00 (1994).

b. No cassava starch available for sale.

from P 1,400 in Zambales to P 12,350 in Cagayan. Cost per unit of energy (P/Kcal) is lower for sweetpotato (P 0.04-0.16) than for maize (P 0.62-0.75).

For regional processing potential in the Philippines, an economist worked with CIP staff and UPWARD and SAPPRAD scientists to consider several factors. Sweetpotato production is least seasonal in the regions of South Mindanao, East and West Visayas, and the Cagayan Valley. The climate favors natural drying at harvest time in Central Luzon, Ilocos, and Bicol. Average monthly prices (1993) were lowest in West Mindanao, South Mindanao, and Bicol, and were also seasonally low in Central Luzon. Political support for sweetpotato enterprise development is highest in Cagayan and Central Luzon, especially in the areas still gravely affected by the eruption of Mt. Pinatubo in 1991.

Considering different sweetpotato products in detail, demand for dried chips for feed use, for example, depends on the relative price of sweetpotato versus maize. Demand for commercial feeds is increasing: from 1985 to 1990, the growth rate of pig and poultry inventory was 4.9%. After falling in the early 1980s, mixed feed production increased by 6% from 1985 to 1990. Half of feed-mill capacity is located near Manila, with another 20% in Central Luzon.

Sweetpotato and maize compete for land (correlation coefficient of -0.35). Dried sweetpotato chips must be priced at 80% or less of the maize price because of lower feed value (less protein). During most of the 1980s, the ratio of the maize price to the theoretical dried sweetpotato chip price (i.e., calculated from fresh-root price x conversion factor) was less than 1, so it was better to use maize. This is why sweetpotatoes have not yet been used in significant volumes for feed in the Philippines. However, if domestic production expands and prices fall, this picture could change. It is also predicted that the new General Agreement on Tariffs and Trade (GATT) will lead to a 10% increase in international maize prices over time.

All of the wheat used to make flour in the Philippines is imported, an average of 1.3 million metric tons (1988-1990). Some 12 flour mills, located mostly in Metro Manila, currently use only half of their operating capacity. Wheat prices are maintained above the world market price by tariffs of 30% on flour and 10% on wheat grain. Bakers are interested in trying sweetpotato flour as an alternative as long as its price is lower than that of wheat flour. ViSCA has, in the past, developed many food and bakery products using sweetpotato flour, but has paid less attention to cost-efficient production of the flour itself. Current processes are inefficient, comprising more than 50% of total production costs. Based on experience with cassava flour in Latin America and Indonesia, CIP postharvest specialists envision a considerable payoff from research investment to lower these costs. There may also be potential for producing high-quality flour by low-cost natural or mixed drying systems in regions such as Zambales and Tarlac, with favorable climate during the main harvest period. This would be extremely cost-effective. In order to make sweetpotato flour more economically viable, CIP staff and Philippine specialists now agree on the need to define better the product against which such a flour would compete. Research at ViSCA shows that sweetpotato flour is an excellent substitute for wheat flour for sweet bakery goods like cakes and cookies. Wheat flour for this market has a higher price than standard wheat flour, making sweetpotato flour more attractive if we can obtain adequate quality. The potential of sweetpotato flour for food use therefore depends on reduced raw material costs and research to improve processing efficiency and adjust quality to market needs.

Finally, analysis of domestic resource costs shows that processing of sweetpotato has a comparative advantage in saving foreign exchange when fresh-root prices are below P 2.00/kg. The study recommended that farm credit be as available for sweetpotato as for maize or rice, in order to improve crop production. Regions most favored for sweetpotato-processing projects are Cagayan Valley and the Central Luzon/Mt. Pinatubo area. Processing should be rural-based. This has a strong justification on equity and sustainability grounds, and potential for saving foreign exchange.

Kenya. A sociologist at the University of Nairobi completed a study on the potential of sweetpotato for processing into a wide range of products, with support from Program 6 and CIP social scientists based in Kenya. She surveyed urban consumers in Nairobi and Kisumu (Kenya's third-largest city, located in a major sweetpotato production area) on their attitudes toward sweetpotato and products based on this crop. She also surveyed other groups involved, or with potential involvement, including owners of existing food-processing industries using other raw materials, plus traders and farmers.

Table 7. Consumers from Nairobi and Kisumu, Kenya, willing to consume foods containing sweetpotato (fresh, flour, or starch).

Food product	Respondents willing to consume (%)	
	From Kisumu	From Nairobi
Crisps	68	74
Bread	89	88
Chapati	58	78
Ugali	33	54
Chips	50	68
Biscuits	50	68
Cakes	75	84
Mandazi	69	83

Consumers sampled a wide range of sweetpotato-based products. Inclusion of sweetpotato was more acceptable in some products than in others, and in that regard Nairobi and Kisumu consumers differed (Table 7). In both cities, bread incorporating sweetpotato was the most highly accepted food product (almost 90% of the consumers interviewed). More than 70% of respondents in Nairobi and 50% in Kisumu consumed bread for breakfast the day before the survey. Cakes and biscuits were also generally acceptable for use of sweetpotato, but consumption of these foods is limited to special meals (e.g., celebrations) in all except high-income groups. Inclusion of sweetpotato in ugali, a staple food of lunch and dinner in both cities, was not acceptable, especially in Kisumu, where only 33% of consumers responded positively to this product. This survey therefore helped to identify a few specific products for which sweetpotato product development research should be targeted. But we also need to study the economic aspects of using sweetpotato in bread, cakes, and biscuits, especially for raw material costs as compared with those of existing flours.

A survey of local industrialists identified problems with both wheat and maize flour, which are not produced in the immediate vicinity of these cities. These cereal-based flours are the major raw material in 87% and 60% of industries surveyed in Nairobi and Kisumu, respectively. In both cities, more than 70% of industries reported problems in the supply of wheat and maize flours. The use of locally available raw materials (e.g., sweetpotato) was seen positively in this light. Prices of wheat flour and sweetpotato will determine to a great extent the commercial feasibility of any substitution. In many regions of Kenya, sweetpotato prices are highly seasonal. Kisumu, however, has stable prices, at a level below seasonal minima in other regions, that make it the most promising location to begin sweetpotato processing. Furthermore, a comparison of prices for sweetpotato and wheat flour in Kisumu from 1989 to 1992 (Table 8) shows that the trend in fresh-root prices relative to flour prices favors sweetpotato. The potential for processing sweetpotatoes in Kisumu seems promising. In Nairobi, the picture is different, with much higher prices (the ratio of wheat flour to fresh sweetpotato root prices was only 1.9 in 1992) and pronounced seasonality of sweetpotato supply. It may nevertheless be possible to incorporate fresh sweetpotato into bread, as was successfully reported for CIP projects in Peru and Burundi (see *CIP in 1992, Program Report*).

Finally, the economics of flour production also depends on the rate of conversion of fresh sweetpotato roots to flour, and the costs (variable, fixed, and capital) of this transformation. Results from the evaluation trials have identified clones with good processing potential: high fresh-root yields and root DM content (i.e., high DM production per hectare). Using varieties with high DM content, a target conversion rate of 3.5:1 (fresh root to flour) is possible, leaving a margin for both flour processing and marketing costs.

Peru. New uses for sweetpotato have focused on feed and bread-making–in either fresh, grated form or as flour. Results of two M.Sc. theses done by students at Wageningen University in affiliation with CIP suggest that, in the long run, sweetpotato and wheat flour prices move in the same direction, but have large short-term fluctuations. Although the magnitude of the variations in sweetpotato real prices is twice that of wheat flour, actual sweetpotato prices average only 33% of wheat-flour real prices (and only 50% of real cassava prices). The use of sweetpotato flour instead of wheat flour depends, therefore, on the processing costs and efficiency (conversion rates) with which sweetpotato roots can be transformed into a high-quality flour. Experimental data on the costs and efficiency of sweetpotato drying, milling, etc., are not yet available for Peruvian varieties. Generating this information is the next step in a feasibility analysis for sweetpotato flour production in Peru.

Table 8. Trends in wheat flour and sweetpotato root prices in Kisumu, Kenya, 1989-1992.

Price	Year			
	1989	1990	1991	1992
Wheat flour price (Ksh/kg)[a]	8.8	10.5	12.1	14.1
Sweetpotato price (Ksh/kg)	2.0	2.7	1.9	2.4
Wheat:SP price ratio	4.4	3.9	6.4	5.9

a. Ksh = Kenyan shillings.

Product development

CIP has supported research on sweetpotato processing at the Sichuan Academy of Agricultural Sciences (SAAS) since 1989. A wide range of small- and medium-scale equipment for starch extraction from sweetpotato roots and the manufacture of noodles from this starch has been developed in an attempt to improve traditional household practices. In 1994, SAAS and CIP conducted detailed process appraisals of both starch- and noodle-making household enterprises to document the effects of technological change at the level of individual enterprises, and identify any remaining constraints in terms of equipment, raw material supply, product quality and marketing, and enterprise profitability. The noodle enterprise study conducted in January 1994 involved a detailed analysis of five household enterprises using the new technology, based on a small-scale extruder, and five still using the traditional manual method of noodle manufacture. The results showed that households that invested in the extruder (local government has provided considerable support for this, including loan programs) have two advantages over households using the traditional method: greater profit per kg of noodles produced and a higher production volume (Table 9). This combination generates a significantly greater enterprise profit in households with extruders. The capital investment is not excessive and, according to users, can be paid off in one processing season.

Based on these results, it is clear that we need no further research to improve the extruder process for noodle production—this successful technology needs to be more widely promoted within China and its impact documented. The study did, however, highlight the need to improve and standardize starch quality. It should be noted that the noodle product is highly tuned to Chinese consumers' textural preferences, which may restrict its acceptability to other population groups.

As the noodle-making research winds down, Program 6 is now giving special emphasis in China to developing efficient pig-feeding systems based on local feed resources, especially sweetpotato roots and vines. Field data from March 1994 clearly demonstrate the poor performance of current pig-feeding practices based on sweetpotato (Table 10). Compound feed rations are rapidly becoming more available in Sichuan, and represent a more efficient (but not much more profitable; Table 10) option for farmers. The best option for farmers by far, based on simulation modeling using data from Suining County, is the use of sweetpotato combined with appropriate quantities of a feed supplement designed to complement the nutritional inadequacies of the root crop (protein, vitamins, and minerals). CIP and SAAS are therefore developing a project with relevant provincial and national institutions in China to address this issue. This will complement an ongoing project on sweetpotato for animal feed, being implemented by the Chinese Academy of Agricultural Sciences (CAAS) in Beijing. This project has collected samples of sweetpotato-processing residues from 12 sites across China, including Sichuan, and evaluated them for their nutritional value. Residues include those from starch processing and brewing. Researchers also

Table 9. Profit/production comparisons of noodle-making enterprises using traditional (manual) and new (extruder-based) technologies. Information from field appraisal, Santai County, Sichuan Province, China, January 1994.

Profit/production	Extruder enterprises (N=5)	Manual enterprises	
		A (N=5)	B (N=4)
Profit per kg noodles (Y)	0.63	0.18	0.53
Total production volume 1993 (kg)	11,000	4,160	5,025
Total profit (Y)	7,295	2,399	3,236

Note: One of the manual technology enterprises made a loss (noodle production costs exceeded sales price). Column A includes this enterprise in the analysis, column B excludes it. Y 8.70 = US$1.00 (1994).

Table 10. Comparison of modeled annual productivity under different pig-feeding systems in Suining County, Sichuan Province, China, based on data.

	On-farm feeds only	On-farm feeds + concentrate	Compound feeds only
Sweetpotato (kg)	2,000	2,000	0
Maize (kg)	200	200	0
Other on-farm feeds (kg)	1,000	1,000	0
Concentrate (kg)	0	205	0
Compound feed (kg)	0	0	436.00
Investment in feeds (Y)	0	409.60	409.60
Total liveweight produced (kg)	128	267	108.00
No. of pigs reared	1.60	3.34	1.35
Mean time to slaughter (days)	278	125	100.00
Income from pig production (Y)	576.00	1,202.18	487.41
Total feed costs (Y)	490.00	899.60	899.60
Total revenue over input costs (Y)	14.00	152.30	16.89
Profit per pig (Y)	8.75	45.61	12.47

Note: All prices and costs are in yuan (Y). Y 8.70 = US$1.00 (1994).
Definitions:
Concentrate: supplement of protein, minerals, and vitamins.
Compound feed: commercially purchased balanced feed. On-farm feed resources sold at market prices.

analyzed vine and leaf material. They found a high protein content in the brewer's waste (more than 11% on a DM basis), compared with only 2.2% in the residues from starch extraction. Based on these results, CAAS is formulating a series of additive premixes and feed concentrates, which will be tested in trials with commercial pig-raising enterprises starting in 1995.

Vietnam. During the 1980s, CIP, together with the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), the Centre for Grains, Pulses, Roots and Tubers (CGPRT) in Bogor, Indonesia, and Vietnamese national institutions such as the Institut National des Sciences Agronomiques (INSA), conducted a national survey and analysis of sweetpotato production and marketing. This survey identified potential for the use of sweetpotato starch in transparent noodle production, as a substitute for more expensive canna starch. Subsequent CIP support for an M.Sc. thesis at the Asian Institute of Technology (AIT) on the use of sweetpotato starch for noodle production was followed by the implementation of an UPWARD-financed and supported project, carried out by INSA, to introduce sweetpotato processing into a village (Thanh Gia) in Thanh Hoa Province, southeast of Hanoi. INSA and UPWARD established two household enterprises, one producing starch from sweetpotato roots and the other producing and marketing noodles from a mix of sweetpotato and canna starches (proportions varied according to the relative prices of the two starches in the marketplace) (Figure 5). INSA introduced the manual technology for noodle production to the village through training provided by a noodle producer from a canna noodle-producing village close to Hanoi. The noodles made from a

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Figure 5. Sweetpotato/canna noodles ready for marketing, Vietnam.

mixture of sweetpotato and canna starches were well accepted in the marketplace. During 1994, the family producing these noodles switched away from rice noodle production completely because of the market success of this new product and the good profit margins. Labor shortages were the major constraint to the starch production enterprise. The small-scale and largely manual nature of starch extraction technology represented a brake on enterprise expansion to satisfy demand for starch.

In 1994, another M.Sc. thesis was supported at AIT. This thesis evaluated two improved semimechanized but small-scale starch extraction systems and compared them with the traditional manual methods. The Postharvest Technology Institute (PHTI) in Hanoi developed the two systems, principally for use with cassava, but optimal operational procedures for sweetpotato had yet to be identified. The comparison of the three systems showed nonsignificant differences in extraction efficiency and end-starch quality. Labor costs, however, differentially affected profitability. Sensitivity analysis showed that the traditional, manual process had the highest financial rate of return (FRR) when labor costs were low (US$0.66 per man-day), but that partial mechanization was best when labor cost rose to US$0.95 per man-day. This result corresponded closely to the situation in the Thanh Gia project, where poor availability of labor was the major constraint to increased starch production using the existing manual system. In August 1994, PHTI and INSA introduced partial-mechanization equipment into the starch-producing household, and observed an immediate increase in starch production. This coincided with a period of high prices for canna starch. This successful pilot enterprise project is now ready for replication in other households in Thanh Gia, and in other areas of Vietnam.

Building on this success, INSA, PHTI, and several other Vietnamese institutions, with support from UPWARD and Program 6, are conducting a diagnostic survey in four targeted locations in North and Central Vietnam to identify research priorities in utilization. This survey takes a participative approach to analyzing food systems for root crops, including cassava, thanks to collaboration with the Centro Internacional de Agricultura Tropical (CIAT).

Kenya. Since 1992, the Food Science Laboratory of the Kenyan National Potato Research Center at Tigoni has been developing a series of food products that incorporate sweetpotato. These include mandazi (a kind of doughnut), chapati (a form of unleavened bread), crisp (or chips), and cakes from raw, grated, and dried as well as from cooked and mashed sweetpotato. Researchers found that mixing wheat flour and mashed sweetpotato produced the best mandazis, chapatis, and cakes. Grating was too labor-intensive and off-colors developed because of enzymatic browning. Furthermore, in collaboration with the U.K.'s Natural Resources Institute (NRI), CIP provided support for a Kenyan scientist to demonstrate a range of sweetpotato products to a women's group in Uganda, where local varieties were used to replace up to 30% of the flour in bread, biscuits, and cakes.

Peru. Studies conducted in Lima demonstrated that, with a 50% (fresh-weight basis) substitution of grated sweetpotato for wheat flour in bread rolls, quality did not differ from that of bread rolls with 100% wheat flour as long as the sweetpotato was peeled and grated finely. Researchers at the Universidad Nacional Agraria La Molina found significant differences in crust color and crumb structure when sweetpotato was unpeeled or coarsely grated, but no significant differences in taste or texture except for finely grated sweetpotato with peel (Table 11).

Sweetpotato starch in Peru has growing commercial interest, and commercial operation of the first medium-scale starch extraction enterprise started in the Cañete Valley, an irrigated coastal production region, in 1994. In support of this and other future ventures, and in coordination with the private sector, CIP began screening sweetpotato varieties to identify material with starch characteristics (compared with those of potato starch) of specific industrial interest. CIP complemented chemical and physical analyses by characterizing swelling power and solubility of the starches extracted at the industrial plant from six clones and one local variety. Results showed that clones MC880-016, YM89-133, and YM89-232 have the greatest swelling power and solubility (although the highest amounts are still only 54% and 73%, respectively, of those of potato starch at 90°C).

Breeding and selection

SAAS is one of the institutions collaborating in the evaluation of sweetpotato varieties for processing. In work linked to the starch enterprise evaluations mentioned above, this study is testing two of the promising new materials. The lead institution for the breeding for processing project in China is the Xuzhou Sweetpotato Center. Researchers evaluated 23 new varieties in four provinces during the 1993-1994 season in Xuzhou itself, plus the provinces of Jiangsu, Zhejiang, and

Table 11. Sensory evaluation of bread from sweetpotato and wheat versus wheat-only, Lima, Peru, 1994.[a]

	Treatment				
	1	2	3	4	5
Sweetpotato treatments					
Grating	fine	coarse	coarse	fine	wheat only
Peel removed	no	no	yes	yes	wheat only
Sensory evaluation					
Symmetry	**2.27**	**2.65**	**2.93**	**3.58**	**3.57**
Crust color	2.27	2.53	2.92	**3.37**	**3.92**
Crumb color	2.12	2.50	2.70	**4.13**	**3.95**
Crumb structure	2.33	2.58	2.60	**3.95**	**3.53**
Texture	2.50	**2.78**	**2.65**	**3.55**	**3.52**
Aroma	2.33	**3.10**	**3.15**	**3.22**	**3.20**
Taste	2.50	**2.85**	**2.93**	**3.52**	**3.20**

a. Treatments 1 to 4 used a 50% grated sweetpotato substitute for wheat flour, treatment 5 is 100% wheat-flour control; sensory evaluation was conducted with panel of 10 members, using a 1-5 scale (5 = excellent, 1 = bad); values in bold are not significantly different from the 100% wheat-flour bread control.

Sichuan. Xushu 18 was used as a check variety because it is widely adapted to the trial locations. Indeed, only in Jiangsu and Sichuan was Xushu 18 consistently outperformed for fresh and dry matter yields. All clones that outperformed (or nearly outperformed) Xushu 18 were advanced breeding lines. For example, Xu90-19-3 outperformed Xushu 18 in Xuzhou and Zhejiang, although this was not significant in Xuzhou. Chuan 8129-4, Chuan 8801-1, and Chuan 8410-788 from Sichuan performed well at all locations where they were tested. High DM clones Chuan 8410-788, Mienfenl, Shengnan, Xu90-30-9, and Zhe84-64 performed well at all locations, although the latter failed in Sichuan. Roots from Sichuan had higher DM content than those from other locations. Researchers carried out further quality evaluations for specific products at different locations: for starch extraction in Sichuan and Zhejiang, and for fried chips in Xuzhou. Based on these comprehensive evaluations for productivity and processing quality, clones retained for evaluation in 1994 included Chuan 8410-788, Xu90-9, NingR61-4, Lu86320, Yil506, Xushu 18, Shengnan, and Xu90-51-1. In addition, based on productivity and processing quality, CIP and Chinese collaborators have recommended four clones for fried chip production, four for candied strips, and six for starch extraction. Multiplication of these clones will begin in 1995.

Philippines. ViSCA is also evaluating CIP-introduced germplasm for processing characteristics. Results to date in observational trials have identified several clones with potential for high DM content, such as 440084 and 440003, although the local check VSP-15 had the highest fresh and DM yield per ha. Researchers also identified clones with high starch and low total sugar content. In the preliminary trial, clones 440004, BC101, and R16-2 had higher fresh yields than the local checks. In addition, clones with orange flesh suitable for snack and beverage production—such as 440003, 440084, and TN 66—have been identified. Researchers evaluated these clones in taste panels with ViSCA variety VSP-1 for various sweetpotato products, and found them to be equal to VSP-1 in organoleptic quality and product acceptability. Selected clones will enter replicated trials and multilocational regional trials in 1995 for further evaluations.

Indonesia. The CIP team in Indonesia collaborates with the Central Research Institute for Food Crops (CRIFC) in evaluating both CIP-introduced clones and promising clones bred by CIP in Indonesia. Researchers selected 22 CIP pathogen-tested clones based on 1993 results, and planted them at both Bogor (200 m) and Lembang (1,600 m) in 1994. Results (Table 12) show that, even in a year badly affected by drought, several different clones performed better than the local check, SQ 27, at both sites. In addition, the team found significant (P=0.001) correlations between fresh and DM yields at both Bogor and Lembang (0.972 and 0.945, respectively), but not between DM yield and root DM content at either site. Correlations between sites and between years (1993 and 1994) were also significant for fresh and DM yields and DM content. This implies that selecting for widely adaptable varieties may be possible. In another trial located in West Sumatra, CIP and CRIFC tested eight locally selected clones and three advanced clones from the ESEAP breeding program at Bogor for productivity in the field and flour production, in collaboration with a commercial flour producer. All ESEAP-bred clones were superior to the local germplasm for flour production and fresh-root yield under poor fertility conditions. CRIFC and CIP selected clone B0053-9 as the most promising. It had white skin and flesh, the highest fresh-root yield (12.8 t/ha) under acid-soil conditions, and the best conversion (24.7%) to dehydrated diced cubes (the penultimate step before flour is obtained through milling/sifting). In comparison, SQ 27 had fresh-root yield of only 9.2 t/ha, conversion of 24%, and a poor final-product color after drying. This identification, by a commercial processor in collaboration with CIP, of a new clone that outperforms existing materials for both crop productivity (on poor, acid

Table 12. Results from evaluations of 22 CIP pathogen-tested clones in Bogor and Lembang, West Java, Indonesia, 1994.

	Bogor			Lembang		
	Fresh yield (t/ha)	DM content (%)	DM yield (t/ha)	Fresh yield (t/ha)	DM content (%)	DM yield (t/ha)
Maximum	15.4	38.4	5.07	26.3	36.7	6.86
Minimum	0.5	22.2	0.16	1.6	21.4	0.50
Mean	5.4	30.3	1.60	12.9	28.2	3.60
SQ 27 check (mean of 3 reps)	3.8	35.8	1.38	12.0	31.9	3.87
No. clones > SQ 27	15	2	11	11	4	11
Top 3 clones[a]	440084	SQ 27	440084	440056	188005.1	440056
	440005	188005.1	400005	440084	440100	440084
	440025	440100	440025	440021	SQ 27	440024

a. 440025 is Xushu 18, 440056 is Ivoire, 440084 is IITA-TIS 8250, 400005 is CEMSA 78-326, 440100 is IITA-TIS 9162, 440021 is W-226, and 440024 is Yan Shu 1.

soils) and end-product yield and quality demonstrates the potential of sweetpotato in Indonesia.

Kenya. With collaboration from CIP, the Kenyan national research system has established a comprehensive series of regional trials to test local and CIP-selected clones. The results are highly encouraging, in that the best local clones have produced excellent yield and root quality (dry matter) for processing (Table 13). Several CIP-selected clones are promising in terms of overall yields, but do not yet present advantages in DM content. With the establishment of a project funded by the Kenyan research system, this series of trials will continue in the future, and provide a solid basis for conducting regional research on local and introduced materials. Several trial sites are close to Kisumu, where good potential for sweetpotato processing was identified. The good yields and excellent DM content recorded at these sites suggest that superior raw material quality will be one additional advantage in this area. Besides carrying out quality and yield analyses in these trials, we identified some clones with superior processing quality for specific products.

Peru. CIP evaluated three groups of sweetpotato clones in field trials in Cañete during 1994. Group 1 included 18 advanced clones from CIP's high DM recurrent selection population. Group 2 contained 20 clones selected from a total of 60 elite clones from other countries and international centers. Group 3 contained 18 selected clones (based on yield and other agronomic traits) from 100 clones on the CIP pathogen-tested list. Of these clones, 23 yielded significantly more than the local check cultivars (María Angola and Jonathan), whereas 30 clones had significantly higher DM yield (Table 14). Eight clones yielded 50% or more dry matter and starch than the local checks. As an added advantage, most of these clones also had a growing season 20-30 days shorter than that of the local checks.

CIP also subjected roots from Group 1 clones to starch content determinations, in both the laboratory and a

Table 13. Summary of data[a] from eight regional trial locations in Kenya, comparing local and CIP-introduced sweetpotato clones.

Measurement	Trial location				
	Mtwapa	Kakamega	Siaya	Mosocho	Kabondo
Fresh-root yield (t/ha)					
Mean	6.23	19.19	6.78	11.40	14.11
Best local	11.96	34.50	9.61	23.00	31.22
Best CIP	**34.25**[a]	**46.11**	**10.61**	12.39	14.72
Root dry matter content (%)					
Mean	31.30	30.00	31.50	34.70	29.70
Best local	37.50	36.10	39.80	42.00	37.00
Best CIP	33.50	30.10	34.90	37.00	39.00
Dry matter yield (t/ha)					
Mean	1.92	5.62	2.11	3.97	4.06
Best local	3.77	10.37	3.83	8.12	9.99
Best CIP	5.82	9.64	2.41	3.84	5.18

a. Data are placed in bold where the best CIP-introduced clone outperformed the best local clone at the same trial location.

Table 14. Results from evaluations of promising clones in Cañete, Peru, 1994.

Group	Fresh yield (t/ha)	DM content (%)	DM yield (t/ha)
Pathogen-tested clones (N=18)			
Mean	33.89	29.03	9.81
Maximum	41.65	33.87	13.48
Minimum	27.31	20.02	6.70
María Angola	33.26	30.99	10.31
Top 3 clones	YM89.052	YM89.104A	YM89.052
	YM89.208	YM89.259	MC88.016
	MC88.016	SR90.025	YM89.133
Elite clones from other breeding programs (N=21, summer harvest)			
Mean	27.69	32.20	8.59
Maximum	52.08	40.90	17.00
Minimum	6.61	21.30	2.45
María Angola	13.52	32.10	4.34
Top 3 clones	NG 7570	AVDRC 21-005	L 49
	L 49	JPKY 5-018	JPKY 19-008
	SAPR 1-005	JPKY 7-014	SAPR 1-005
CIP pathogen-tested (N=18 fresh yield, N=7 DM content and yield)			
Mean	26.08	24.27	8.36
Maximum	41.42	31.15	10.78
Minimum	13.02	17.32	5.15
María Angola	24.49	23.24	5.69
Top 3 clones	IITA-TIS 8524	Viola	IITA-TIS 9265
	Tainung 64	IITA-TIS 9265	Viola
	IITA-TIS 9265	Tainung 64	IITA-TIS 8524

medium-scale starch extraction plant located near the field site in Cañete. Whereas the laboratory starch determinations showed values of 14.8% to 27%, those in the starch factory, based on dry starch produced from the sampled roots, ranged from 10.1% to 14.9%. The total recovery rate of extracted starch ranged from a maximum of 85.6% to a low of 45.2% (mean recovery, 62.8%) of the total starch contained in the roots.

United States. CIP has also supported a project on the enhancement of sweetpotato nutritional quality for food and feed uses conducted at North Carolina State University. This project principally concerns starch digestibility and trypsin inhibitor activity (TIA) in sweetpotato roots. Both of these antinutritional factors are significant drawbacks to increased use of sweetpotato products, especially for feed. Studies at NCSU have quantified the narrow-sense heritability of TIA and crude and true protein based on both family means and individuals (Table 15). Genotypic correlations showed little correlation between crude and true protein, but crude protein correlated with nonprotein nitrogen. TIA correlated slightly with true protein, but moderately with crude protein. A breeding strategy based on

Table 15. Narrow-sense heritability of trypsin inhibitor activity and crude protein and true protein content based on family means and individuals, North Carolina State University, USA, 1994.

Selection unit	Trypsin inhibitor activity	Crude protein	True protein
Family means	0.89	0.57	0.52
Individuals	0.79	0.15	0.17

mass selection would be the most effective strategy for changing TIA levels in sweetpotato roots, whereas a strategy based on family selection would be better for manipulation of protein content as such. Selection for protein content should be based on true protein, not crude protein. Selection for low TIA would not result in lower root protein content.

A study is currently under way on 43 clones selected from a high DM population. NCSU will analyze samples from all clones for β-amylase, DM percentage, starch digestibility plus amylose content, gelatinization, and viscosity characteristics, as well as correlations between these characteristics.

Postharvest Management of Andean Food Commodities

Introduction

In the past two years, CIP's collaborative program of postharvest research activities has expanded to include lesser-known Andean roots and tubers such as oca, mashua, ulluco, yacón, achira, and arracacha. Work on native potato varieties is also part of this recent initiative. The thrust of these efforts is to document postharvest characteristics of these crops and current use and marketing patterns, and, most important, to identify possible ways of expanding current household uses and commercial outlets. Improved postharvest management and marketing can greatly enhance the long-term viability of continued cultivation of these crops—otherwise destined for further decline. The initial geographic focus of the work has been Bolivia, Ecuador, and Peru, with some effort in Brazil and Colombia. Because research on these various crops began recently, this report highlights results from work done to date on achira.

Achira

Achira *(Canna edulis)* is a common backyard plant in mesothermic areas of the Andes. It is essentially known as an ornamental and source of large leaves (for tamales, etc.). It is common to encounter bundles of achira leaves in the vegetable section of markets in the northern Andes. For example, the leading supermarket in Quito, Ecuador, has these leaves on hand year-round. In contrast, the plant's edible starchy rhizome is rarely appreciated, even in the countryside, and direct consumption of the rhizome—once a staple along the pre-Columbian Peruvian coast—is disappearing. The reasons for this are obvious to travelers who have a chance to witness the preparation of achira. The rhizome must be cooked for several hours (!) to soften. Texture and taste of the cooked rhizome are not unlike those of sweetpotato, but it is more fibrous—a rather mediocre food compared with common root staples.

The starch contained in achira rhizomes has the largest granule known, and the fact that the starch settles out rapidly from a suspension of grated tissue must have been discovered independently in several places. Starch extraction from achira, however, although still more common than rhizome consumption, is confined to specific areas. For example, in

Ecuador, Quito residents are totally unaware of the existence of achira starch, whereas people in Loja in southern Ecuador include achira starch regularly in their cuisine, especially in the countryside, where households themselves (perhaps several thousand) produce minute quantities for domestic consumption. The situation is similar in Colombia and Peru. Elderly informants confirmed the antiquity of this type of processing as did the persistence of local names for the achira plant and its starch (achira, chuño, sagú, etc.).

It is obvious from interviews that the oldest and in most areas still prevailing mode of achira use is small-scale and for domestic consumption. Typically, a few hundred square meters of achira are planted near houses (to minimize transport of rhizomes to the processing site). Mostly women engage in harvesting and grating the rhizomes. Extraction is done with primitive equipment (manual laminar graters) and total annual production per household rarely surpasses 40 kg. Occasionally, women sell some excess starch to shopowners in nearby towns, or, when prices are high, to wholesalers who may come long distances (e.g., Bogotá to Huila; southern to central Ecuador).

In Patate (central Ecuador), and in some achira-growing regions in Cundinamarca, Colombia, however, more entrepreneurial-minded farmers have small achira starch operations with daily outputs ranging from 50 to 300 kg of dry starch (20-100 batches per year). There is great diversity in processing time (continuous throughout the year versus strictly seasonal), varietal use, cultivation method, extraction technology, provision of raw material, market channels, and use of family versus hired labor. The most "evolved" operations are perhaps in Patate and Cundinamarca. There, farmers use engine-powered graters able to process several hundred kg of rhizomes per hour. Pulps are no longer washed in traditional wooden "badeas" (trays) but in large cement tanks. The investment needed amounts to perhaps US$1,000-$3,000 for the grater and settling tanks. Either family (minga) or hired labor is used for the onerous task of harvesting and cleaning the rhizomes (about 40 person-hours per ton of rhizomes) and extracting the starch (about 30 person-hours per ton of rhizomes). In Patate (Ecuador) and Nariño (Colombia), we met farmers who would buy most of their raw material from other farmers not engaging in extraction themselves. Arrangements whereby farmers make their equipment available to neighbors in return for a share of the extracted starch are also common. However, even under such "advanced" production conditions, the typical achira plot rarely covers 1 ha or more.

Table 16 presents data on the chemical composition of achira rhizomes and the efficiency of starch extraction. The term "processor starch" refers to the amount of starch recovered by the farmer and "laboratory starch" denotes the amount recovered in the laboratory from bagasse by further crushing the material in a commercial food processor. Total starch is the sum of processor and laboratory starch and approximates the potential starch yield achievable with better extraction equipment. Because the equilibrium humidity of achira starch is around 20% (considerably higher than that of cassava starch—12%), starch contents in Table 16 are expressed accordingly.

Starch contents under the rather moist conditions of Huila are considerably lower than in Nariño and Patate

Table 16. Chemical composition of achira *(Canna edulis)* and parameters of starch extraction (in % of rhizome fresh matter).[a]

Locality	Processor starch[b]	Laboratory starch[c]	Total starch[d]	Extraction efficiency[e]	Total fiber	Soluble solids	Total dry matter
Nariño, Colombia (2,050 m, 1.37° N)	11.3	4.7	16.0	71	4.1	6.4	23.8
Huila, Colombia (1,800 m, 1.57° N)	9.0	2.0	11.0	82	3.8	9.1	22.1
Huila, Colombia (1,800 m, 1.57° N)	5.9	1.9	7.8	75	5.9	7.4	19.8
Patate, Ecuador (2,350 m, 1.19° S)	13.6	4.4	18.0	75	6.4	2.1	23.5

a. All starch contents are expressed as starch with 20% humidity.

b. Starch extracted by farmer.

c. Starch extracted from processed bagasse.

d. Potential starch yield.

e. % ratio actual/potential starch yield.

(Table 16). Although total DM content of the rhizomes is high (20-24%), a maximum of only 13.6% starch was recovered from the rhizomes. As evident from Table 16, two factors explain the low extraction rates. First, the proportion of total starch content recovered by rural processors is only around 75%. This is most likely a consequence of the inadequate grating surfaces that fail to totally release starch from the fibrous rhizome tissue. Second, soluble solids, most of which are sugars, account for as much as 41% of total dry matter. Obviously, achira cultivars are poor converters of sugars into starch, and this indicates opportunities for crop improvement.

As a result of the inefficient and costly extraction process, achira starch throughout the region is traded at premium prices, typically three times the price of wheat starch, if not higher. It would follow that achira starch is used only in recipes in which the widely available wheat starch gives unsatisfactory results or where achira starch represents a minor proportion of total product costs. Indeed, both conditions are met for most products using achira starch.

The most widely used product made of achira starch is "bizcochuelos," a traditional recipe containing achira starch, a large amount of eggs, and condiments. Loja (Ecuador) is known for its achira-based bakery products (quesadillas, carmelitas, etc.). Cundinamarca (Colombia) invented the popular "pan de sagú," a type of cheese-bread similar to "pan de yuca." So far, these are traditional products more or less confined to the areas of achira cultivation or adjacent areas.

The only product that has transcended municipal or regional boundaries is salt biscuits, called "achiras," once a local delicacy in Altamira (Huila, Colombia), but improved and popularized all over Colombia in recent times by a Bogotá-based cookie producer. Several other companies imitate the recipe and these biscuits can now be bought throughout Colombia. Avianca, the Colombian national airline, offers these biscuits on its international flights as a genuinely Colombian snack. The product even appeared recently on the Ecuadorian market. There is little doubt that, as a consequence of the popularization of this product, achira area in Colombia must have expanded over the past 10 years.

The functional properties of achira starch and their significance for product development are not yet understood. Based on experience with traditional products, we believe that exceptional expansion of achira doughs and the granular and light textures achira starch confers to bakery products are the features sought by achira starch users. Nevertheless, there is evidence that both potato and arrowroot starches (from *Maranta arundinacea*) can replace achira starch to some extent in the preparation of bizcochuelos, and we have seen large amounts of Dutch potato starch in the market of Loja used to that effect. There is reason to be concerned about the influx of the Dutch starch because it will increasingly replace the erratic supply of domestic achira starch. Maranta is very rarely grown in the Andes and it represents no competition to achira. Our informants consistently perceived cassava starch, priced much cheaper than achira starch, as quite distinct from the latter and unsuited for most recipes requiring achira or maranta starch.

Training

Literature surveys, field visits, a training workshop, and thesis research have provided information to develop an up-to-date manual on potato storage in developing countries. The manual will serve as a vehicle for diffusing information about the various components of the technological package on rustic storage for table potatoes, especially the latest developments and the application of these principles. The target users of this publication are scientists, rural development specialists, and extension personnel. Topics will include storage needs for potato in developing countries; simple storage systems in different regions; principles of storage in a systems context; biological and physical damage during storage; storage design specifications; store management; and storage economics. A draft of the manual was presented for comments at a regional training workshop on "Storage of potatoes in developing countries," held 26-31 March 1994 at the Pakistan National Agricultural Research Center in Islamabad, Pakistan. Scientists from Bangladesh, Kenya, Nepal, Pakistan, Rwanda, Sri Lanka, and Vietnam participated. Resource persons present were from the United Kingdom, United States, CIP-Tunisia, CIP-Delhi, FAO, the Swiss/Pakistan potato project, Pakistan's national potato program, and the Postharvest Institute in Faizalabad, Pakistan (Figure 6).

Because of structural adjustment and trade liberalization, recent years have witnessed a growing interest on the part of national programs, NGOs, rural development projects, and policy-makers in developing countries in domestic agricultural marketing issues. CIP responded by preparing a collection of papers to be published on these issues in collaboration with social scientists from CIMMYT, CIAT, IFPRI, ICLARM, ILRI, and leading developing-country research institutes. This document is unusual in several respects. It provides the reader with a set of practical, applied methods for rapid assessment of marketing problems and opportunities based on the authors' experiences in Asia, Africa, and Latin America. It covers field methods for analyzing marketing systems and particular product markets, with a focus on data collection procedures, and analytical methods for prices and other marketing issues such as impact assessment.

Figure 6. Training course in Pakistan on storage of potatoes in developing countries.

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1993-94 Research Projects and Partners

This list contains titles of research projects, names of principal research partners and responsible CIP scientists, collaborating institutions, and, when applicable, countries where work is conducted.

Expanding utilization of potato in developing countries. S. Ilangantileke.

- Low-cost storage of consumer potatoes in India. J.P. Singh, N.P. Sukamaran (CPRI); S. Ilangantileke, M. Upadhya, V.S. Khatana.
- Piloting of diffuse light storage in farmers' fields. Indonesia. A.A. Asandhi, A. Asgar (LEHRI-AARD); E. Rasco, S. Ilangantileke (SAPPRAD).
- Potato breeding for processing in developing countries. H. Mendoza, G. Scott, M. Ato.
- Processing potato variety trials. Thailand. M. Thongjiem (DA), E. Rasco, H. Mendoza (SAPPRAD).
- Marketing and demand for potatoes in developing countries. G. Scott, R. Basay.
- Assessment of promising clones under seed and ware conditions. Kenya. J. Kabira (KARI), H. Kidane-Mariam.
- Storage of ware and seed potatoes. Egypt. A. Sharara, S. Doss, N. Farag (MA); R. El-Bedewy.
- Potential for potato processing in Tunisia. B. Khedher (ESH), M. Fahen (CPRA), C. Martin.
- Rustic storage of consumer potato in South Asia. S. Ilangantileke.
- Rustic potato storage and processing in Inner Mongolia. Song Bo Fu.

- An analysis of demand for potatoes in Bangladesh. F. Goletti (IFPRI), G. Scott.

Product development for sweetpotato in developing countries. C. Wheatley.

- Sweetpotato cultivars for processing in developing countries. Kenya. P.J. Ndolo, J.N. Kabira (KARI); E. Carey.
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- Improved sweetpotato processing in China. Z.F. Tang, L.P. Lin (SAAS); C. Wheatley, Song Bo Fu.
- Sweetpotato cultivars for processing in Peru. J.P. Molina (INIA), D. Zhang, L. Díaz, M. Ato.
- The use of sweetpotato roots, vines, and processing residues for pig feed in China. Li Wei Ge (CNCQS, CAAS), C. Wheatley, Song Bo Fu, G. Scott.
- Product development for sweetpotato in Southeast Asia. N.D. Duc (PHTI); C. Wheatley, G. Scott, G. Prain.
- Development and diffusion of processing technology for sweetpotato transparent noodle production in Vietnam. D. Thi Lan, Le Doan Dien (PHTI, INSA); G. Prain, C. Wheatley (UPWARD).
- Pilot production of sweetpotato chips and other sweetpotato products. Philippines. L. Lopez, E.B. Orolfo (PCARRD); E. Rasco, C. Wheatley (SAPPRAD).
- Market development for sweetpotato and sweetpotato products. Philippines. E.L. Lopez, E.B. Orolfo (PCARRD); E. Rasco, C. Wheatley (SAPPRAD).
- Sweetpotato industry development for the upland areas of the Bicol region. Philippines. E.L. Lopez (PCARRD), E. Rasco, C. Wheatley (SAPPRAD).
- Product development for sweetpotato in sub-Saharan Africa. J. Kabira (KARI), V. Hagenimana, P. Ewell.
- Product development for sweetpotato in Latin America. C. Gómez, V. Guevara, Z. Reynoso (UNA); M. Sánchez-Griñón, M. Fukumoto (IIN); N. Espinola, J. Herrera, G. Scott.
- Breeding sweetpotatoes with enhanced nutritional quality for human food and animal feed. W. Collins (NCSU), E. Carey, G. Scott.
- Survey of traditional storage and processing of sweetpotato in India. G.T. Kurup, J.N. Moorthy, T. Pram Kumar (CTCRI); T.R. Dayal, V.S. Khatana.
- Sweetpotato in the economy of China. S. Rozelle (Stanford U), J. Huang (CRRI), G. Scott, C. Wheatley.
- Sweetpotato cultivars for processing in developing countries. Philippines, Vietnam. E. Chujoy, J. Bacusmo (ViSCA).
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- Quality evaluation of promising sweetpotato varieties from CIP evaluations and Irian Jaya collections. C. Wheatley, J. Schneider, Il Gin Mok (ESEAP); D. Damardjati, S. Widowati (BORIF); J.E. Rickard (NRI).
- Market/technology/policy assessment for sweetpotato in Bangladesh. N. Higginson (CIDA), S. Ilangantileke.
- A socioeconomic assessment of sweetpotato market potential in Nairobi, Kenya. M. Omosa (U Nairobi), P. Ewell, E. Carey.

Postharvest management of Andean food commodities. M. Holle.

- Product development for Andean roots and tubers. Bolivia. G. Alfaro (UMSS), M. Holle.
- Inventory, research, and diffusion of processing technologies for Andean roots and tubers. Ecuador. G. Enríquez, B. Jaramillo (FUNDAGRO); M. Holle.
- Evaluation, improvement, and diffusion of storage and processing systems for Andean roots and tubers. Peru. F. Ccama, O. Chaquilla, W. Salas (IAPA); M. Holle.
- Evaluation, improvement, and diffusion of storage and conservation systems for Andean tubers. Peru. A. Tupac Yupanqui, M. Holle.
- Political economy and its impact on peasant potato production in Ecuador with emphasis on producers of native varieties. H. Ramos (CEICA), M. Holle, G. Scott.
- Relative importance and potential of native potato varieties in the diet of rural and urban consumers in Peru. H. Creed (IIN), M. Holle, N. Espinola, G. Scott.
- Technical aspects in processing potatoes in Peru. M. Alvarez (Centro IDEAS), M. Holle, G. Scott.
- ARTC carbohydrate characterization and utilization. M. Hermann.
- Arracacha and achira processing and product development. M. Hermann.

Streamlining and Integrating Information Services

In 1993, the Information Department began a three-year program to revamp its organization, draft a new information strategy, and acquire the personnel, specialized training, and tools necessary to achieve CIP's goals. By matching CIP's information strategy with the Center's unique, decentralized institutional structure, CIP could fulfill its vocation of service to national programs and farmers, incorporate new technologies, and adapt to budget realities. The goal was to translate CIP research results and know-how into suitable information products and greater public awareness.

Teamwork

The Information Department worked to diffuse more effectively results achieved over the past 20 years, but not readily accessible to all users interested in new technologies. This approach means that the Department has worked closely with researchers and support personnel to determine what information products should be developed and how they should be packaged. Then, the Department assists with the resources needed (on staff or hired temporarily) to achieve the goals, and supervises progress. Scientific staff, however, determine whether an initiative is worth the investment and meets their needs.

For instance, CIP's main scientific databases (germplasm, in vitro, seed distribution, and pedigree) were integrated, linked to a genetic resources work group, and also made available on-line so that those working directly with the information could have ready access. This new, comprehensive database will be compatible with the CGIAR Systemwide Information Network on Genetic Resources (SINGER).

The Department was instrumental in putting together the first workstation for geographic information systems (GIS) by encouraging pooling of resources from various disciplines. The Department also set up a gopher (a structured text database for access over the Internet) to permit international access to CIP information and publications.

CIP's information strategy also aims to use formats and tools that will allow regionally based staff to have the same kind of access as headquarters scientists. Greater use of the Internet and electronic communications will assist in this task.

Library

Although the library underwent a sharp staff reduction, reorganization, and change of name (it was previously called the Information Unit), the staff maintained their high standard of research services to CIP scientists, national programs, and other clients. The library's bibliographic database has 48,000 entries. Its information profiles reached more than 300 priority clients, mainly national programs and libraries. It continued to broaden the scope of its core collection by expanding sweetpotato literature, christening an Andean root and tuber crops collection, and acquiring more material on ecology and mountain farming systems.

The library has effectively tapped into nonconventional literature, such as research theses and national program training materials, that would not normally find its way into more conventional reference libraries.

The library is now venturing into new areas by setting up an on-line free-form text database of CIP-generated information for scientists and senior management. It is also helping to reorganize the photography archive as a preliminary step toward setting up an image database linked to the text and genetic resources databases.

Communications

In conjunction with the Director General's Office, the Communication Unit revamped the yearly corporate report, the biennial program report, and the *CIP Circular*, and prepared institutional brochures and other products. The Unit continued to put out the *Circular* in three editions, English, Spanish, and French. On an experimental basis, the Unit began distributing an electronic edition in English and Spanish on the Internet. As CIP's flagship publication, the *Circular* now reaches more than 6,000 subscribers around the world. The Unit also made all of its most recent institutional publications available on-line through CGNET Services in the United States.

The Unit has provided enhanced editing services to the institution to improve the clarity and presentation of CIP documents, in both English and Spanish. It has also increased the visual impact of its products by incorporating more modern design and style. Desktop publishing has allowed the Unit to modernize its production system while still taking advantage of installed printing capacity.

The Unit updated its photo collection to reflect current activities and it joined with the Peruvian Social Photography Workshops (called TAFOS in Spanish) to expand the range of images. In support of CIP's public awareness activities, the Unit has also been highly successful in preparing specialized exhibits and targeted publications for donors, research partners, and the general public.

The Communication Unit relaunched a popular series of field manuals with the publication of *Major Diseases and Pests of Sweetpotato in Eastern Africa.* New versions of field manuals for potato and sweetpotato were under way, in both English and Spanish. A manual for other Andean roots and tubers is also in preparation.

Information Technology

The ITU (formerly called the Computer Unit) helped CIP to go on-line to the Internet, with the Peruvian Scientific Network as its local carrier. This move provided enhanced electronic mail and fax services to research and support staff at headquarters and in regional offices. The mushrooming use of electronic communications has changed the way that CIP staff operate. For instance, computerized ordering helped the Logistics Unit to eliminate the use of 21,000 paper forms per year. When the Internet link is fully established, CIP scientific staff will have access to the same electronic research tools as any university campus in the United States or Europe.

With a more powerful generation of desktop computers connected to the headquarters network, the Information Department has steered the Center toward a Windows operating environment. This move included a policy of major software upgrades, such as Microsoft Office, to increase staff productivity, and a switch to Microsoft Mail. CIP signed onto the CGNET Services' main e-mail and fax system (CGNET II). This investment in equipment and software was paired with a flexible training program adapted to user needs and skills. An outside service company provided training to small groups of staff.

Finally, CIP increased its participation in systemwide efforts to coordinate information and dissemination and to find integrated, efficient, and inexpensive solutions to problems shared by all the agricultural research centers in the CGIAR. The CG SINGER initiative and Integrated Voice Data Network (IVDN) were the two major components.

Cross-Program Training Courses 1993-1994

In 1993, CIP and PRODASA (Proyecto de Desarrollo Agropecuario Sostenido en el Altiplano) organized a short course on Bibliographic Database Information Management at INIA (Instituto Nacional de Investigación Agraria) facilities in Puno, Peru. The course emphasized management of CIP's bibliographic database. It included the use of micro-isis software, inputting and editing data, search and recovery, information import and export, and visual analysis and printing. It also covered format design for databases.

A Course for Training Trainers on Agricultural Extension was held in Paraguay, sponsored by the Ministry of Agriculture, IAO (Istituto Agronomico per l'Oltremare), PROCIPA (Programa Cooperativo de Investigaciones en Papa), and CIP. The main objectives were to discuss the basic concepts involved in training extension agents to organize activities aimed at producers, plan training events, and produce training documents. The training materials used were reproduced and distributed to participants for immediate use.

CIP, IITA (International Institute for Tropical Agriculture), ISABU (Institut des Sciences Agronomiques du Burundi), and ESARRN (East and Southern Africa Root Crops Research Network), in collaboration with FAO (Food and Agriculture Organization of the United Nations), IDRC (International Development Research Centre), and UNICEF (United Nations International Children's Emergency Fund), sponsored an in-country course in Burundi on Cassava and Sweetpotato Production and Postharvest Technology, with French- and English-speaking participants. It covered the socioeconomic importance of root and tuber crops in Burundi, cassava and sweetpotato rapid multiplication techniques, agronomy of root crops, diseases and pests and their control, and field plot techniques. The course also discussed field plot layouts and agronomic practices. Participants observed and identified diseases and pests.

An international training workshop on Methods for Agricultural Marketing Research was held in New Delhi, India, in collaboration with ICAR (Indian Council of Agricultural Research), IARI (Indian Agricultural Research Institute), and CIP. Some 37 scientists from different parts of the world participated, including representatives from CIP, IFPRI (International Food Policy Research Institute), UPWARD (User's Perspective with Agricultural Research and Development), Australia, Bangladesh, China, Ethiopia, India, Japan, Nepal, Pakistan, the United Kingdom, the United States, and Vietnam. The workshop permitted an open exchange of ideas, methods, and experience in agricultural marketing among researchers and national program leaders.

We organized a course in collaboration with PROINPA, Bolivia, on Analysis and Presentation of Scientific Data, Report Preparation, and Lecturing Methods. The course had three parts. The first part addressed problems commonly found by research scientists in planning analysis and interpreting results as well as in reporting and presenting scientific results orally. The second part dealt with generating scientific databases and following up different research projects. The third part was a seminar on the most relevant subjects of the two previous parts.

A meeting on Planning and Priority Setting on Andean Natural Resources took place for five days at CIP-Lima. Program planning by objectives (PPO) covered the following subjects in Andean agriculture: land and water management, policy and socioeconomics, livestock and pastures, agroforestry, and training and communications. The meeting included a proposal and design for a Consortium for the Sustainable Development of the Andean Ecoregion (CONDESAN). Participants prepared a strategy for partnership to promote development of the Andean agroecosystem. Some 43 participants from national, international, and donor agencies attended.

CIP and the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) organized an eight-day course on Serological and Molecular Identification of the Granulosis Virus in Egypt. The course emphasized the use of ELISA, nucleic probes, and techniques to detect and diagnose the virus.

In 1994, CONDESAN sponsored a two-day international workshop for INFOANDINA participants at CIP headquarters in Lima, Peru. Its main objectives were to organize and analyze existing electronic communication facilities, the exchange of information, and access to databases, with emphasis on the management of natural resources and sustainable development, for INFOANDINA members in the Andean ecoregion.

A two-day workshop on Macroeconomic Policies, Regional Integration, and Andean Food Systems: The Case of Potato was held at CIP-Lima. It covered the identification of problems derived from changes in macroeconomic policies of Colombia, Bolivia, Ecuador, and Peru, and analyzed their effects on highland agriculture both nationally and regionally.

Contributions to Scientific Literature by CIP Staff

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* Some staff members appearing on this list worked under temporary or special contracts.
1 Staff who joined in 1993
2 Staff who joined in 1994
3 Staff who left in 1993
4 Staff who left in 1994
5 Staff funded by special projects
6 Project leader
7 Died in 1993

The CGIAR: A Global Agricultural Research System

CIP is a member of the Consultative Group on International Agricultural Research (CGIAR), an association of public and private sector donors that supports a worldwide network of agricultural research centers. Together, the 16 CGIAR centers have more than 1,000 scientists, representing more than 50 nationalities, stationed in 51 developing countries, where they work closely with national partners to promote sustainable agricultural advances. Their research involves crops that provide 75% of food energy and a similar share of protein requirements in the developing countries.

The other 15 centers are:

CIAT
International Center for Tropical Agriculture
Cali, Colombia

CIFOR
Center for International Forestry Research
Bogor, Indonesia

CIMMYT
International Maize and Wheat Improvement Center
Mexico City, Mexico

ICARDA
International Center for Agricultural Research in the Dry Areas
Aleppo, Syria

ICLARM
International Center for Living Aquatic Resources Management
Manila, Philippines

ICRAF
International Centre for Research in Agroforestry
Nairobi, Kenya

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

IFPRI
International Food Policy Research Institute
Washington, D.C., USA

IIMI
International Irrigation Management Institute
Colombo, Sri Lanka

IITA
International Institute of Tropical Agriculture
Ibadan, Nigeria

ILRI
International Livestock Research Institute
Nairobi, Kenya

IPGRI
International Plant Genetic Resources Institute
Rome, Italy

IRRI
International Rice Research Institute
Manila, Philippines

ISNAR
International Service for National Agricultural Research
The Hague, Netherlands

WARDA
West Africa Rice Development Association
Bouake, Côte d'Ivoire

Acronyms and Abbreviations

AARI	Aegean Agricultural Research Institute, Turkey
AARI	Agricultural and Animal Production Research Institute, Uganda
ACP	acid phosphatase
Acvs	Andean cultivars
ADB	Asian Development Bank
AGCD	Administration Generale de la Coopération au Développement, Belgium
AIT	Asian Institute of Technology
APLV	Andean potato latent virus
APMV	Andean potato mottle virus
APW	Andean potato weevil
ARTC	Andean root and tuber crops
AUDPC	area under the disease progress curve
AVRDC	Asian Vegetable Research and Development Center, Taiwan
BARI	Bangladesh Agricultural Research Institute
BID	Banco Interamericano de Desarrollo
BORIF	Bogor Research Institute for Food Crops, Indonesia
Bt	*Bacillus thuringiensis*
BW	bacterial wilt
CAAS	Chinese Academy of Agricultural Sciences
CEICA	Corporación de Estudios sobre Inversión y Comercio Agrícola, Ecuador
CGIAR	Consultative Group on International Agricultural Research, USA
CGPRT	Centre for Grains, Pulses, Roots and Tubers, Indonesia
CIAAB	Centro de Investigaciones Agrícolas A. Boerger, Uruguay
CIAT	Centro Internacional de Agricultura Tropical, Colombia
CICA	Centro de Investigación en Cultivos Andinos, Peru
CIDA	Canadian International Development Agency
CIED	Centro de Investigación, Educación y Desarrollo, Peru
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo, Mexico
CIP	Centro Internacional de la Papa, Peru
CIRNMA	Centro de Investigaciones de Recursos Naturales y Medio Ambiente, Peru
CNCQS	Chinese National Centre for Quality Supervision and Test of Feed
CNPH	Centro Nacional de Pesquisa de Hortaliças, Brazil
CONDESAN	Consortium for the Sustainable Development of the Andean Ecoregion
Cornell U	Cornell University, USA
CORPOICA	Corporación del Instituto Colombiano Agropecuario
COTESU	Cooperación Técnica Suiza, Switzerland
CPB	Colorado potato beetle
CPRA	Centre de Perfectionnement et de Recyclage Agricole de Saïda, Tunisia
CPRI	Central Potato Research Institute, India
CRIFC	Central Research Institute for Food Crops, Indonesia
CRRI	Chinese Rice Research Institute
CTCRI	Central Tuber Crops Research Institute, India
CURLA (UNAH)	Centro Universitario Regional del Litoral Atlántico-Universidad Autónoma de Honduras
DA	Department of Agriculture
DAS	double-antibody sandwich
DECS	Department of Education, Culture, and Sports, Philippines
DGIS	Directorate General for International Cooperation, Netherlands
DIA	diaphorase
DM	dry matter
DNA	deoxyribonucleic acid
DOH	Department of Health, Philippines
EAPR	European Association for Potato Research

ELISA	enzyme-linked immunosorbent assay
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária, Brazil
ENEA	Comitato Nazionale per la Ricerca e per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative, Italy
EPAMIG	Empresa de Pesquisa Agropecuária de Minas Gerais, Brazil
ESARRN	East and Southern Africa Root Crops Research Network
ESCAP	Economic and Social Commission for Asia and the Pacific
ESEAP	East and Southeast Asia and the Pacific, CIP region
ESH	Ecole Supérieure d'Horticulture, Tunisia
EST	esterases
FAO	Food and Agriculture Organization of the United Nations, Italy
FONAIAP	Fondo Nacional de Investigaciones Agropecuarias, Venezuela
FORTIPAPA	Fortalecimiento de la Investigación y Producción de Semilla de Papa, Ecuador
FRKN	false root-knot nematode
FRR	financial rate of return
FUNDAGRO	Fundación para el Desarrollo Agropecuario, Ecuador
GAAS	Guandong Academy of Agricultural Sciences, China
GATT	General Agreement on Tariffs and Trade
GIS	geographic information systems
GOT	glutamate oxaloacetate transaminase
GTZ	German Agency for Technical Cooperation
IAO	Istituto Agronomico per l'Oltremare, Italy
IAPA	Instituto de Análisis de Política Agraria, Peru
IAPAR	Instituto Agronômico do Paraná, Brazil
IAR	Institute of Agricultural Research, Ethiopia
IARI	Indian Agricultural Research Institute
IBTA	Instituto Boliviano de Tecnología Agropecuaria
ICA	Instituto Colombiano Agropecuario
ICAR	Indian Council of Agricultural Research
ICLARM	International Center for Living Aquatic Resources Management, Philippines
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
IDEA	Instituto Internacional de Estudios Avanzados, Venezuela
IDH	isocitric acid dehydrogenase
IDIAP	Instituto de Investigación Agropecuaria, Panama
IDRC	International Development Research Centre, Canada
IFPRI	International Food Policy Research Institute, USA
IIN	Instituto de Investigación Nutricional, Peru
IITA	International Institute for Tropical Agriculture, Nigeria
ILRI	International Livestock Research Institute, Kenya
INIA	Instituto Nacional de Investigación Agraria, Peru
INIA	Instituto Nacional de Investigaciones Agropecuarias, Chile
INIA	Instituto Nacional de Investigaciones Agropecuarias, Uruguay
INIAP	Instituto Nacional de Investigaciones Agropecuarias, Ecuador
INIFAP	Instituto Nacional de Investigaciones Forestales y Agropecuarias, Mexico
INIVIT	Instituto de Investigaciones de Viandas Tropicales, Cuba
INRA	Institut National de la Recherche Agronomique, France
INRAT	Institut National de la Recherche Agronomique de Tunisie
INSA	Institut National des Sciences Agronomiques, Vietnam
INTA	Instituto Nacional de Tecnología Agropecuaria, Argentina
IPM	integrated pest management
IPO-DLO	Institute for Plant Protection-Agriculture Research Department, Netherlands
IPR	Institute for Potato Research, Poland

ISABU	Institut des Sciences Agronomiques du Burundi
ISAR	Institut des Sciences Agronomiques du Rwanda
IVDN	Integrated Voice Data Network
IZ	Instytut Ziemniaka, Poland
KARI	Kenyan Agricultural Research Institute
LAC	Latin America and the Caribbean, CIP region
LB	late blight
LCG	low-cost greenhouses
LEHRI	Lembang Horticultural Research Institute, Indonesia
LMF	leafminer fly
LSU	Louisiana State University, USA
MA	Ministry of Agriculture
MAbs	monoclonal antibodies
MAP	*Mirabilis* antiviral protein
MDH	malate dehydrogenase
MENA	Middle East and North Africa, CIP region
MIP	Programa de Manejo Integrado de Plagas, Dominican Republic
Miss SU	Mississippi State University, USA
MLOs	mycoplasma-like organisms
MOA	Ministry of Agriculture, Tanzania
MS	Murashige & Skoog
MSIRI	Mauritius Sugar Industry Research Institute
NAARI	Namulonge Agricultural and Animal Production Research Institute, Uganda
NARO	National Agricultural Research Organization, Uganda
NARS	national agricultural research systems
NASH	nucleic acid spot hybridization
NAvs	North American varieties
NCM	nitrocellulose membrane
NCSU	North Carolina State University, USA
NGO	nongovernmental organization
NPRC	National Potato Research Center, Kenya
NPT	national performance trials
NRI	Natural Resources Institute, UK
ODA	Overseas Development Administration, UK
OP	open-pollinated
OPEC	Organization of Petroleum Exporting Countries
ORSTOM	Office de Recherche Scientifique et Technique Outre-Mer, France
PCARRD	Philippine Council for Agriculture & Resources, Research & Development, Philippines
PCN	potato cyst nematode
PCR	polymerase chain reaction
PGI	phosphoglucose isomerase
PGM	phosphoglucomutase
PGS	Plant Genetic Systems, Belgium
PHTI	Postharvest Technology Institute, Vietnam
PIABS	Proyecto de Investigaciones Agrarias de la Provincia Bautista Saavedra, Bolivia
PICA	Programa de Investigación de Cultivos Andinos, Peru
PICTIPAPA	International Cooperative Program for Potato Late Blight, Mexico
PLRV	potato leafroll virus
PMTV	potato mop-top virus
PPO	program planning by objectives
PRACIPA	Programa Andino Cooperativo de Investigación en Papa, CIP network
PRAPACE	Programme Régional de l'Amélioration de la Culture de la Pomme de Terre et de la Patate Douce en Afrique Centrale et de l'Est, CIP network
PRECODEPA	Programa Regional Cooperativo de Papa, CIP network in Central America and the Caribbean
PRN	potato rosary nematode
PROCIPA	Programa Cooperativo de Investigaciones en Papa, CIP network in Southern Cone
PRODASA	Proyecto de Desarrollo Agropecuario Sostenido en el Altiplano
PRODE-KON	Proyecto de Desarrollo Rural Integral, Peru

PROINPA	Proyecto de Investigación de la Papa, Bolivia
PSTVd	potato spindle tuber viroid
PTM	potato tuber moth
PVM	potato virus M
PVS	potato virus S
PVT	potato virus T
PVX	potato virus X
PVY	potato virus Y
RAPD	randomly amplified polymorphic DNA
RES	Rothamsted Experiment Station, UK
RFLP	restriction fragment length polymorphism
RH	relative humidity
RIPA	rapid immunofilter paper assay
RKN	root-knot nematode
ROR	rate of return
RT	reverse transcription
RTIP	Root and Tuber Improvement Program, Tanzania
SAAS	Sichuan Academy of Agricultural Sciences, China
SAPPRAD	Southeast Asian Program for Potato Research and Development, CIP network
SCRI	Scottish Crop Research Institute
SEINPA	Semilla e Investigación en Papa, Peru
SENASA	Servicio Nacional de Sanidad Agraria, Peru
SINGER	Systemwide Information Network on Genetic Resources
SPCFV	sweetpotato chlorotic fleck virus
SPFMV	sweetpotato feathery mottle virus
SPLSV	sweetpotato leaf speckling virus
SPLV	sweetpotato latent virus
SPMMV	sweetpotato mild mottle virus
SPSVV	sweetpotato sunken vein virus
SPVDC	sweetpotato virus disease complex
SQM	Sociedad Química y Minera, Chile
SSA	Sub-Saharan Africa, CIP region
Stanford U	Stanford University, USA
SWA	South and West Asia, CIP region
TALPUY	Grupo de Investigación y Desarrollo de Ciencias y Tecnología Andina, Peru
TCRC	Tropical Crops Research Center, Bangladesh
TGA	total glycoalkaloid
TIA	trypsin inhibitor activity
TPS	true potato seed
U Fla	University of Florida, USA
U Inner Mongolia	University of Inner Mongolia, China
U Nairobi	University of Nairobi, Kenya
U Naples	University of Naples, Italy
U Tacna	Universidad Jorge Basadre Grohmann de Tacna, Peru
U Tuscia	University of Tuscia, Italy
UMSS	Universidad Mayor de San Simón, Bolivia
UNA	Universidad Nacional Agraria, Peru
UNCP	Universidad Nacional del Centro del Perú
UNDAC	Universidad Nacional Daniel Alcides Carrión, Peru
UNDP	United Nations Development Programme, USA
UNICEF	United Nations International Children's Emergency Fund
UNMSM	Universidad Nacional Mayor de San Marcos, Peru
UNSCH	Universidad Nacional San Cristóbal de Huamanga de Ayacucho, Peru
UPLB	University of the Philippines, Los Baños
UPWARD	Users' Perspective with Agricultural Research and Development, CIP network
USAID	United States Agency for International Development
UTO	Universidad Técnica, Oruro, Bolivia
ViSCA	Visayas College of Agriculture, Philippines
Wageningen U	Wageningen University, Netherlands
XSPRC	Xuzhou Sweet Potato Research Center, China
YNU	Yunnan Normal University, China

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(as of June 30, 1995)

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CIP Networks

CIP's Networks and Their Partner Countries

PRACIPA	PRAPACE	PRECODEPA	PROCIPA	SAPPRAD
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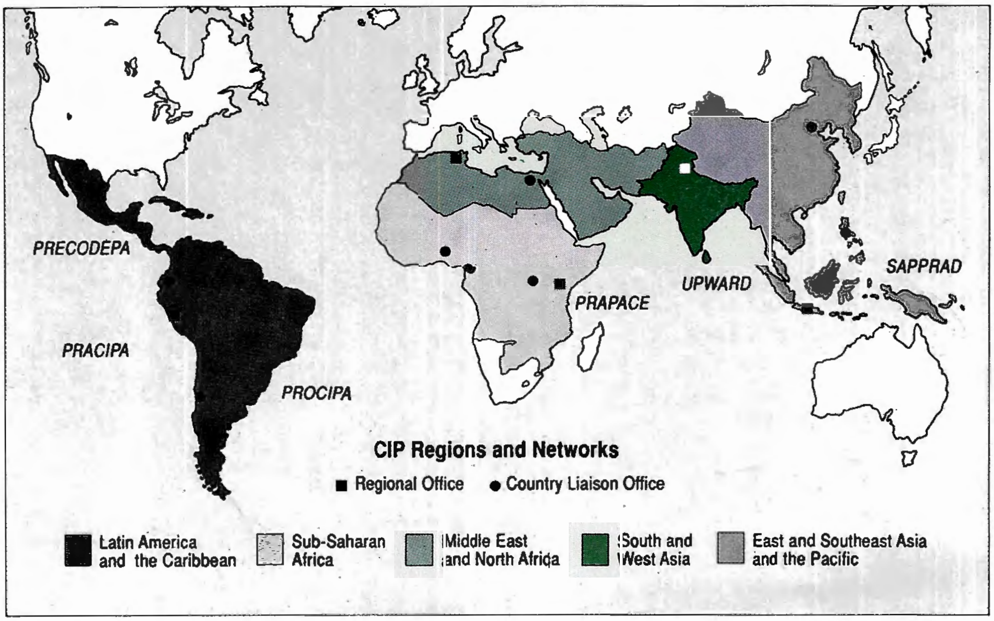
Bolivia, Colombia, Ecuador, Peru, Venezuela	Burundi, Eritrea, Ethiopia, Kenya, Rwanda, Uganda, Zaire	Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama	Argentina, Brazil, Chile, Paraguay, Uruguay	Indonesia, Malaysia, Papua New Guinea, Sri Lanka, Thailand
				UPWARD
				Users' Perspective with Agricultural Research and Development
				China, Indonesia, Nepal, Philippines, Sri Lanka, Vietnam

CIP Regions and Networks



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