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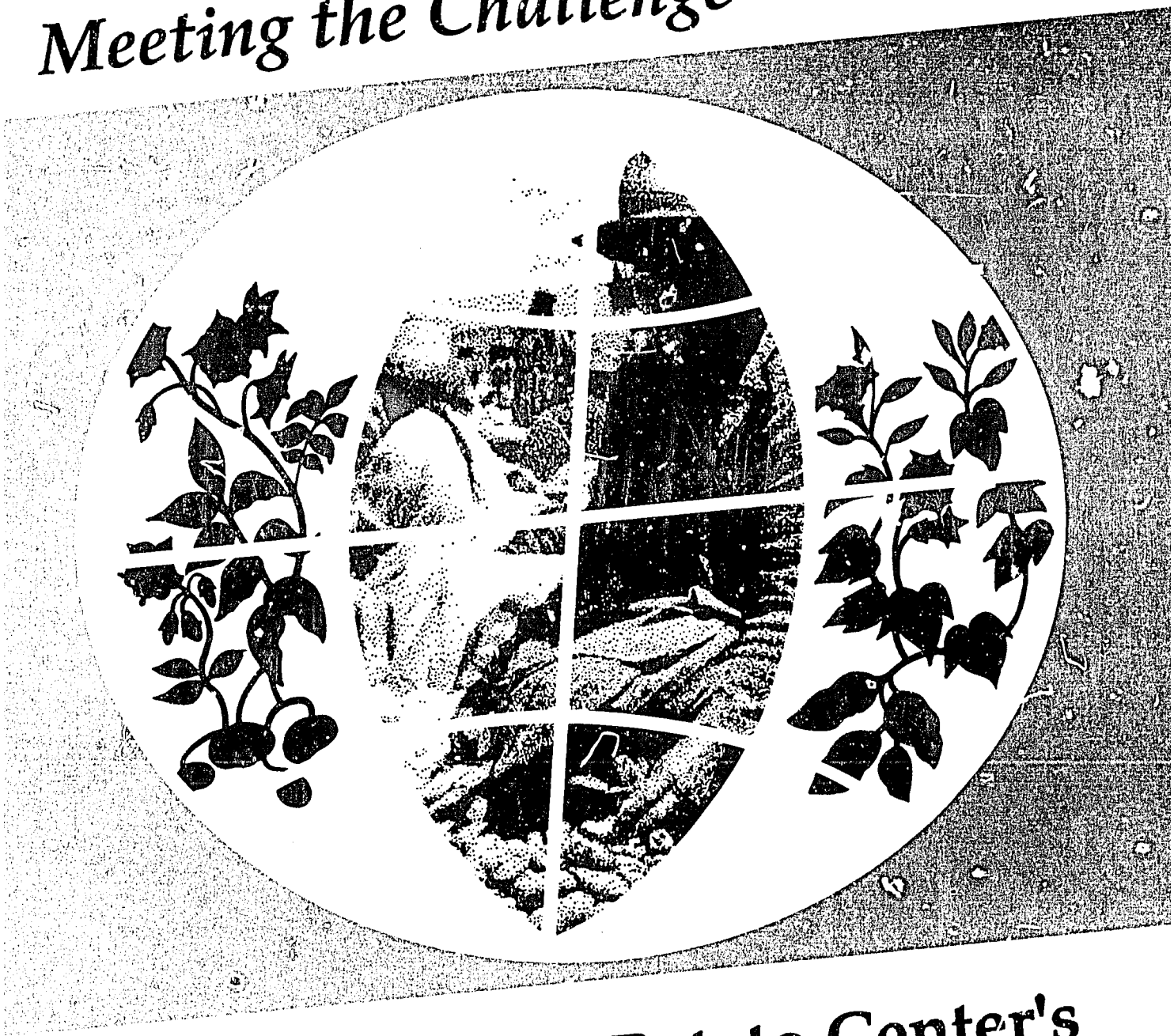
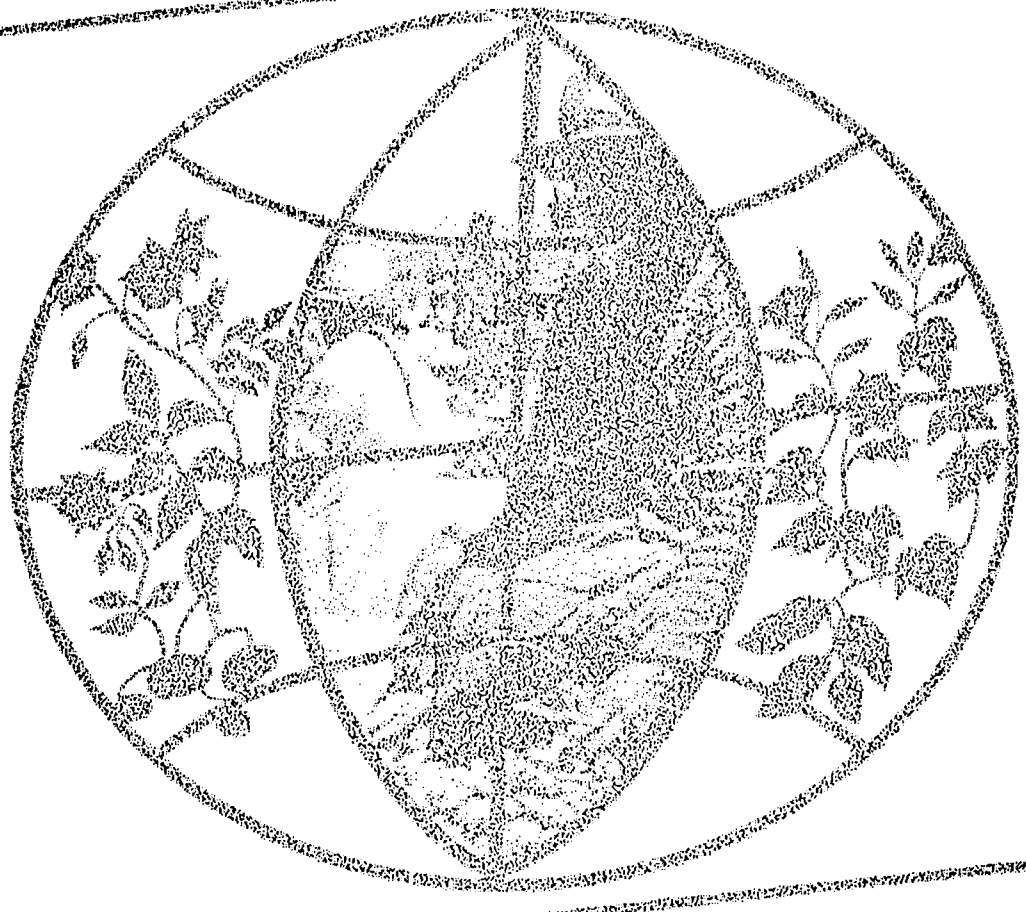
Meeting the Challenge



The International Potato Center's

PN-ABJ-740

Meeting the Challenge



The International Potato Center's Strategy for the 1990s and Beyond

INTERNATIONAL POTATO CENTER Apartado 5969 - Lima, Peru

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CIP's Mandate

To conduct the research necessary to solve priority problems that limit potato and sweetpotato production and consumption in developing countries. This includes adaptation of the collective knowledge existing in the industrialized countries, as well as pertinent postharvest research.

CIP Board of Trustees, 1985

CIP's Mission

CIP's mission is to contribute to increased food production, the generation of sustainable and environmentally sensitive agricultural systems, and improved human welfare by:

- *conducting coordinated, multidisciplinary research programs;*
- *carrying out worldwide collaborative research and training designed to enhance national research programs' capacity to determine and utilize the unique potential of CIP's mandate commodities within diverse food systems;*
- *catalyzing collaboration among countries to promote mutual comprehension and interdependence in solving common problems;*
- *helping scientists worldwide to respond flexibly and successfully to changing demands in agriculture.*

CIP Board of Trustees, 1991

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 between countries;*
- *conducting appropriate research in cooperation with national program 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 national programs in reaching and maintaining their fullest potential.

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Acronyms

AVRDC	Asian Vegetable Research and Development Center (Taiwan)
CGIAR	Consultative Group for International Agricultural Research (US)
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (Mexico)
DLS	diffused light storage
ELISA	Enzyme-Linked Immunosorbent Assay
ESARRN	East and Southern Africa Root Crops Research Network
GATT	General Agreement on Tariffs and Trade
GNP	gross national product
IBPGR	International Board for Plant Genetic Resources (Italy)
IBSRAM	International Board for Soil Research and Management (Thailand)
ICIMOD	International Centre for Integrated Mountain Development (Nepal)
ICIPE	International Center of Insect Physiology and Ecology (Kenya)
ICRAF	International Council for Research in Agroforestry (Kenya)
IFPRI	International Food Policy Research Institute (US)
IIMI	International Irrigation Management Institute (Sri Lanka)
IITA	International Institute of Tropical Agriculture (Nigeria)
ILCA	International Livestock Center for Africa (Ethiopia)
INIAA	Instituto Nacional de Investigación Agropecuaria y Agroindustrial (Peru)
IPM	integrated pest management
IRRI	International Rice Research Institute (the Philippines)
ISNAR	International Service for National Agricultural Research (the Netherlands)
NASH	Nucleic Acid Spot Hybridization
PLRV	potato leafroll virus
PRACIPA	Programa Andino Cooperativo de Investigación en Papa
PRAPAC	Programme Régional d'Amélioration de la Culture de Pomme de Terre en Afrique Centrale
PRECODEPA	Programa Regional Cooperativo de Papa
PROCIPA	Programa Cooperativo de Investigaciones en Papa
PRU	propagation and redistribution unit

PTM	potato tuber moth
PVX	potato virus X
PVY	potato virus Y
RFLP	restriction fragment length polymorphism
SAPPRAD	Southeast Asian Program for Potato Research and Development
SPCLV	sweetpotato caulimo-like virus
SPFMV	sweetpotato feathery mottle virus
SPMMV	sweetpotato mild mottle virus
TAC	Technical Advisory Committee
TPS	true potato seed
UPWARD	User's Perspective with Agricultural Research and Development

Foreword

This strategic document – CIP's fourth – presents our position in the light of many challenges facing the future role of potato and sweetpotato in food production and consumption systems. It describes the goals and objectives formulated to effectively carry out CIP's mission in support of research and technology application.

The present strategy builds on a process begun more than a dozen years ago. CIP's first strategic plan, drawn up in 1978, focused mainly on making the potato widely available in its client countries by the end of the century. Germplasm collection, conservation, and dissemination was stressed as the basis for this activity. The strategy called for the development of a strong, decentralized, global research program involving effective partnerships with national systems and advanced research institutions. Strengthening national program capacity was signalled as a key element.

In 1982, CIP's second plan demonstrated the progress made. Potato collecting activities were scheduled for completion by 1983, and the termination of taxonomic work was expected by mid-decade. True potato seed and tropical seed potato storage were emphasized in research for potato production in non-traditional climates.

The strategy was restructured a third time in 1987 to accommodate shifts in research emphasis on potato as well as the incorporation of sweetpotato into the center's mandate. The 1987 plan reiterated the principles of decentralization and cooperation that guided previous efforts. It called for a strengthened role of the research thrusts, and emphasized the complementarity of potato and sweetpotato research.

The current strategy responds to changes in CIP's scientific and institutional environment, as well as to the insights gained from our self-study and the 1989 external program and management reviews. CIP's decentralized structure together with its organizational flexibility, reliance on collaborative bridges, and low-cost, low-profile approach have served the center well for 20 years. We will capitalize on these strengths, making the adjustments necessary to respond to a changing environment and to reinforce areas where need for attention has been demonstrated.

Population growth and environmental degradation have underlined the need to review the center's future direction. The increased capability of national research systems as well as increased opportunity for crop improvement and integrated pest and nutrient management also justify a review of program focus and resource allocation. New centers are being included within the Consultative Group for International Agricultural Research (CGIAR), and the system is evolving towards increased concern for effective ecoregional coverage. Though this heightens opportunities for collaboration, at the same time it creates greater demands for future funding from public sources.

The importance of a carefully focused approach to research and capability building is foremost. CIP will limit its research to well identified priorities for addressing global, commodity-related constraints as well as those related to ecoregion-specific conditions of its client countries. Conservation, evaluation, enhancement, and worldwide distribution of valuable genetic resources will continue to be among CIP's major activities in the future. Emphasis will be placed on providing national programs with advanced clones or cultivars that have desirable traits and can be adapted to or selected for specific needs. Future emphasis on research and training in the regions, conducted in close collaboration with national colleagues, underlines CIP's long-standing philosophy of developing self-reliance as the basis for solving food and equity problems.

To implement the strategy, CIP is adapting and regrouping its research projects, and their role in the management of its program and budget is changing. At the same time, coordination between regional and headquarters activities is being strengthened.

CIP's strategy for the 1990s is the result of a process involving many participants. Dr. Richard L. Sawyer, CIP's founding Director General, directed the preparation of the first drafts. Our Board of Trustees dedicated many of its meetings to discussing strategic options, providing guidance and sharpening the focus. The final draft was discussed with the CGIAR's Technical Advisory Committee (TAC), national program representatives, and donors. Together with CIP headquarters and regional staff, they made important contributions which have been incorporated into this document. We are particularly indebted to Christine Graves, who wrote the document; to committee members Pons Batugal, Jim Bemis, Ken Brown, John Dodds, Peter Gregory,

Ed Sulzberger, and Tom Walker; to the other thrust leaders and CIP scientists who provided valuable information and comments; and to all the staff members who made it possible to produce this strategy document in an extremely short time.

N. L. Innes

N. L. Innes
Chairman, Board of Trustees

Hubert Zandstra
Director General

Introduction

This document has been organized in four basic parts. The first, "The Challenge," describes many of the factors taken into consideration in the strategy development process. These range from global environmental concerns to more specific issues confronting international agricultural research in general and CIP in particular. This section also describes the role of the center, and of its commodities, in meeting the challenge.

The second section outlines our strategy for addressing research and resource priority setting. The key elements underlying the "Strategy" section are:

- impact-driven thrust and project planning;
- sustainable and environmentally sound crop, pest, and nutrient management;
- the reflection of ecoregional concerns in project planning;
- increased efficiency of decentralized participatory research.

In the "Implementation" section we describe the operational elements that will be applied to meet the established priorities. Many of these reflect traditional approaches, refocused and fortified. The major strategic changes include project-based research management, increased emphasis on participatory center management, and heightened women's participation.

In preparing the strategy document, we have kept a wide range of audiences in mind. It is intended to be used as a tool over the coming years by:

- CIP's staff, to provide administrative and philosophical guidelines for planning and decision making and to encourage active participation in the strategic process;
- the members of the CGIAR and its Technical Advisory Committee, to help them in evaluating CIP's approach for the decade and beyond;
- other supporters, partners, and clients of the center, as a means of keeping them informed and of welcoming their constructive input into our ongoing strategic process;
- any other institution or individual interested in learning about our center and about what we can share with them with regard to the role of international agricultural research in the world of the future. Many operational details of the mechanisms described in

this document are still in the process of development, since the changes must be incorporated gradually to provide continuity. The final section, "The Way Ahead," presents CIP's vision of how these changes will be reflected in the center's institutional profile.

The Challenge

The preparation of a strategy for CIP's development over the coming decade and beyond called for the analysis of many factors. The majority of the center's concerns are common to all those involved in international agricultural research and in a larger sense to people everywhere. The environment in which research is conducted, and to which it must respond, continues to change rapidly. The major challenges to be confronted involve, among others, population growth, threatened natural resources, and poverty. Equity, nutritional status, and family food security also play a role in the setting of research priorities and the measurement of impact.

CIP has focused attention on its particular responsibilities, opportunities, and comparative advantage in addressing growing international challenges, and the issues that these bring to bear on agricultural research. The benefits of international agricultural research in general are reaching an ever-increasing range of people and institutions. CIP's strategy will include diverse approaches that together will contribute to making gains in agricultural production while protecting or enhancing natural resources; to creating

CIP's Partners and Beneficiaries

The international agricultural research centers in general, and CIP in particular, recognize that the environment in which they conduct research includes many institutions, individuals, and entities with similar interests. All of these are CIP's partners in international agricultural research. Yet one of the fundamental elements that characterize the work of CIP and its sister centers is their mandate to serve the countries where the need for technical advancement is greatest. Among CIP's partners, these countries – their researchers, extensionists, national institutions, agricultural agencies, and universities – are the center's primary clients.

In addition to these clients, CIP has numerous other partners including private and public sector institutions and organizations worldwide. Across this range of partners, CIP uses many approaches for collaboration. The relationship with some partners is primarily participatory, with others it is more receptive, while others still – such as CIP's donors – play a decisive supporting role. In many cases, there is a mixture of these elements.

CIP's principal and direct beneficiaries are the farmers and consumers of its client countries, though benefits often accrue to its participatory and supporting partners. In CIP's client countries, the benefit from research depends on the existence of strong national programs that can effectively transfer techniques and germplasm to farmers and support sustainable production. The existence of appropriate national agricultural policies is a crucial factor.

CIP's challenge is to efficiently coordinate cooperation among its partners so as to extend the range and amount of impact to its beneficiaries. In the future, there will be a greater emphasis on tailoring research collaboration and training to the differing levels of expertise existing among national programs. Where appropriate, CIP's group of national clients will be expanded to include private sector institutions and non-governmental organizations whose cooperation can complement and support the efforts of the national programs in CIP's client countries.

improved sources of nutrition, employment, and income for the poor people of the world; and to extending the base of knowledge and capabilities available to meet new and growing needs.

The current situation in Eastern Europe is a special case. Political liberalization has created new opportunities for cooperation that can generate benefits for CIP's clients, in particular through the horizontal exchange of potato germplasm and technology. Though CIP will not divert core funds from the existing research program, complementary funding will be sought to explore possibilities for collaboration with the former Eastern block countries.

The Changing Environment

Though the world has changed greatly since the center was founded twenty years ago, trends and events continue to reaffirm the reasons for CIP's existence. And while in 1971 the agenda for agricultural research in the low-income countries focused squarely on increasing food production, in the future this emphasis will be qualified by considerations such as income and employment generation or the protection of purchasing power. Environmental concerns will take an increasingly important position in the agenda for international agricultural

CIP's Impact

CIP's research program is designed to produce improvements at many stages along the total food production chain that extends from national and international research, through national infrastructure and policy settings, to the producer and finally the consumer. We recognize that there are many types of impact associated with our work, due to the diversity of elements along the food chain.

The direct impact of our research is felt by our clients, the national programs that work with us. Many improvements in installed capabilities, breeding material, and technology are recognized by them as the result of past collaboration (see Figure 8). CIP's indirect impact in farmers' fields is more difficult to evaluate. In the future, we will give increasing emphasis to impact measurement and assessment to provide:

- *greater accountability;*
- *a basis* (ex ante) *for program design and resource allocation;*
- *feedback* (ex post) *for project management and review.*

Ex ante *impact assessment is especially important in the strategy, since research choices and resource allocation will be conditioned to the likelihood of achieving impact. At the same time, CIP's new project-based management system (see Implementation) will improve our ability to analyze how research is applied.*

research in general, and for CIP in particular. The effects of economic and political settings on the impact of agricultural research efforts must be taken into account, as must new possibilities and demands presented by rapidly evolving technologies.

This changing environment has been the subject of careful debate and analysis in the process of formulating CIP's strategy for the 1990s and beyond. It poses considerable challenges for the center and for our collaborations worldwide. CIP's specific capabilities and approaches for meeting them are presented in the following sections.

Food Production

Population growth is still the driving force behind the demand for increased food production. The amount of additional food that will be required yearly, simply to keep pace with population growth in the 1990s, is equivalent to what is now needed to feed 90 million people, about the present population of Nigeria or Bangladesh.

Over the past three years, food prices have risen in response to supply shortfalls, and carry-over stocks have been reduced to disconcertingly low levels. Also, growth in cereal productivity is slowing down, a disquieting trend in any scenario for increasing food production in the low-income countries. Yet, except for some countries, agricultural production on new land can no longer be relied on to contribute to expanded production. Investment in agricultural projects, particularly large-scale irrigation and drainage systems, has declined. Without additional investments in the rehabilitation and maintenance of such systems, yield-increasing technological change will be difficult to achieve.

Commodity research must focus on increasing the efficiency of crops within existing production systems. Urbanization and the growth of "supercities," especially in the low-income countries, has led to new requirements in modes of food production. In many countries, concentration of the population in the big cities is rapidly increasing. Most of these inhabitants have little or no capacity for personal food production. Therefore, agriculture in the surrounding areas must be intensified markedly, and storage and marketing technologies enhanced.

The Economic and Political Environment

The creation of economic settings that favor food production on behalf of low-income farmers will depend largely on the outcomes of the ongoing General Agreement on Tariffs and Trade (GATT) negotiations. Successful negotiations would result in diminished protectionism, enhanced global economic growth and improved incentives for agricultural production in CIP's client countries.

In some countries the general economic environment has improved the options for increasing food production. Economic restructuring and greater market orientation have opened up and reinforced opportunities to benefit from agricultural activity. Declining consumer subsidies on cereal imports and less overvalued exchange rates should stimulate domestic production of crops such as potato and sweetpotato, which, because of their bulk and perishability, are seldom traded internationally or subsidized domestically.

Economic growth can also change patterns in demand for food. As income levels rise, consumer preferences change. For instance, economic expansion in China, the world's largest

Agricultural Sustainability

Sustainability is defined by the dictionary as the ability to maintain an effort at a given level or intensity. Many traditional agricultural production systems were characterized by sustainability in this static sense. They were able to maintain a continuing, stable level of production for many centuries. However, the needs of growing numbers of people have required changes in production practices, many of which impose heavy demands on natural resources. Concern for the earth's threatened ecology has increasingly focused on agricultural technology as a major contributor to the problem.

The CGIAR's approach to sustainable agriculture is to successfully manage resources to meet changing human needs without degrading the environment or the natural resource base on which agriculture depends. CIP scientists treat sustainability as a dynamic concept, allowing for and adapting demands in ways that do not reduce – but rather enhance when possible – future options for efficient resource utilization.

Among the areas in which our research has traditionally addressed environmental concerns are:

- *the introduction of wide genetic diversity into cultivars to avoid genetic erosion and increase crop efficiency;*
- *the identification of improved sources of host plant resistance and methods for its utilization;*
- *the development of integrated component technologies for the reduction of harmful chemical fungicide and insecticide use.*

producer of sweetpotatoes, unleashed a rising demand for animal products, and thus for livestock feed. Though utilization of fresh sweetpotato for human consumption dropped from roughly 70% in 1977 to 50% in 1987, use as feed rose from 20% to 40%. Demand shifts between cereal and root and tuber crops as well as among root and tuber crops must also be considered.

The Natural Resource Base

Considerations of CIP's future operating environment must contemplate the protection of the natural resource base on which agriculture depends. Growing concern for world ecology has highlighted the interdependence of all aspects of human activity and the physical environment. This is reflected in agricultural research, in general terms, by a growing emphasis on an integrated resource management approach to research and technical change.

Other issues have to do directly with commodity-specific production systems. Intensive potato production in many parts of the world is currently based on use of harmful chemical pesticides and fungicides. Also, potatoes and sweetpotatoes are

CIP's strategy will strengthen the incorporation of sustainability concerns into research planning and review through:

- *the development of indices of sustainability, in close collaboration with sister institutions;*
- *the evaluation of proposed research projects and new technologies against criteria for sustainability;*
- *the incorporation of sustainability measurement and evaluation techniques into CIP's training and network activities.*

We will also increase the emphasis given to resource management in our research agenda. There is a risk of erosion involved in potato and sweetpotato cultivation in many areas. CIP will seek collaboration with other institutions conducting research in this highly specialized area, to ensure that our crop management practices ensure soil preservation. In training programs, the importance of soil and water conservation will be emphasized, as will the need to minimize possible damage to the environment resulting from technological innovation.

Another important topic in resource management is the use of fertilizer. At CIP we will conduct research aimed at increasing crop efficiency and lowering nutrient input requirements. By doing so, we hope to contribute to increased productivity while enhancing the natural resource base – of which our crops form a part – and protecting the environment.

often cultivated on steep slopes where soil erosion is a major problem, though sweetpotato canopy can, on the other hand, be used to control erosion. Expanding potato production in nontraditional areas of the subtropics must take into account problems of land degradation.

The possibility of global climatic change – particularly increases in ultraviolet radiation and global warming – also has implications for the center's research priorities. Because they are intensively produced, both potato and sweetpotato would respond to land scarcity problems caused by rising sea levels, which are foreseen as a possible result of global warming.

The Institutional Environment

In developing this strategy, CIP also considered the changing institutional environment for agricultural research. In general, the number of scientists in national agricultural research programs is increasing, though operating budgets have not kept pace with growth in personnel. Many of the national programs in CIP's client countries have developed strong research and training capabilities. These increased capabilities will be reflected in differential research and training programming, and in the geographical concentration of regional research teams.

CIP has an excellent working relationship with the official and institutional entities of Peru, the center's host country. There is continuous interchange with colleagues in the Instituto Nacional de Investigación Agropecuaria y Agroindustrial (INIAA) and the Agrarian University. To provide heightened capacities in this particular region, these relationships will be further strengthened in the future, with an emphasis on training at the advanced-degree level.

In general, the international agricultural research system is emphasizing greater orchestration of research among many partners. This is especially important as a means of maximizing results in the scenario of economic reductions and funding uncertainties that is foreseen for this system. The CGIAR is including more centers – and more diversified concerns – in its agenda, and there is a move towards increased collaboration in research and institution strengthening. CIP plans to build on its already effective collaborative bridges, as a means of contributing to and participating in this effort.

The Technological Environment

Biotechnology has given new impetus to agricultural research – especially to commodity research that features the collection, preservation, and utilization of germplasm – and has created opportunities for collaboration between the public and private sectors. At the same time, the issue of intellectual property rights has entered the working environment, and will require careful attention. CIP's challenges include the careful management of this issue, to achieve the maximum benefits while ensuring that these benefits are shared. The enhancement of national program capabilities is an area where international agricultural research can play an especially important role in catalyzing links between the public and private sectors.

Advanced computer and electronic communication technologies also have crucial implications for the future. While they are valuable tools, an immediate challenge is posed by the growing volume of data and messages being generated within the broad community of agricultural researchers, decision makers, and international donors. The ability to respond swiftly and accurately to this data flow is fundamental. Information processing and storage will continue to take on more significant dimensions, and capabilities for application of these technologies must be shared, if they are to achieve their potential in contributing to the well-being of national systems and the people they serve.

The Role of Potato and Sweetpotato

Conventional wisdom looks to cereals as the world's main emergency foods. Yet in the past, potato has fueled industrial growth in the industrialized countries and has played an important role in alleviating urgent food needs in many parts of the world. Also, in many areas cereals are difficult to grow, and cereal imports are a drain on foreign exchange.

Current food reserves amount to only 20% of annual global needs. At present, CIP's client countries control about a third of these reserves (China and India have more than half of this last

amount). To meet domestic food requirements, many countries are trying to increase food self-reliance rather than depend on imported grain. Greater production of root and tuber crops can considerably expand food supplies under such circumstances. CIP can help to meet this challenge by optimizing the productivity of its mandate crops and by expanding their role in solving food shortages and nutritional deficiencies.

Globally, close to 30% of world potato production and more than 95% of sweetpotato production is located in Asia, Africa and Latin America (Figures 1 and 2). China harvests 85% of global sweetpotato production from two-thirds of the land devoted to the crop worldwide. Because of the concentration of sweetpotato production in China, this country often dominates the statistics for that crop. In this document, therefore, figures for China and for the rest of CIP's client countries have often been considered separately, to provide selective analysis according to the topics under consideration.

In terms of the potential benefits that a commodity can contribute for technological change, potato ranks fourth after rice, milk, and wheat, followed immediately by maize and sweetpotato (Figure 3). Because of their phytosanitary characteristics as well as their short growth period and high productivity per unit of time and area, both potato and sweetpotato can be used together with cereals in intensive, diversified land use

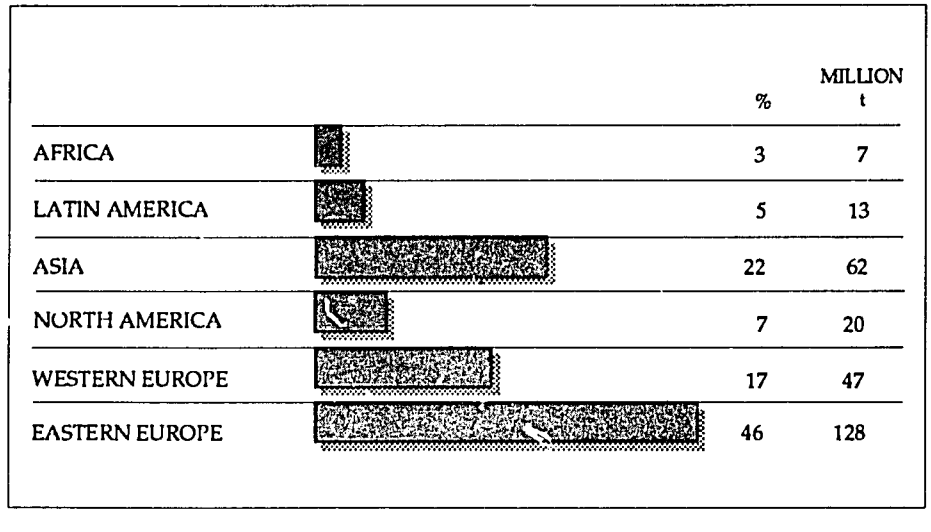


Figure 1. World Potato Production -1989
Source: Constructed from data from various *FAO Production Yearbooks.*

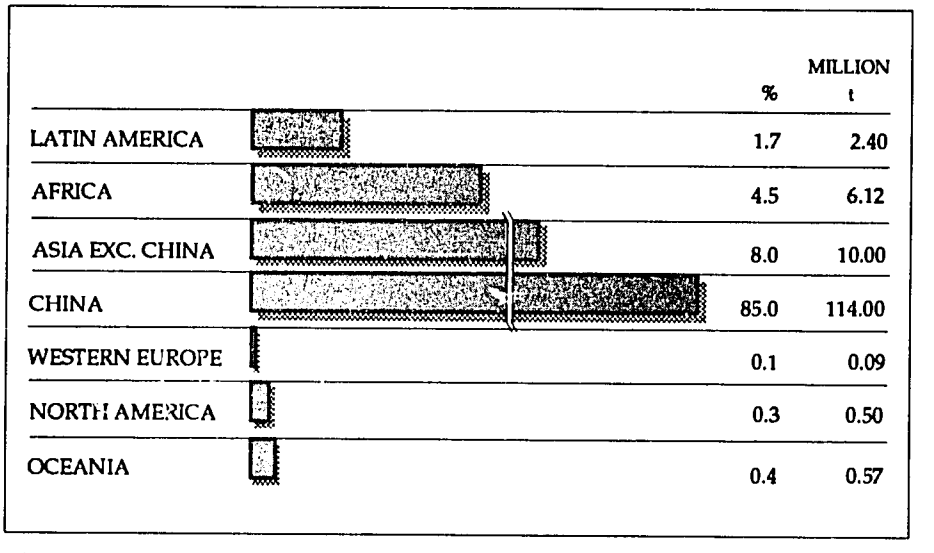


Figure 2. World Sweetpotato Production - 1989
Source: Constructed from data from various *FAO Production Yearbooks.*

patterns, and are often cultivated by low-income farmers to improve cash flow. Potato is a high-value crop that can also be useful for weed and pest control. Sweetpotato is inexpensive to

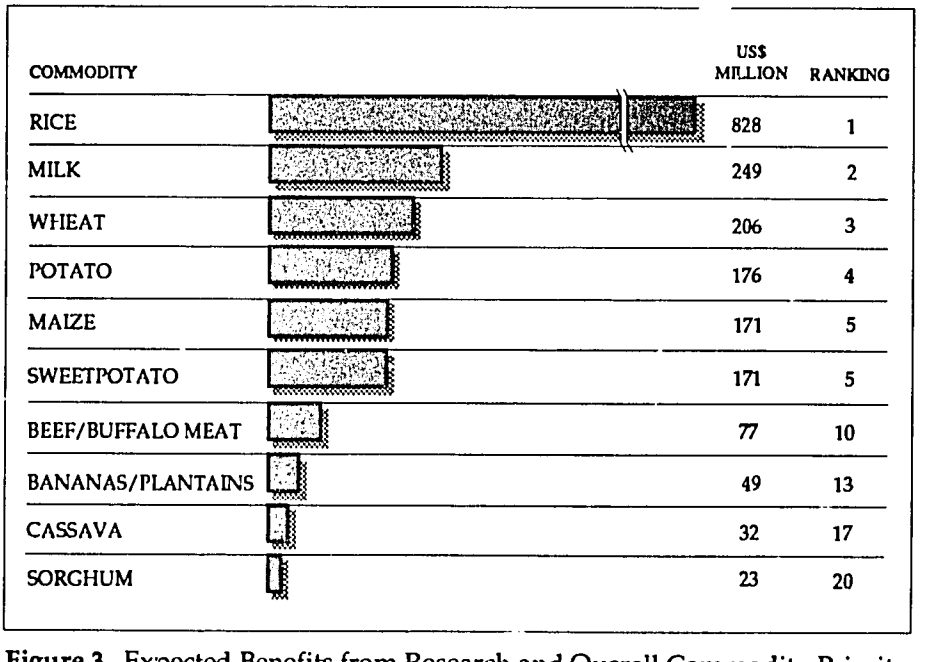


Figure 3. Expected Benefits from Research and Overall Commodity Priority Ranking for Developing Countries
Source: James G. Ryan and Jeff S. Davis. "Assessing Agroecological and Commodity Priorities in International Agricultural Research," unpublished paper, 1991.

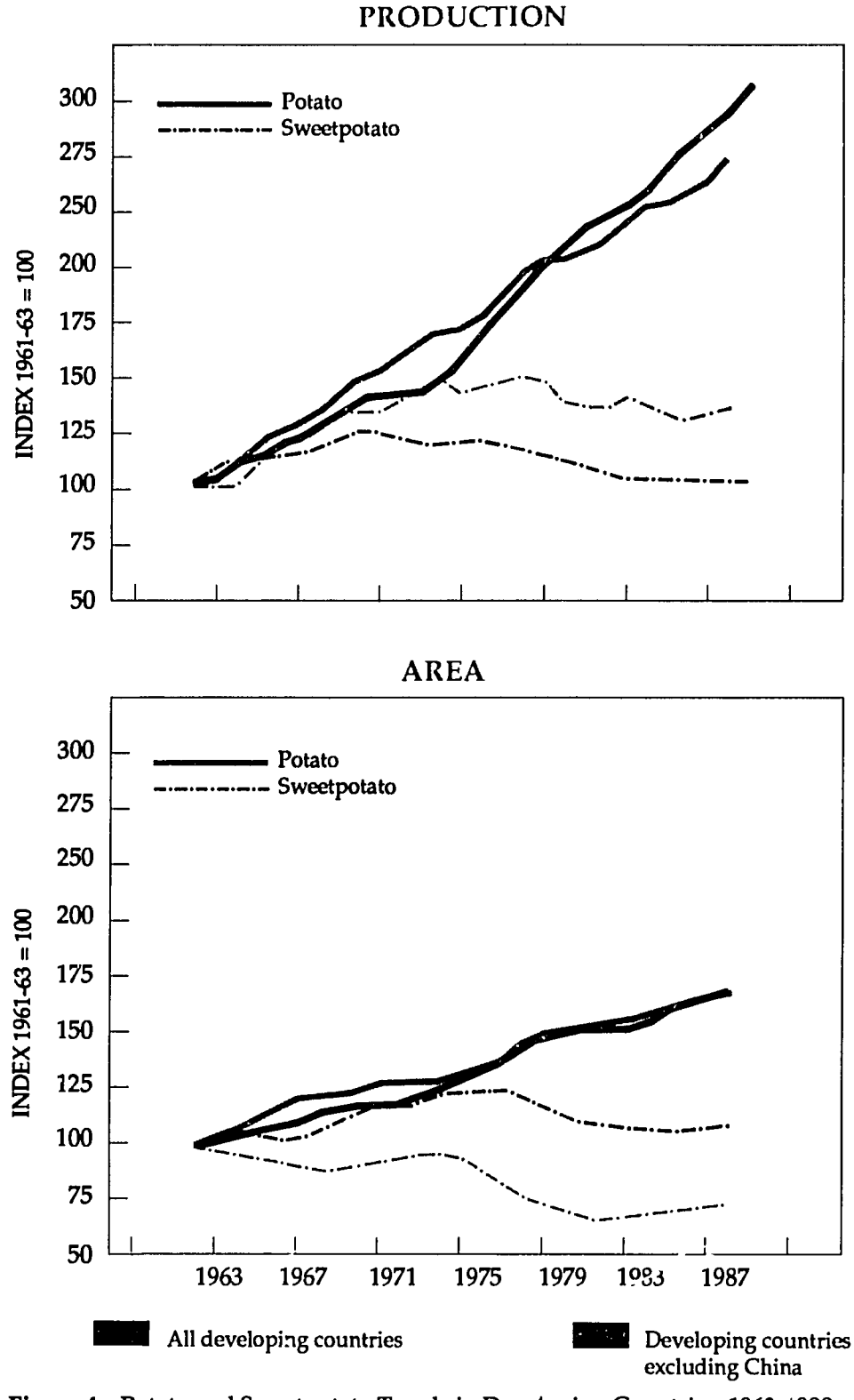
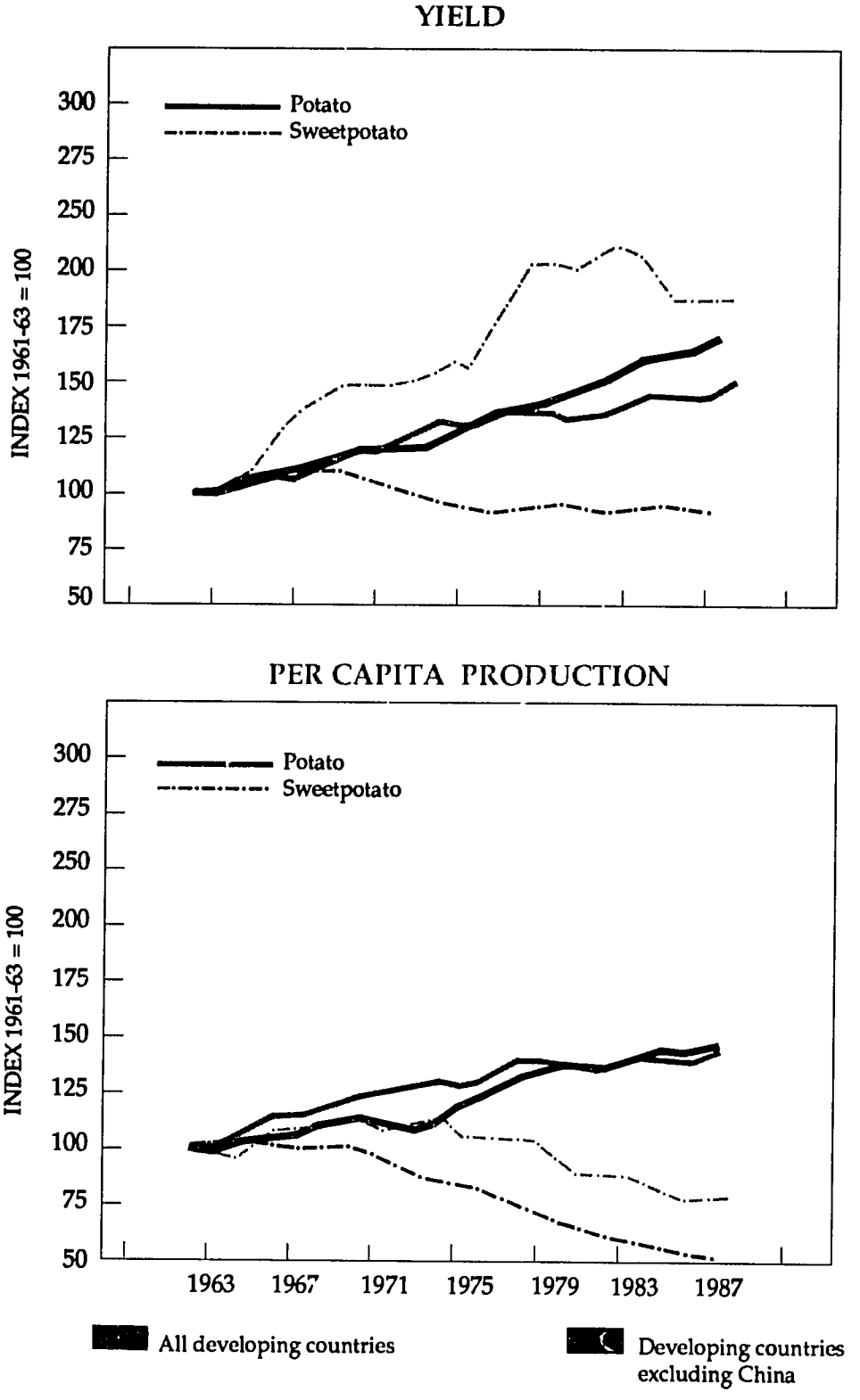


Figure 4. Potato and Sweetpotato Trends in Developing Countries, 1963-1988 : Three-Year Moving Average



Source: Constructed from data from various FAO *Production Yearbooks*.

produce and is highly adaptable to stress conditions. In addition, both potato and sweetpotato are excellent food sources, providing high energy and protein production per unit of cultivated area and time, as well as important vitamins and minerals.

Potato and sweetpotato's adaptability is increased by the fact that for both crops, planting materials can be multiplied in a variety of ways. Potatoes can be grown from true potato seed (TPS), stem cuttings, mini-tubers, and whole or cut seed tubers. TPS can be seeded directly or planted in nursery beds to produce plants for transplanting or seed tubers. Stem cuttings, sprouts, and root sections can be used for planting sweetpotatoes.

Perhaps the most marked difference between these two crops is in recent trends in production, area, and yield (Figure 4). Since the early 1960s, potato production has expanded more rapidly than any other major root or tuber crop in Asia, Africa, and Latin America. As its availability has grown, its dietary role in many countries has significantly broadened. An example is Bangladesh, where per capita potato consumption rose from 6 kg to 15 kg between 1975 and 1982. In contrast, growth rates for sweetpotato have been low. In most countries, sweetpotato production has not kept pace with population growth, though some countries of East Africa present an important exception to this trend. Declining area, which appears to be mainly responsible for reduced production, is symptomatic of weak commercial demand.

Though consumption trends show that potatoes are in general a popular food in CIP's client countries, greater consumption is constrained by high prices resulting from insufficient supply. And although production has risen markedly, potatoes in general remain less affordable in those countries than in industrialized economies. Price fluctuations resulting from supply, storage, and transport problems are also notable in many areas.

Demand for sweetpotato could be greatly increased by exploiting new uses for the crop, for instance in response to the pressure on food systems to provide livestock feed products. Both roots and tops can serve as important sources of animal feed and human food. Traditionally, sweetpotato is a source of food security for poor households in marginal areas. New applications can include a range of processed and industrial products, including use as a flour substitute for wheat.

These crops can play an important role for rural, low-income families, as well as for the growing urban populations. CIP's challenge will involve augmenting the productivity and utilization of potato and sweetpotato within sustainable farming systems to make use of the crops' full potential as sources of income, employment, and nutrition.

Andean Root and Tuber Crops

CIP is recognized by the Peruvian government as a root and tuber crop center, though its focus to date has been directed almost exclusively to its two CGIAR-mandated commodities. Nonetheless, CIP's location in the Andes and its extensive activities in the highland ecoregion provide the center with opportunities to address that region's special needs.

Farmers in the Andes domesticated some 25 species of edible roots and tubers, many of which are highly adaptable to and can be grown in a range of environments. Among them only potato, sweetpotato, and cassava have achieved international importance. Most of the others are locally consumed, and little is known about how they might perform in other parts of the world. However, among them several are known to be cultivated in countries such as Brazil, New Zealand, and Vietnam, and some can already be found in specialty shops in the US and Europe as gourmet foods. What is known is that many Andean crops are important sources of protein, starch, and nutrients for some of the poorest people of South America. Some of these crops grow extremely well under harsh conditions, while others have the potential to become industrial crops and income generators.

In recognition of their value, Bolivia, Colombia, Ecuador, and Peru have research programs dedicated to the conservation and utilization of Andean roots and tubers. However, there is already evidence of severe genetic erosion in some species. Also, several large collections have been lost due to lack of resources and socio-political instability. Among the remaining collections there is a high degree of duplication and a lack of geographical comprehensiveness.

With complementary funding, CIP is currently helping to consolidate the efforts of the national systems in Bolivia, Ecuador, and Peru to collect and conserve the most promising species. These include three tubers: *oca* (*Oxalis tuberosa*), *ulluco* (*Ullucus tuberosus*), and *mashua* (*Tropaeolum tuberosum*); and several root crops known as *arracacha* (*Arracacia xanthorrhiza*), *yacón* (*Polymnia sonchifolia*), *achira* (*Canna edulis*) which is actually a rhizome, and *maca* (*Lepidium meyenii*), the only domesticated crucifer from the Americas, and perhaps the only crop in the world that thrives over 4,000 meters. These collections will be maintained by the national programs in the field, and duplicates stored in vitro at CIP's station in Ecuador for safe-keeping.

The International Board for Plant Genetic Resources (IBPGR) provides some support for the collection of Andean roots and tubers, but no CGIAR center has assumed responsibility for long-term maintenance of this germplasm, nor is research for these crops covered in any center's mandate. CIP is well qualified to take on this task for several reasons: its location in the center of genetic diversity; its experience with tissue culture, rapid propagation, virus identification and eradication, and other aspects of germplasm management with similar crops; and perhaps foremost, its experience with the Andean highland production systems in which these roots and tubers are closely associated with potatoes. These crops are well adapted to this highly complex ecoregion and to the harsh conditions of the Andes.

CIP's ecoregional focus on the Andean highlands (above 2,000 m) will initially include an approach similar to that taken with potato and sweetpotato, involving studies of the ecoregion's crop production systems. This will not, however, be reflected in CIP's projected core resource allocation. Complementary funding will be sought for priority research areas.

The strengthening of capabilities in crop resource management and closer collaboration with institutions working on other Andean crops will also be essential for dealing with this heightened ecoregional focus. Linkages for gaining knowledge from sister centers such as the Centro Internacional de Agricultura Tropical (CIAT), the International Council for Research in Agroforestry (ICRAF), and the International Livestock Center for Africa (ILCA) for resource management and livestock research, and with institutions conducting research on mountain

production systems and with comparative advantage in these areas, will be fundamental. CIP will also support the strengthening of national capabilities for production systems research in this ecoregion.

Conservation and exploitation of the Andean root and tuber crops can result in substantial improvements in the production of food and income for the poor people of the Andes. Their further expansion to countries with similar ecological and social concerns will also be explored.

The future role of these crops in CIP's mandate will be determined as their potential is explored, in accordance with CIP's comparative advantage and resources.

Equity

CIP's many clients and beneficiaries are characterized by diverse needs and circumstances. In assessing the benefits that can be generated by root and tuber crop research, these factors must be taken into consideration to ensure that CIP's contributions are distributed equitably.

Production

One of CIP's major challenges is the widespread poverty that characterizes many of the potato and sweetpotato growing regions in the tropics and subtropics. The data on gross national product (GNP) per capita in relation to the production of major food crops in CIP's client countries (Figure 5) provides a very rough idea of the general level of income in those countries where potato and sweetpotato are prevalent. Per capita income with relation to sweetpotato is shown to be among the lowest, and for potato it is substantially lower than for other crops. The role of both of these crops as subsistence foods is an important consideration in CIP's strategy. Potato in particular also has great potential as a generator of income and employment.

For potatoes, small-scale, rain-fed production tends to be centered in the highlands or mountains. Larger, irrigated cultivation is often located in the seasonally cool lowlands. In general, the scope for cost savings in increasing production of potato

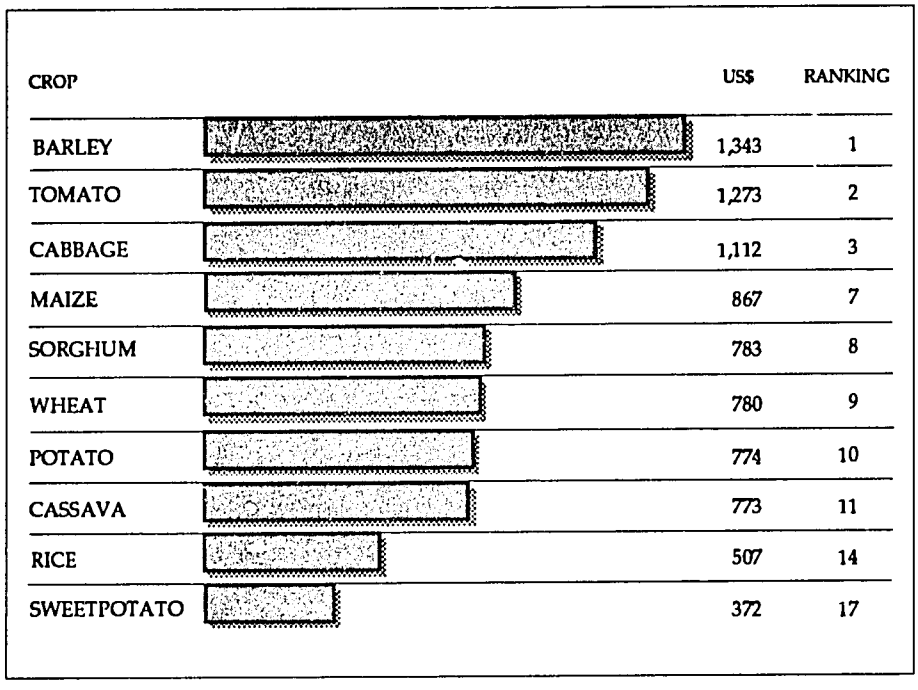


Figure 5. Average Income Per Capita and Commodity Ranking in Relation to Major Food Crop Production in Developing Countries

Note: Average income per capita = the average, over all developing countries, of proportion of overall production of the crop in each country multiplied by that country's per capita GNP.

Source: Constructed from data from the *1989 FAO Production Yearbook* and the *World Bank 1990 World Develpoment Report.*

is substantially greater in the lowlands (primarily in the cool winter season) than in the highlands.

CIP's strategy for achieving equity in responding to producers' needs involves lowering potato production costs by developing technologies that will reduce dependence on expensive inputs such as pesticides and fertilizer. The development of improved cultivars is one way to increase productivity while lowering costs. Other approaches include the reduction of postharvest and storage losses and the development and dissemination of low-cost seed schemes.

All of these technologies are designed to benefit both the larger, seasonal producers of the lowlands as well as the resource-poor farmers of the highlands, enabling them to sell their products at competitive prices. The price effects of CIP's strategies will become increasingly significant over time, allowing the benefits from lower prices brought about by yield-increasing or

cost-saving technologies to accrue to consumers. This is especially important in the light of the rapidly growing urbanization in CIP's client countries.

For sweetpotatoes, CIP will explore new avenues for processing and marketing as a means of increasing demand. The use of this crop in a wide range of products for human consumption can provide valuable food sources for the world's expanding population. At the same time, attention to quality characteristics will reinforce sweetpotato's role as a source of food security for poor, rural or urban families. Use of sweetpotato as livestock feed holds promise as an important source of income for poor farm households. CIP will select cultivars for high yield and dry-matter content, to improve economic viability with relation to other feed sources. Only by creating diverse sources of demand and exploiting the crop's efficiency can the full income generation potential of sweetpotato be realized.

Gender

Women constitute a large percentage of the food producers in the developing world, perhaps a majority. Studies have shown that they are also often the neediest of food producers. CIP recognizes the importance of considering the differential impact of its technology on women farmers and food producers. The User's Perspective with Agricultural Research and Development (UPWARD) network in Asia focuses on users in potato and sweetpotato food systems, with an emphasis on gender.

CIP's strategy for the future will emphasize the collection and review of data to provide a better perspective on the particular concerns of women in farms, households, and markets of the center's client countries. Improved gender analysis will be sought in training activities, as well as in *ex ante* and *ex post* impact assessment of research. This data will be used by CIP in setting its research priorities and in project design, to ensure that the women's perspective receives adequate attention.

Information

Information equity is also an important factor in CIP's relations with its clients. Not all national programs have equal capabilities for information generation, reception, and processing. These

differences are accentuated by the rapid evolution of information technology. CIP will give special attention to the differential design of training materials and information services according to clients' capabilities, and will include a focus on improved communications skills in selected training activities.

CIP's Comparative Advantage

CIP's comparative advantage in conducting root and tuber crop research for increased national food production capacity involves a range of capabilities and operational factors.

International Agricultural Research

As a member of the CGIAR, CIP participates in a carefully guided and well supported group of institutions and donors whose mission is as follows:

Through international research and related activities, and in partnership with national research systems, to contribute to sustainable improvements in the productivity of agriculture, forestry and fisheries in developing countries in ways that enhance nutrition and well-being, especially of low-income people.

CIP's membership in the CGIAR provides opportunities for close collaboration and sharing of resources with sister centers. These opportunities are being heightened as new centers and mandates are included in the CGIAR system. Greater integration is also being achieved through an expanded system-wide focus on resource management and ecoregional considerations.

CIP's challenge as a member of the CGIAR is to see that its strategy responds directly to the system-wide mission, building on the available opportunities for cooperation to ensure maximum effectiveness and avoid duplication of efforts

The Germplasm Collections

CIP's greatest assets are its germplasm collections. The center's location in the geographical area of origin of its mandate crops has contributed greatly to germplasm collecting efforts. In 1983, a CGIAR report noted that of the 138 plants in gene banks of 450 organizations, the CIP potato collection was one of only

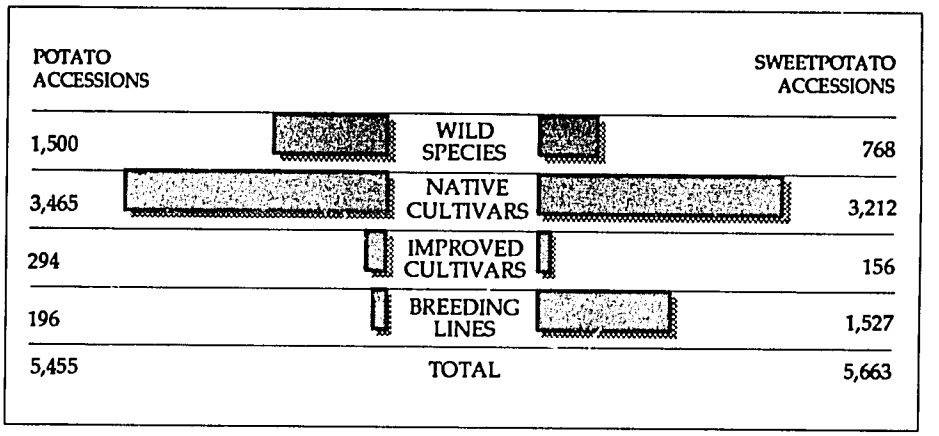


Figure 6. CIP's Potato and Sweetpotato Collections

three rated as comprehensive. CIP has also established a world sweetpotato gene bank. Substantial contributions were made by the Asian Vegetable Research and Development Center (AVRDC) and the International Institute of Tropical Agriculture (IITA), as well as by national programs in the crop's centers of diversity. Systematic exploration and collection are conducted by CIP in Latin America and the Caribbean to cover ecological niches not represented by the accessions from other collections.

These genetic resources are maintained and utilized by CIP in breeding programs to provide its clients with valuable sources of improved material (Figure 6). Both potato and sweetpotato have an advantage over other crops, such as the cereals, in the wealth of unexploited genes to be found in their wild species. The potato and the sweetpotato collections undergo systematic duplicate elimination to make them more manageable. In the case of potato, the number of accessions has been reduced from 15,000 to 5,455. To safeguard these valuable resources, CIP maintains duplicates of its collections in collaborating institutions in Ecuador, Germany and the US.

CIP's very recently acquired duplicates of Andean root and tuber germplasm comprise close to 500 accessions of eight crops. Currently, efforts are focused on helping to collect and maintain these genetic resources. In the future, one or several of these crops may, like potato, grow in importance, providing valuable sources of nutrition in particularly needy areas of the world.

Geographical Location

The geographical locations of CIP's headquarters experiment stations make it possible to conduct research that responds to a wide range of ecological conditions (Figure 7). Initial testing of cultivars and techniques can be tailored to the needs of many clients before they are transferred for further adaptation to the diverse regions and ecologies served by the center.

Expertise

Twenty years of experience provide CIP with an important comparative advantage in many research areas related to root and tuber crop management. Extensive experience with potato, for example, allowed the center to readily include sweetpotato within its mandate in 1985. CIP's ample experience in the Andean ecoregion today permits the center to consider the inclusion of Andean roots and tubers in its future agenda.

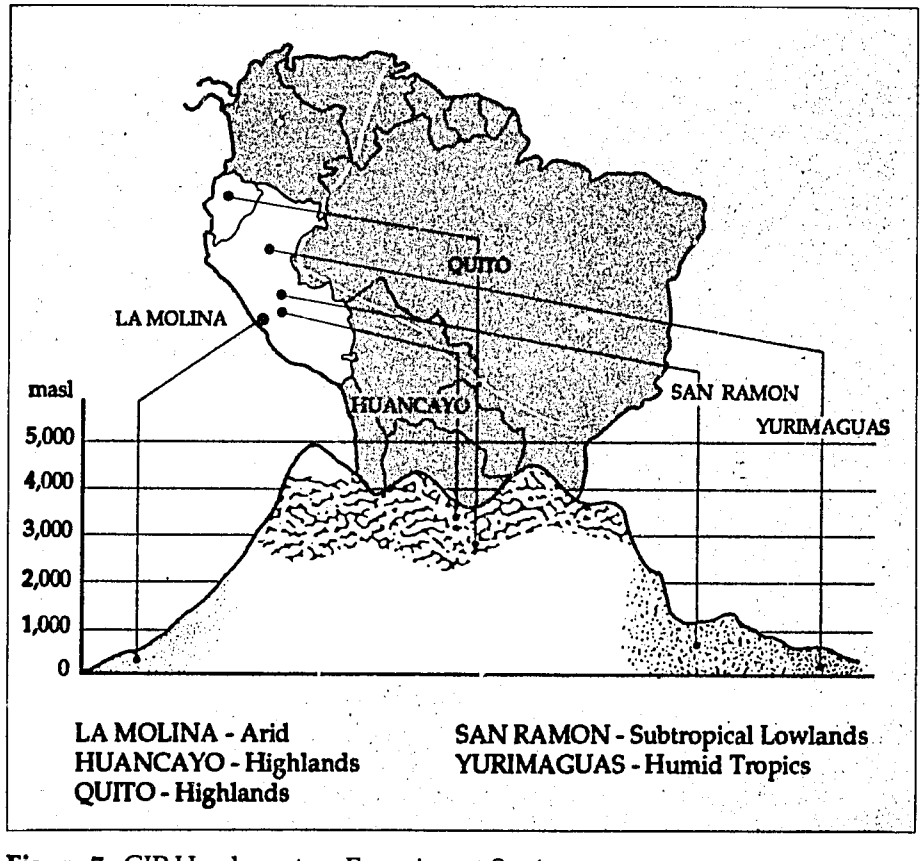


Figure 7. CIP Headquarters Experiment Stations

Another important advantage is the complementarity of the expertise that can be applied in the management of potato and sweetpotato constraints which are, in many cases, similar. This expertise includes techniques in the areas of germplasm management and distribution, virus detection and elimination, integrated pest management (IPM), propagation, postharvest and processing, and food systems research, among others.

Decentralization

To date, excellent relations and ample collaboration with client countries are among the center's greatest strengths. Nearly half of CIP's internationally recruited staff works side-by-side with colleagues in more than 80 countries. CIP's decentralized, collaborative operational structure helps ensure the relevance of research worldwide. Interdisciplinary research teams in the regions evaluate needs and constraints in direct coordination with national scientists. By gaining the user

Nutritional Value of Potato and Sweetpotato

Malnutrition and vitamin and mineral deficiencies in CIP's client countries are well documented. Potato and sweetpotato are both excellent sources of energy, protein, vitamins, and minerals, and thus have great potential for alleviating these deficiencies. However, this potential is often limited by factors of production, prices, income, and consumer preferences. Furthermore, nutritional characteristics are often inversely related to other desirable traits, and nutritional content is susceptible to environmental interactions.

CIP's strategy must ensure that potato and sweetpotato improvement are conducive to enhanced energy and other key nutrient intake. Since inexpensive and reliable methods for testing for some key nutritional components do not yet exist, we will seek complementary research collaboration in this area. Collaboration with specialized institutions will include the routine analysis of potato breeding material for potentially toxic glycoalkaloids, research to ensure that the nutritional status of advanced breeding material has not deteriorated, and highly selective research related to nutritional conditions in potato and sweetpotato growing regions. Vitamin A deficiency in areas where sweetpotato can be more effectively utilized is an example of a topic meriting such case-study research.

In sweetpotato research, we will place an emphasis on breeding for improved starch digestibility. Improved digestibility can lead to considerable energy savings and a resulting cost advantage, allowing fresh roots to be fed to livestock without cooking. It should also contribute to heightened consumer preference for the crop. Finally, an important source of improved nutrition can be found in sweetpotato leaves.

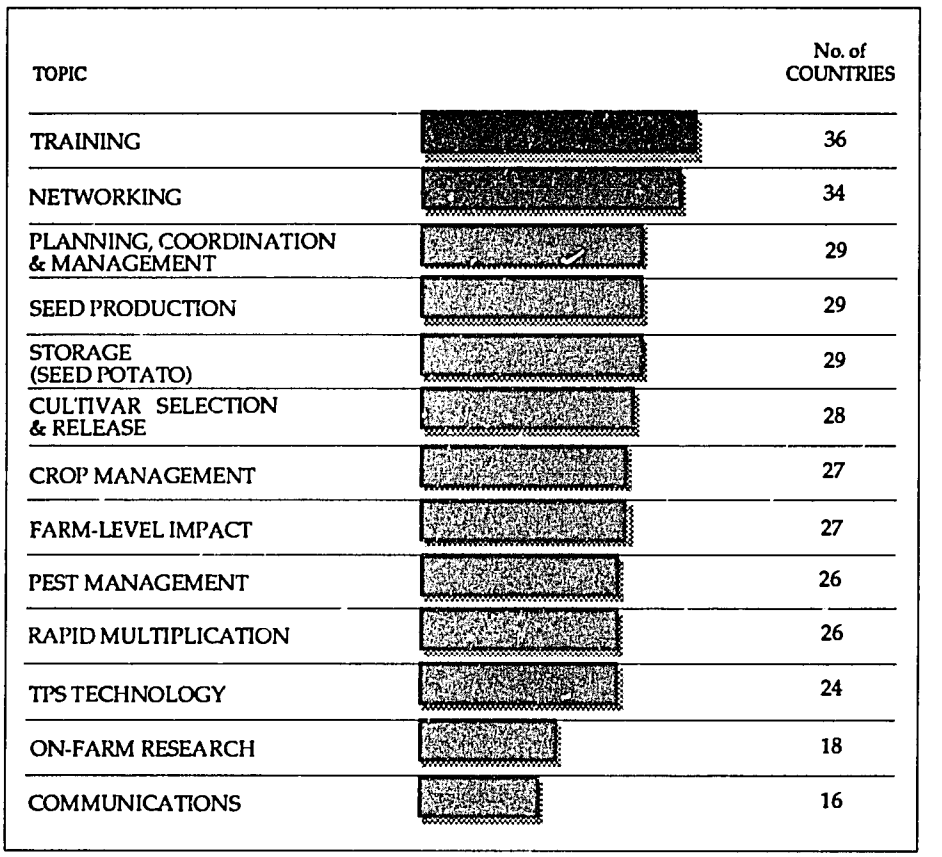


Figure 8. Areas in which Collaboration with CIP has Resulted in Significantly Improved Capabilities in the National Programs of Client Countries

Source: Survey of national program leaders of 52 countries, 1987.

perspective, CIP's research can be tailored to respond effectively to those needs.

Cooperative training programs in a range of scientific disciplines establish a practical framework for translating improved cultivars and crop management techniques into impact in farmers' fields. CIP has an excellent record in the transfer of expertise to national programs (Figure 8). In addition, specialized information services allow the center to share its research results with root and tuber crop scientists around the world. They also provide a means for redistributing information collected worldwide, be it the result of research in partner institutions, or indigenous knowledge gathered by scientists in the field.

Integration

CIP's research matrix is based on the integration of scientific disciplines, for effective assessment and response to clients' needs. Because of the potato's wide adaptability, CIP's research has been based from the outset on a systems approach. This enables technologies, cultivars, and management techniques to be developed and combined in accordance with diverse demands and conditions. The combined work of social and biological scientists on the research teams has strengthened CIP's capability to respond to diverse constraints within specific production systems.

CIP's challenge for the coming years involves making its global interactive model of research collaboration and institutional coordination function even more efficiently, so that the center's comparative advantage can be shared with its clients to the greatest possible measure.

The Strategy

CIP's research strategy is designed to meet the growing challenges that confront agricultural research. It addresses potato and sweetpotato cultivation in both traditional and non-traditional areas and production systems, including cereal- and agroforestry-based schemes. Other Andean root and tuber crops are also contemplated within CIP's plans for the future, with a particular emphasis on the Andean ecoregion.

The principles that guide the strategy are:

- *cohesion and integration of research, training, and information activities at headquarters and in the regions within a client-oriented, constraint-driven system;*
- *concentration of resources through project-based management, with a strong commodity focus;*
- *development of stable host plant resistance to reduce losses and enhance input efficiency, for sustainable, cost-effective, and environmentally sound production systems;*
- *emphasis on design of research and technical cooperation to generate equitable benefits among CIP's many clients and beneficiaries;*
- *more precise evaluation of research priorities focused on high potential and impact in farmers' fields in diverse production systems.*

The Research Program

CIP's successes with potato include the development of basic knowledge about the crop, the collection and maintenance of germplasm, and the assembly of advanced populations containing resistance or tolerance to the major biotic and abiotic stresses of this crop worldwide. In the process, extensive international collaboration for research and capability building was established. Efforts in the future will be focused on maximizing the impact of these achievements in farmers' fields.

In the case of sweetpotato, CIP is working from a much narrower knowledge base. Current emphasis is on exploiting available germplasm variability for increased yield and stability while meeting demands for increased utilization.

Recent changes have been made in the center's organization to provide strengthened research capabilities and integration. The research thrusts have been reduced from ten to six (Figure 9) for administrative streamlining and fuller cohesiveness. Breeding, social science, training, and information activities have been included in each thrust as project components. Breeding work will be concentrated on a reduced range of selected priorities with good potential for impact.

CIP will continue to emphasize the conservation, characterization, and enhancement of the germplasm collection. These activities provide the basis for the development of CIP's advanced populations. Increased crop efficiency resulting from the use of improved cultivars in combination with appropriate agricultural practices is designed to make CIP's crops more cost-effective. Genetic engineering will likely speed up these efforts by providing access to new and more readily manipulated sources of resistance.

Sustainability and environmental protection are central to the strategy. For instance, the use of advanced genetic material within integrated pest management schemes will significantly reduce the use of harmful chemical inputs.

In the future, more emphasis will be placed on *ex ante* assessment of the usefulness of research. Measurement of impact will be a

function of each research thrust. In order to increase the center's ability to program and prioritize activities, CIP will implement a project-based research management system (see Implementation). In this system, project content and resources will be directly linked to priority constraints. This will help the center to adapt to change and to capitalize on new opportunities by aligning its activities more precisely with clients' needs.

Activities at the regional and headquarters levels will be fully integrated within the project-based system. Continuing regional consolidation will be based on the location of appropriate multidisciplinary teams in key areas, and increased research, training, and information decentralization.

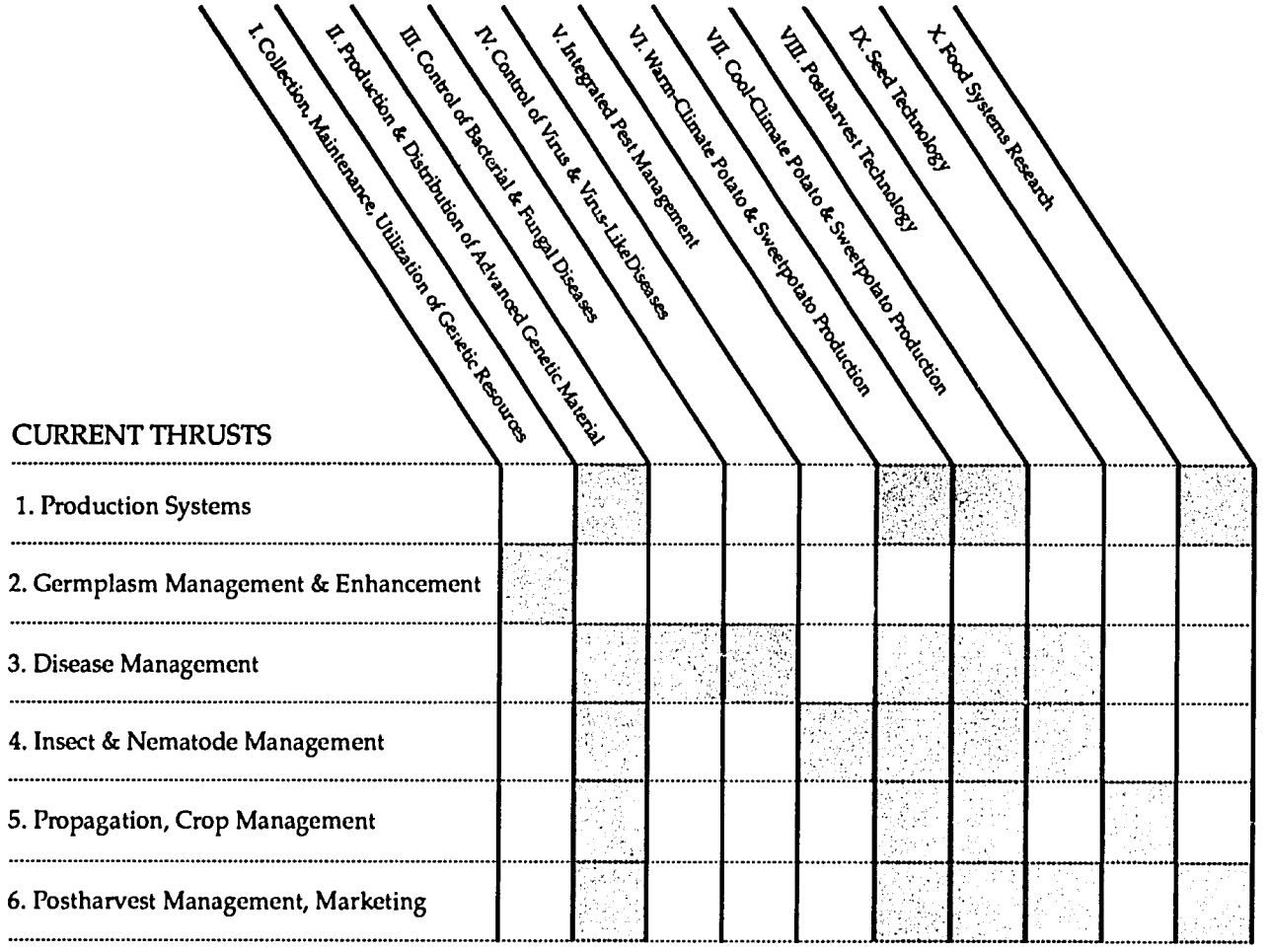


Figure 9. Thrust Restructuring and Redistribution of Activities
Note: The shaded areas indicate the distribution of previous thrust activities within the current thrusts.

CIP will be moving further upstream in some subjects and further downstream in others. The move upstream relates mainly to the center's need to know more about:

- basic biological mechanisms, such as those underlying host resistance to pests and tolerance to abiotic stresses;
- the molecular biology of potato and sweetpotato, to make rapid gains in genetic engineering and related activities;
- potato and sweetpotato food systems, to help scientists understand the crops' relationships to the physical and social environments in which they are grown.

Increased downstream work will strongly emphasize subjects and locations where research results can be effectively utilized. For example, the practical application of present knowledge on potato tuber moth control can be accelerated in North Africa, where the pest causes significant economic losses and where pesticide use has led to environmental and health problems. Special attention will be given to adjusting the design of research, training, and information to address differing levels of institutional capabilities in national programs.

CIP's objective will continue to be the progressive transfer of responsibilities to national programs. Aside from providing technology and monitoring techniques, CIP will help its clients to identify areas of need, possible collaborative linkages, and sources of funding. The existing CIP inter-country networks will serve as an important mechanism for catalyzing such activities. Downstream work will also focus on more equitable design and implementation of research and training with relation to gender.

Major External Program Review Recommendations

That CIP develop mechanisms for:

- *continuous feedback on genetic materials supplied to national agricultural research systems;*
- *ex ante impact assessment as an integral part of planning;*
- *incorporation of information resulting from constraints studies into research planning;*
- *alignment of regional activities with global research and technology transfer objectives;*
- *in potato research, integration of component technologies within sustainable cropping systems;*
- *in sweetpotato research, integration of high-potential production and processing technologies within sustainable cropping systems.*

Agroecological Considerations

Most major constraints of CIP's mandate crops cut across ecoregions, that is, across specific geographical areas and the agroecologies they comprise. However, to add to the ability to evaluate the potential of and prioritize research for its commodities, CIP has determined the principal agroecologies for potato and sweetpotato in its client countries. This classification is based on climatic and geographical criteria (Figure 10). The TAC agroecologies were also taken into consideration, with relation to the particular production systems of CIP's mandate commodities.

The geographical distribution of potato production is better understood than for sweetpotato production. Potatoes are grown in a broader range of altitudes, latitudes, and climatic conditions than any other major food crop (Figure 11). The most important agroecologies with relation to potato production in CIP's client countries are the subtropical lowlands with cool-season production, the temperate zones, the tropical and subtropical highlands, and the arid and Mediterranean lowland climates. Subtropical, winter-season, lowland production is found mainly in Asia, extending from Pakistan through India and Bangladesh into China. Production in the temperate zones is also concentrated primarily in Asia, though there is an important share in Latin

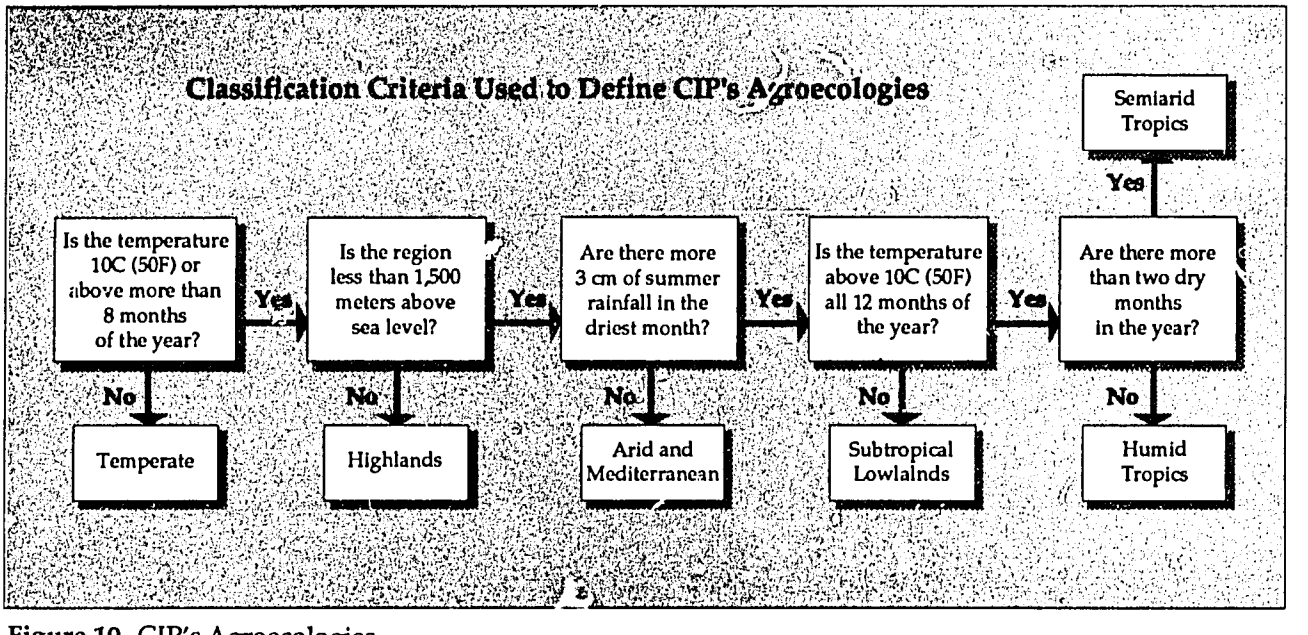
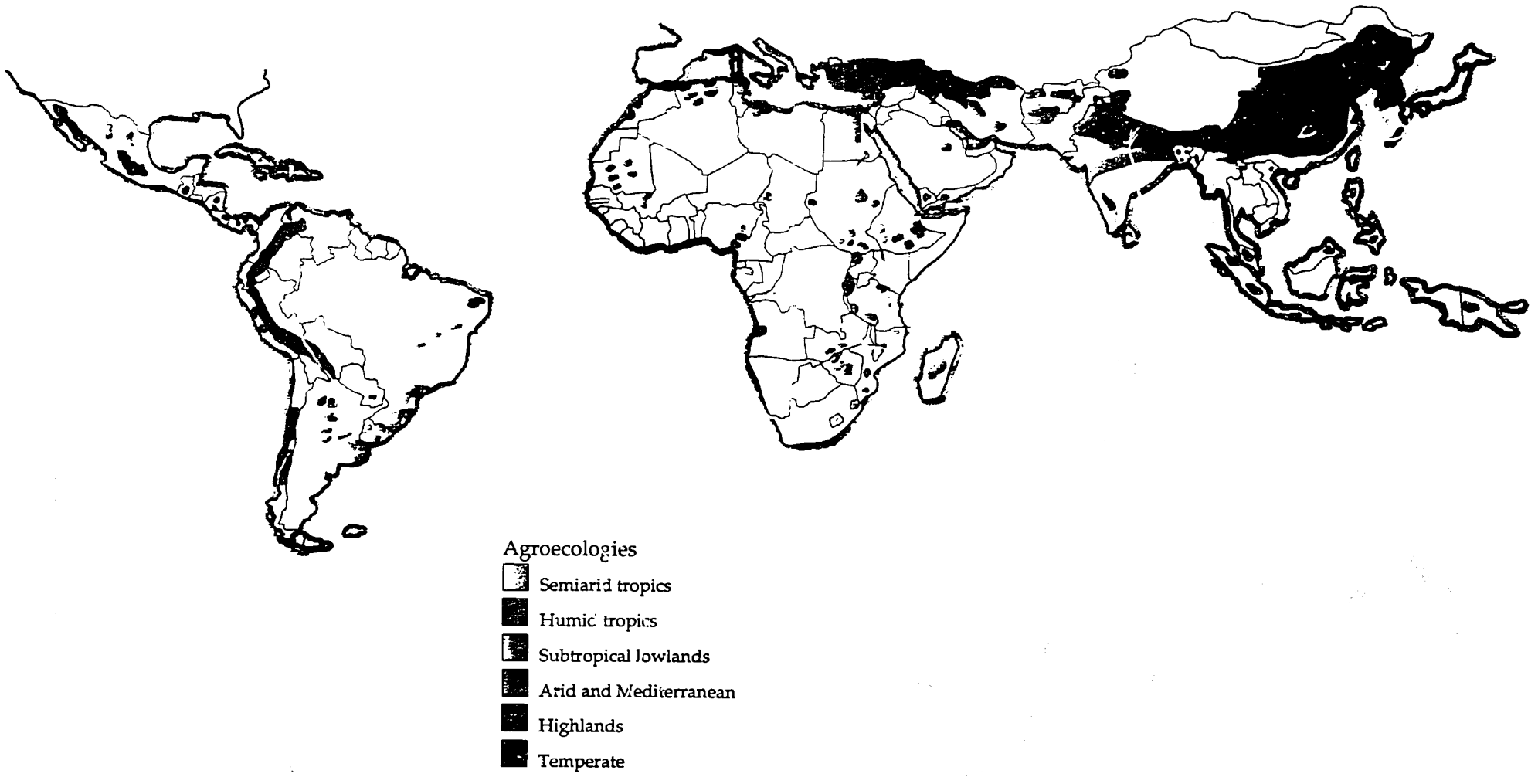


Figure 10. CIP's Agroecologies

Figure 11.

Potato Production Zones by Agroecologies in CIP's Client Countries



1987

Source: World Geography of the Potato - CIP ongoing project

America. Highland as well as arid and Mediterranean production are dispersed throughout Africa, Latin America, and Asia (Figure 12).

Over the last three decades potato has witnessed extensive growth in the Indo-Gangetic plain. The reasons for this include the crop's short growth cycle, increased demand, and the introduction of improved, short-duration cereal cultivars, providing farmers the opportunity to grow a third crop. Area expansion has played a major role in contributing to growth in potato production (over 5% per annum) in the arid and Mediterranean climatic group, as well as in the highlands of sub-Saharan Africa. In the temperate climates and in the Andes, higher yields have been the major source of increased production (about 3% per annum).

Current sweetpotato production in CIP's client countries is heavily concentrated in the subtropical lowlands and the temperate zones, which also account for a large share of potato production. However, in the subtropical lowlands potatoes are planted in the cool, winter season while sweetpotato is primarily a summer or autumn crop. Nonetheless, China accounts for 86% of sweetpotato production in CIP's client countries. Over half of this crop's production outside of China is in the humid and semiarid tropical lowlands, which account for less than 2% of potato production.

Although the estimates in Figure 12 provide only rough guidelines, it is clear from them that both potato and sweetpotato's adaptability is very broad. CIP's commodity mandate must increasingly involve an ecoregional focus, to ensure the applicability of advanced breeding materials and techniques under diverse conditions. Much of this work will be done in cooperation with specialized institutions and national programs. CIP's networks will also play a key role in coordinating research and information exchange in the areas they serve.

In the future, CIP will increase the use of agroecological analysis as a tool for research decision making, bringing environmental considerations to bear on priority setting and resource allocation. Links among the biological, social and information sciences will be strengthened to better exploit the potential of CIP's crops in traditional agroecologies and to explore their heightened role within cereal-based and other farming systems.

POTATO

CONTRIBUTION BY CONTINENTAL REGION (CONTINENTAL REGION)					AGROECOLOGY	CONTINENTAL REGION				CONTRIBUTION BY AGROECOLOGY
TOTAL	Latin America	North Africa and West Asia	Asia	Sub-Saharan Africa		Sub-Saharan Africa	Asia	North Africa and West Asia	Latin America	TOTAL CONTRIBUTION OF AGROECOLOGY
100	73.9	0.0	0.0	26.1	Semiarid Tropics	5.3	0.0	0.0	2.9	0.7
100	6.1	0.0	90.7	3.2	Humid Tropics	0.9	1.3	0.0	0.3	0.9
100	3.0	0.0	97.0	0.0	Subtropical Lowlands	0.0	58.6	0.0	6.8	38.7
100	15.5	54.7	29.6	0.2	Arid and Mediterranean	0.7	6.7	52.0	13.2	14.6
100	55.6	15.6	12.5	16.3	Highlands	93.1	3.7	19.2	61.5	19.0
100	10.0	17.0	73.0	0.0	Temperate	0.0	29.7	28.8	15.3	26.1
100	17.2	15.4	64.1	3.3		100	100	100	100	100
TOTAL CONTRIBUTION OF REGION						TOTAL				

SWEETPOTATO

CONTRIBUTION BY CONTINENTAL REGION (CONTINENTAL REGION)						AGROECOLOGY	CONTINENTAL REGION					CONTRIBUTION BY AGROECOLOGY	
TOTAL	Latin America	North Africa and West Asia	Asia	China	Sub-Saharan Africa		Sub-Saharan Africa	China	Asia	North Africa and West Asia	Latin America	TOTAL CONT. OF AGROECOLOGY	TOTAL CONT. OF AGROECOL. EXC. CHINA
100	16.6	0.0	27.3	0.0	56.1	Semiarid Tropics	59.5	0.0	19.3	0.0	46.4	5.1	36.6
100	0.9	0.0	88.5	0.0	10.6	Humid Tropics	8.6	0.0	47.6	0.0	1.9	3.9	28.0
100	0.8	0.0	2.4	96.8	0.0	Subtropical Lowlands	0.0	69.2	20.6	0.0	25.6	61.5	14.0
100	7.0	1.0	0.1	91.8	0.1	Arid and Mediterranean	0.2	6.1	0.1	100.0	21.9	5.7	3.4
100	3.7	0.0	22.1	0.0	74.2	Highlands	31.7	0.0	6.3	0.0	4.2	2.1	14.8
100	0.0	0.0	2.0	98.0	0.0	Temperate	0.0	24.7	6.1	0.0	0.0	21.7	3.2
100	1.8	0.1	7.2	86.1	4.8		100	100	100	100	100	100	100
TOTAL CONTRIBUTION OF REGION							TOTAL						

Figure 12. Shares (%) of Potato and Sweetpotato Production in Developing Countries by Agroecology and by Continental Region

The Andean highland ecoregion provides a particular area of interest for CIP. Subsistence production of potato and other crops – among them the lesser known Andean roots and tubers – is prevalent there. A greater resource management emphasis in this ecoregion will help to better understand tuber and root crop potential, and will facilitate the transfer of impact to similar agroecologies.

If it becomes clear that there is high impact to be made by doing so, CIP will gradually integrate ecoregional considerations into its research agenda within programs, grouping all areas of research and capability building within commodity-specific concentrations according to production systems.

Development and Utilization of Advanced Genetic Material

Though the development of advanced genotypes will be integrated within each thrust, there are many associated strategic questions that cut across the research concentrations. They involve the orientation of CIP's breeding, distribution, and testing schemes to meet diverse needs effectively throughout the many stages extending from the laboratory to the field (Figure 13). At the same time, though potato and sweetpotato share many common research approaches, there are important differences that characterize CIP's strategy for each crop.

Potato Breeding

Potato breeding is highly complex. Though potato is a tetraploid crop, some work is done at the diploid level, followed by tetraploid-diploid crossing. Haploid techniques are also an important part of CIP's enhancement strategy. Tetraploid breeding makes use of advanced populations as well as germplasm from the collection. Potato breeding is made even more challenging by the significant variability in this crop's adaptation to agroclimates and in the occurrence of potato pests and diseases.

CIP will seek a balance between achieving long-term germplasm improvement and the immediate impact of making existing advanced genetic materials available to national programs for

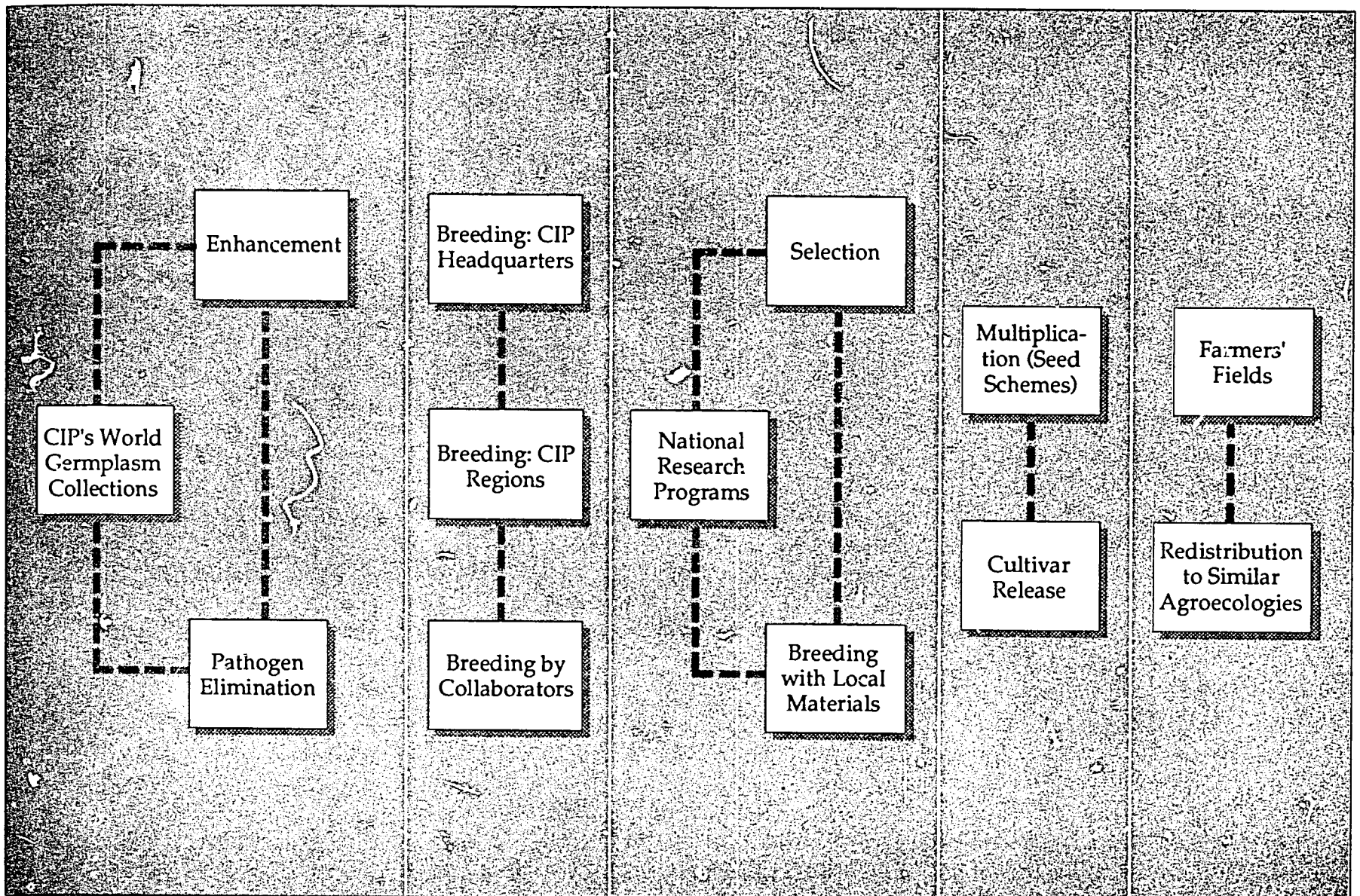


Figure 13. Stages in the Development and Distribution of Advanced Breeding Material

selection. It is envisaged that biotechnology will, in some cases, speed up the process by allowing desirable traits to be inserted into advanced genotypes without the recombination problems associated with conventional breeding programs (see Biotechnology).

CIP's overall approach is to work closely with its national program clients to determine their priority constraints. Based on this input, advanced populations combining desirable attributes are developed. Until 1985, most of CIP's potato population breeding was carried out in Lima. Since then, CIP has located an increasing number of breeders in the regions to participate in adaptive breeding to meet national program needs.

By breeding for multiple traits in its advanced populations, CIP provides a broad range of durable protection against biotic and abiotic stresses that often interact to reduce the impact of single-factor resistance and desirable agronomic traits. To date, potato breeding populations combine resistance to potato leafroll virus (PLRV), potato virus X (PVX), and PVY with heat tolerance, for the warm lowlands; late blight with PVX and PVY resistance, for use across all potato growing agroecologies; late blight and cyst nematode resistance, for the temperate and highland areas; and *Alternaria*, PVX, and PVY resistance with heat tolerance, for the lowlands.

Enhancement and Breeding

*At CIP, the term "germplasm" is used to refer to the genetic resources of the wild and primitive potato (*Solanum*) and sweetpotato (*Ipomoea*) collections.*

The term "enhancement" – equivalent to "pre-breeding" or "nobilization" – refers to diverse activities aimed at making the valuable genes contained in this germplasm accessible for utilization in breeding programs. This can be done using conventional hybridization, or biotechnological approaches.

The term "breeding" refers to hybridization and screening activities directed to provide national programs with genetic materials (advanced clones and populations) from which they can select cultivars or progenitors. These materials are characterized by wide genetic diversity, high frequency of valuable genes, and desirable agronomic, processing, and eating-quality attributes. Varietal naming and registration is done at the national level. A single clone may be selected for several national seed schemes, and given a different name by each.

Biotechnological tools may be used to simplify certain screening procedures in advanced populations or to engineer and/or introduce specific genes into selected clones.

Desirable traits must be incorporated in the early stages of breeding since abiotic factors may break down biotic stress resistance. This work is often best accomplished through joint projects with national programs in appropriate locations. The integration of research and a heightened ecoregional emphasis will contribute to programming incorporation of multiple resistance and traits in CIP's potato cultivars.

CIP will strengthen the role of breeders in its regional, multidisciplinary teams, aligning research and capability building with the degree of expertise of the national programs in a geographical area. In advanced population breeding in Lima, emphasis will be placed on combining resistances and traits for specific ecoregions. To help in increasing the impact of its cultivars in farmers' fields, CIP will work closely with national programs to encourage greater farmer participation in the evaluation process.

Sweetpotato Breeding

CIP will initially take advantage of available genetic material to heighten efficiency in sweetpotato production while conducting research to improve its processing and consumer quality. Sweetpotato has potential for use as animal feed and as a wheat-flour

Biotechnology

At CIP, we routinely use biotechnological approaches in our research, within the general guidelines of cost effectiveness and comparative advantage. Biotechnology at CIP ranges from relatively simple procedures for germplasm maintenance to complex techniques for production of transgenic plants and gene mapping. For instance, in vitro storage of clonal collections aids in their safe-keeping. In vitro micropropagation has revolutionized potato tuber seed production, and serological methods for detection of viruses and other pathogens have been adapted for routine use by national programs at reduced costs.

Biotechnological methods of germplasm enhancement are used to complement traditional breeding activities where appropriate. The challenges we face in this area of research are numerous. They include biosafety issues, determination of appropriate levels of biotechnology capacity for our research and training responsibilities, achievement of effective and responsible collaboration with the private sector, development of policies and practices for managing intellectual property rights, and catalysis of capacities for biotechnological research in national programs.

In the case of genetically engineered or modified organisms, we will carefully study biosafety concerns involved in the testing of transgenic plants, in compliance with international standards and national biosafety regulations. Measures will be taken to ensure that our partners are also prepared to handle this material

substitute. Also, similar to the case of cassava, sweetpotato can be used as a source of starch for both food and industry. Immediate priority will be given to selection and breeding for high dry-matter content, since this characteristic is important for food, feed, and processing. Earliness, starch quality and quantity, vine production for animal feed, as well as non-sweetness and other taste factors are also under scrutiny.

To generate advanced sweetpotato populations, seed is obtained by open pollination, polycrossing among selected progenitors, and controlled pollinations. CIP's strategy for sweetpotato breeding will involve extensive evaluations of existing cultivars at multiple locations. In many parts of the world, sweetpotato weevils are a major pest. Resistance to these weevils will be combined with other important resistances or tolerances and with desirable agronomic traits according to ecoregions.

Sweetpotato breeders will be located within the multidisciplinary teams at key spots in the regions to work closely with national programs in selecting locally adapted clones to be combined with advanced populations for the agroecologies of the region. CIP will encourage national programs to involve farmers in the selection of clones. In some cases, participation will be sought from the processing industries.

safely. Field testing of transgenic plants will be conducted with the guidance of biosafety groups in partner countries.

Work in biotechnology that demands elaborate facilities is generally conducted through cooperative contract agreements with advanced laboratories. CIP has already developed informal biotechnology research networks to maximize combined comparative advantage. However, although research contracts have kept our scientists abreast of advances in biotechnology to date, more substantial supporting strategies may be needed in the future due to the rapid advances in the field. We will increase our in-house biotechnology expertise to a level sufficient to allow us to draw on opportunities as they develop, in accordance with overall program priorities. This will also help us to make available to national programs techniques and materials that can improve their research capabilities.

A biotask bulletin board currently exists among the centers of the CGIAR for exchange of information on biotechnological advances and their application. In the future, we will seek closer association with other CGIAR centers for biotechnology activities. This will include the development of a cross-center working group, which will sponsor a tele-conferencing initiative and possibly establish shared facilities with advanced institutions. Other potential mechanisms include the appointment of biotechnology experts to our staff as consultants, and training for CIP and partner staff at specialized institutions.

One of the principal reasons for the immediate decentralization of sweetpotato breeding activities is to overcome the current quarantine problems associated with the distribution of genetic material. Study of quarantine problems and development of methods for safe germplasm exchange will be important in facilitating transfer and redistribution of advanced materials to appropriate areas.

At CIP headquarters, innovative methods for sweetpotato genetic enhancement will be developed. Other headquarters activities will involve the development of virus detection techniques, population breeding for key traits, breeding for the Latin American ecoregions, evaluation of local germplasm, and germplasm collection, maintenance and characterization.

Distribution and Testing of Advanced Genetic Material

Clones with potentially useful traits are routinely distributed to CIP regional scientists and national programs for testing, selection, and adaptation (Figures 14 and 15). To date, close to 400 national program scientists have been trained in efficient management of this material.

CIP also redistributes clonal material or cultivars selected by national programs to areas with similar agroecological characteristics. The Mexican potato program, for example, has contributed three cultivars that are widely used in Central Africa for their late blight and bacterial wilt resistance. An Argentinean

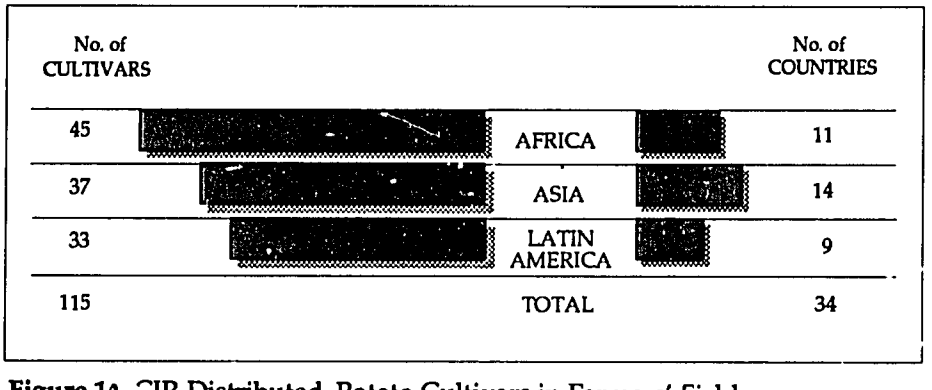


Figure 14. CIP-Distributed Potato Cultivars in Farmers' Fields

Note: 115 cultivars released by national programs from 66 clones distributed by CIP.

cultivar with PLRV resistance and a short growing period is planted to over 80,000 ha in China, and is also grown in Thailand, the Philippines, and Madagascar. Colombian cultivars are used throughout the Andean area. A Peruvian sweetpotato cultivar with resistance to nematodes has been introduced in Central Africa with good results.

Potato. Depending on each national program's needs and capabilities, CIP-distributed genotypes may be selected for immediate multiplication and distribution or used as progenitors to be recombined with locally adapted materials. CIP also provides advanced TPS parental lines for direct use or for further crossing with local material, as well as selected TPS progenies.

Once breeding material has been selected for release by a national program, it enters a seed scheme to provide local farmers with adequate supplies of quality seed, that is, seed that will perform optimally during field establishment and at harvest.

In the future, CIP intends to improve the uniformity of its criteria for evaluating the performance of potato cultivars with relation to the diverse conditions of its client countries. Enhanced database management systems will contribute to more precise feedback on the use of CIP genetic material. The participation of

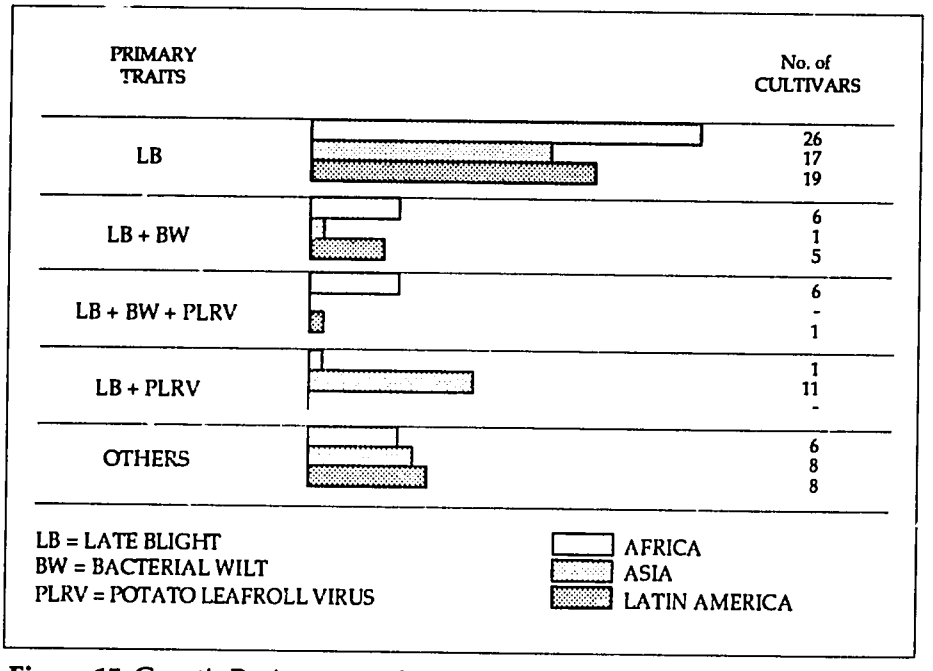
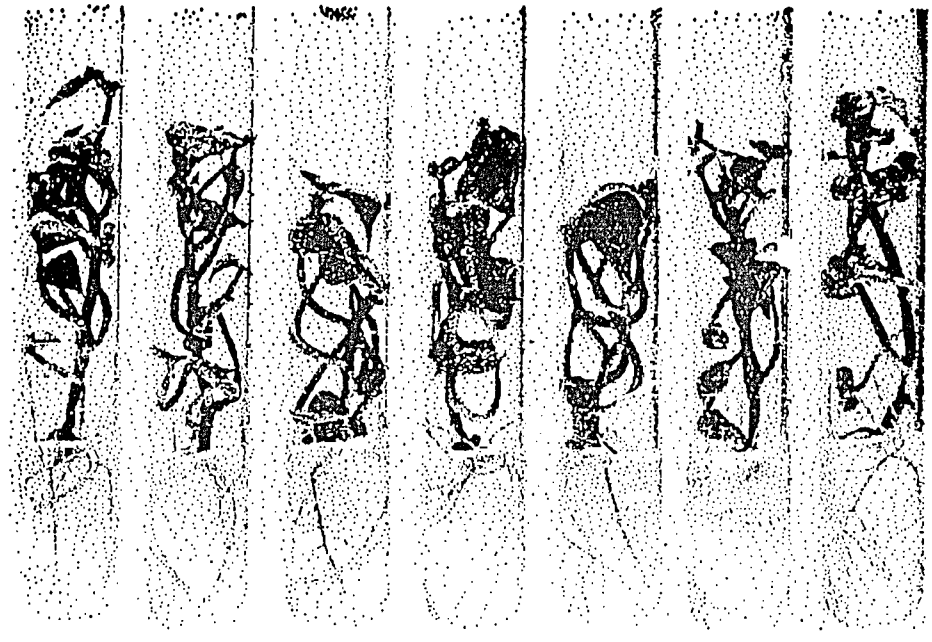


Figure 15. Genetic Resistance and Tolerance in Potato Cultivars Distributed by CIP



multidisciplinary teams will be emphasized during the testing and selection process to ensure wide input for the understanding of local needs, environments, and production systems.

Sweetpotato. Most developing countries do not have cultivar release and seed certification systems for sweetpotato. CIP will work closely with national programs to develop efficient methods for the evaluation and transfer of quality, locally adapted planting material to farmers. CIP's decentralized sweetpotato breeding within multidisciplinary teams will be fundamental to this process. Information gathered at headquarters and in the regions will be centralized and made available through the sweetpotato germplasm database.

Redistribution

To further promote the utilization of its cultivars and support national program efforts, CIP will locate propagation and redistribution units (PRUs) with efficient quarantine facilities in Asia, Africa, and Latin America. These units will play an increasingly important role in identifying potato and sweetpotato material to be redistributed, based on national program requests and input from CIP scientists. They will also aid in testing and multiplying genetic material.

The Research Thrusts

CIP will emphasize the development of mechanisms to ensure the effective recombination of research concerns and findings. Breeding for resistance or tolerance to biotic and abiotic stresses will be grouped with other priority research in the thrusts, CIP's multidisciplinary research concentrations. Effective IPM will involve the coordination of activities across thrusts, with a special emphasis on Thrusts 3 and 4. Within each thrust, prioritization and programming of activities will be commodity-specific.

To provide regular analysis of broad, commodity-oriented concerns, ad hoc working groups will be established. Agroecological analysis of thrust activities will serve as an additional tool for the evaluation and programming of priority research. CIP will assess needs across agroecologies and thrusts to select among them for overall priority setting. The programming of thrust-related training and information activities will be based directly on thrust priorities, and will be done through coordinated planning at the project level (see Training, Information).

Thrust Priorities by Agroecology

POTATO

Semiarid Tropics
- *Assessment of the sustainability of irrigated cropping systems.*

Humid Tropics
- *Assessment of the sustainability of rain-fed cropping systems.*

Subtropical Lowlands
- *Production of potato in irrigated, cereal-based, multiple-cropping systems.*
- *Production of potato in irrigated sugarcane and other cash-cropping systems.*
- *Evaluation of the effects of input subsidies on production.*

Arid and Mediterranean
- *Yield constraint characterization in irrigated sole-cropping systems.*
- *Assessment of the sustainability of irrigated potato monoculture.*
- *Evaluation of the effects of input subsidies on production.*

Highlands
- *Yield constraint characterization in irrigated and rain-fed cropping systems.*
- *Evaluation of the environmental consequences of intensive production.*
- *Characterization of root and tuber production systems in the Andes.*

Temperate
- *Characterization of production systems.*

Thrust 1: Production Systems

Thrust Outputs

- *Information on the demand for and constraints to technological change in potato, sweetpotato, and the lesser known Andean root and tuber crops.*
- *Information on the effects of technological change in potato and sweetpotato.*
- *Integrated technological components, and methods for their assessment within sustainable potato and sweetpotato production systems.*
- *Ecoregional analysis databases and simulation models.*
- *Coordinated impact assessment.*

CIP defines production systems as the totality of farming activities, from planting to harvest, within a physical and social environment, in accordance with household preferences and resources. CIP's root and tuber crop production systems research is guided by the farmer-back-to-farmer model which underscores the importance of interaction with farmers and farm households in identifying research topics, constraints, and opportunities, as well as in evaluating the performance of technologies. However, the identification of constraints and evaluation of technology are not the exclusive domain of the production systems thrust. Each thrust is responsible for carrying out in-depth, field-level, diagnostic research, including yield-loss assessment studies and impact evaluation of thrust-specific component technologies.

The role of this thrust is to coordinate the agenda for research, develop methods for problem identification and technology assessment, and address constraints and consequences at the broader levels of farm, household, and sectorial concerns. Multiple technological components – including genetic and agronomic traits – will be integrated for specific agroecologies and evaluated for their performance. The evaluation process will involve farmers and the production community, in close collaboration with public and private research and development groups in CIP's client countries.

The production system, broadly defined and well characterized in both its agroecological and socio-economic dimensions,

SWEETPOTATO

Semiarid Tropics

- *Characterization of production systems and associated biotic and abiotic stresses.*
- *Characterization of drought management and the potential for intercropping in rain-fed cropping systems.*
- *Characterization of the nutritional status and consumption patterns of semi-subsistence households.*

Humid Tropics

- *Characterization of production systems and associated biotic and abiotic stresses.*
- *Characterization of crop management and the potential for intercropping in rain-fed cropping systems.*
- *Characterization of the nutritional status and consumption patterns of semi-subsistence households.*

Subtropical Lowlands

- *Characterization of production systems and associated biotic and abiotic stresses.*
- *Characterization of crop management, emphasizing nutrient management.*

Arid and Mediterranean

- *Evaluation of crop and water management in irrigated sole-cropping systems.*

Highlands

- *Characterization of biotic and abiotic stresses.*

is used by CIP as an organizing construct for technology design. Simulation modeling, syntheses, and geographic databases contribute to the integration and extrapolation of findings over space and time. In the future, CIP will conduct long-term research with national programs in benchmark sites to promote continuity and sustainability in agricultural research. The methods developed in this thrust for the integration of technological components and technology assessment will be shared with CIP's clients, to assist them in creating tools and management approaches for their particular production systems.

Potato

Characterization of constraints and opportunities in potato production systems will focus on the scope for cost reduction, area expansion, and agronomic and economic yield increases in representative agroecologies. Continuing work on the world geography of the potato will furnish researchers with a more detailed agroecological characterization of potato production systems. This research also lays the foundation for a geographic database on selected dimensions of potato production systems, which will be periodically updated, and for modeling research.

In Asia, the production of potato in sugarcane-based cropping systems and in cereal-based, multiple-cropping systems will be emphasized. Crop diversification can contribute considerably to environmental and agricultural sustainability in these production systems by maximizing efficiency in resource utilization.

In sub-Saharan Africa, the potential for area expansion also will be more accurately quantified. In this region, abiotic, biotic, and financial stresses sometimes interact to restrict growing areas for small farmers. For example, though some highland tracts of East Africa are agronomically suitable for potato production, farmers do not plant the crop because of limited means for the control of late blight, which is predominant. The stagnation of potato yields in areas of rapidly increasing population density is perhaps the most unsettling feature of potato production in sub-Saharan Africa. More systematic information will be sought to understand the constraints on more intensive use of inputs and the factors reducing yield.

In the more commercial arid and Mediterranean production systems of North Africa and West Asia and in coastal Latin America, yield enhancement is a more attainable objective. More systematic

- *Assessment of the environmental effects of rainfed cropping systems.*
- *Characterization of the nutritional status and consumption patterns of semi-subsistence households.*

Temperate

- *Characterization of production systems and associated biotic and abiotic stresses.*

experimental information will be gathered in farmers' fields to highlight the size, sources, and economic recoverability of estimated yield gaps. Yield constraints analysis will also be important in the intermountain Andean valleys with high production potential. In less fertile regions – especially for the less known Andean roots and tubers – constraints analysis will be conducted within a broader systems vision.

The environmental consequences of intensive potato monoculture will receive increasing attention. Ecotoxicology research will center on the effects of heavy application of chemical fertilizers, insecticides, and fungicides in these production systems. Solutions based on more sustainable integrated pest management will be evaluated. CIP will also play a catalytic role in encouraging specialized research institutes to carry out studies on land degradation in selected agroecologies, such as the Andean highlands, and will apply existing knowledge in its research and training activities.

Because many of the benefits of CIP's research will ultimately accrue to poor people in the form of cost savings, more systematic temporal and spatial information will be gathered on production costs, particularly of seed, pesticide, and fertilizer. Production costs can be heavily influenced by government investment in infrastructure and by input pricing and credit supply policies. Changing government policies resulting from economic restructuring – particularly the reduction in or removal of insecticide and fertilizer subsidies – affect production costs, and attention will be given to these factors.

Sweetpotato

Because of the relatively limited existing knowledge on sweetpotato, one of CIP's priorities is to analyze current constraints and potential for the expanded utilization of this crop. Diagnostic studies of farm-family circumstances, objectives, and production constraints will account for the major share of research on sweetpotato production systems. These studies will be conducted in cooperation with scientists in national programs. The results will provide necessary information on the demand for breeding traits and other research priorities.

Initial findings across diverse agroecologies highlight the importance of market demand constraints. Therefore, more in-depth research on household behavior and sweetpotato consumption is planned.

Thrust Priorities by Agroecology

POTATO

Semiarid Tropics
- *Screening for drought stress.*
- *Screening for salt stress.*

Humid Tropics
- *Screening for heat tolerance.*

Subtropical Lowlands
- *Collection of wild species.*

Arid and Mediterranean
- *Screening for drought stress.*
- *Screening for salt stress.*

Highlands
- *Maintenance of the field collection.*
- *Crossing for the transfer of genes to the cultivated gene pool.*

Temperate
- *Crossing for the transfer of genes to the cultivated gene pool.*
- *Maintenance of the field collection.*
- *Characterization of wild species.*
- *Multiplication of wild-species seed.*

SWEETPOTATO

Semiarid Tropics
- *Collection of wild and cultivated germplasm.*
- *Screening for salt/drought tolerance.*
- *Evaluation of morphological characters for duplicate identification.*
- *Maintenance of the clonal collection.*

Thrust 2: Germplasm Management and Enhancement

Thrust Outputs

- *Methods for the storage of genetic resources.*
- *Comprehensive, manageable germplasm collections.*
- *Germplasm databases.*
- *Methods for the detection, mapping, and isolation of genes.*
- *Methods for genetic engineering.*

CIP maintains clonal germplasm in the field, as well as in tissue culture using restricted growth media and reduced incubation temperature (6C for potato, 15C for sweetpotato). In the future, collaboration with institutions with expertise of cryogenic storage will allow CIP to maintain a large amount of germplasm in very restricted space for extended periods of time (40 to 100 years).

Biotechnological methods for gene detection and genetic engineering will continue to be explored in-house, as well as in collaboration with specialized institutions.

Potato

Since initially successful resistances may in some cases be subject to breakdown, new sources of resistance must be sought. CIP will emphasize the characterization of wild species as well as the increased use of other species in enhancement programs. Special emphasis will be placed on the overall improvement of screening methods. Collaboration with national programs for germplasm maintenance and characterization will continue, and the related information will be made available through the center's germplasm database.

Biotechnological methods will be used for the development of virus coat proteins for transfer to breeding lines to produce virus resistance without modifying other clonal characters. Gene transfer will permit the development of a broad spectrum of bacterial and fungal disease resistance to overcome the limitations of traditional approaches where race specificities break down resistance. *Bacillus thuringiensis* toxin genes will be incorporated

Humid Tropics
- *Collection of wild and cultivated germplasm.*
- *Screening for heat tolerance.*

Subtropical Lowlands
- *Collection of wild and cultivated germplasm.*
- *Evaluation of morphological characters for duplicate identification.*
- *Seed multiplication.*
- *Screening for weevil resistance.*
- *Maintenance of the clonal collection.*

Arid and Mediterranean
- *Collection of wild and cultivated germplasm.*
- *Screening for salt/drought tolerance.*
- *Evaluation of morphological characters for duplicate identification.*
- *Maintenance of the clonal collection.*

Highlands
- *Collection of wild and cultivated germplasm.*
- *Evaluation of morphological characters for duplicate identification.*

Temperate
- *Limited collection.*
- *Screening for cold tolerance.*

into advanced populations to aid in combating potato tuber moth. Genetic linkage maps based on restriction fragment length polymorphisms (RFLPs) will be developed to facilitate genetic enhancement efforts. In the short term, molecular probes will be used to trace the movement of particular genes of interest and to screen germplasm at the molecular level. In time, RFLP maps and recombinant DNA technology will permit the isolation, cloning, and transfer of natural resistance genes.

Sweetpotato

CIP has already assembled the world's largest sweetpotato germplasm collection. Priority will be given to achieving comprehensiveness in the collection, and to ongoing duplicate elimination. The emphasis of future collecting work will be in Central America, an underexplored area within the primary center of diversity. Some collecting will also be done in secondary centers of diversity in Asia and Africa. CIP will continue to collaborate with other institutions for sweetpotato germplasm collection and maintenance. A detailed plan for long-term collecting of sweetpotato germplasm is currently being developed, as are methods for duplicate elimination. Characterization of the accessions in the sweetpotato collection will be done in situ in collaboration with the national programs of the countries of origin, to overcome quarantine restrictions.

Enhancement research for sweetpotato will focus on combating sweetpotato weevils, the most important sweetpotato pests. This work will include crossing *Ipomoea batatas* with other *Ipomoea* species to allow access to a new genepool. Biotechnological research will include the development of innovative methods for germplasm multiplication, and genetic engineering for weevil resistance using a cowpea trypsin inhibitor gene as well as various *Bacillus thuringiensis* genes. Collaborative projects will be carried out for the development of a sweetpotato genome map.

Andean Roots and Tubers

CIP will continue to collaborate with national programs in Latin America for the maintenance and characterization of the lesser known Andean roots and tubers. The need for further work with these crops will be determined as CIP sets priorities and finds opportunities for exploring their potential.

Thrust Priorities by Agroecology

POTATO

Semiarid Tropics
- *Leafroll-X-Y virus complex.*
- *Early blight.*
- *Bacterial wilt.*

Humid Tropics
- *Bacterial wilt.*
- *Late blight.*
- *Leafroll-X-Y virus complex.*

Subtropical Lowlands
- *Bacterial wilt.*
- *Late blight.*
- *Leafroll-X-Y virus complex.*

Arid and Mediterranean
- *Leafroll-X-Y virus complex.*
- *Bacterial wilt.*
- *Early blight.*

Highlands
- *Late blight.*
- *Bacterial wilt.*
- *Leafroll-X-Y virus complex.*

Temperate
- *Late blight.*
- *Leafroll-X-Y virus complex.*
- *Dry rot-soft rot disease complex.*

SWEETPOTATO

Semiarid Tropics
- *Disease surveys.*
- *Storage rots.*
- *Feathery mottle, mild mottle viruses.*

Humid Tropics
- *Scab.*
- *Storage rots.*
- *Disease surveys.*
- *Feathery mottle virus.*

Thrust 3: Disease Management

Thrust Outputs

- *Cultivars with resistance or tolerance to viral, fungal, and bacterial pathogens.*
- *Information on the distribution of diseases.*
- *Integrated disease management measures.*
- *Information on the inheritance and durability of disease resistance.*
- *Improved or new pathogen-detection techniques.*
- *Information on the etiology and epidemiology of diseases.*

CIP's strategy for the effective management of viral, bacterial, and fungal pathogens aims at reducing losses during the growth, transport, storage, and marketing of potatoes and sweetpotatoes. Cultivars with resistance and desirable traits are used in combination with appropriate agronomic measures. These component technologies, in combination with approaches for insect, nematode, stress, and nutrient management, will be integrated and evaluated in CIP's production systems thrust for application in specific ecoregions.

Potato

CIP scientists will continue to improve and develop methods for the detection of important viral, bacterial, and fungal diseases. Special attention will be given to increasing capabilities for pathogen detection in national programs, to improve their seed programs.

Viruses. CIP will continue to incorporate PVX and PVY resistance into most or all of its breeding populations. Resistance to PLRV will also be combined with site-specific traits for diverse ecoregions in combination with PVX and PVY resistance, since resistance to PLRV and its aphid vectors is broken down by PVX and PVY.

Late blight. Since resistance to specific races of late blight (*Phytophthora infestans*) can be overcome by other races of this pathogen, a long-term priority will continue to be the production of breeding lines with general or field resistance to this highly damaging fungus. New sources of resistance will also be looked

Subtropical lowlands
- *Storage rots.*
- *Bacterial wilt.*
- *Black rot.*
- *Disease surveys.*

Arid and Mediterranean
- *Disease surveys.*
- *Feathery mottle virus.*

Highlands
- *Dry rot.*
- *Leaf spot, stem blight.*
- *Disease surveys.*

Temperate
- *Fusarium spp.*
- *Feathery mottle virus.*
- *Black rot.*
- *Disease surveys.*

for in wild species. Successful cultivars will be used to generate populations that will be selected and tested for significant residual levels of field resistance by national programs in key areas worldwide. Resistant cultivars will then be used in integrated control strategies, combining agronomic practices, sanitary measures, and timely fungicide use.

Bacterial wilt. This disease, caused by *Pseudomonas solanacearum,* is the most important bacterial pathogen of potatoes in developing countries. CIP scientists will continue to conduct basic breeding and selection directed to combat both the cool-climate highland and the warm-climate lowland strains.

Resistance to highland wilt has already been identified. CIP will collaborate with national programs in the selection of material to be combined with locally adapted cultivars for site-specific resistance and adaptation. Providing general non-heat-labile resistance to the lowland strain is a longer-term project. It will require selection of superior, non-strain-specific resistance, as well as genetic engineering for the transfer of desirable traits. The use of resistant cultivars and healthy seed will be complemented by crop rotation for more effective control of this disease. Serological kits for the identification of latent infection will also be developed.

Late blight and highland bacterial wilt resistance will be combined for the cooler tropical locations, where they are the two major limiting factors.

Early blight. Caused by several *Alternaria* species, currently this disease is severe only in limited geographical areas. However, it is becoming increasingly important. CIP will continue breeding for resistance to several *Alternaria* species within superior germplasm already identified as resistant to *Alternaria solani.*

Other soilborne pathogens. Among these pathogens, the most damaging are the dry rot fungi (*Fusarium* spp) and soft rot bacteria (*Erwinia* spp). For combined *Fusarium* and *Erwinia* resistance, priority is given to those species or strains that readily spread through seed exportation programs. Methods for avoiding tuber contamination and disease development, mechanisms of inheritance of resistance, and improved screening techniques are also being studied. Potentially superior *Erwinia* resistance, transferred by somatic fusion from *Solanum brevidens,* will be tested.

CIP will continue to survey the relative importance of soil-borne pathogens such as the *Verticillium* wilts and powdery scab (*Spongospora subterranea*), and will collaborate with national programs in developing integrated control methods.

Sweetpotato

More needs to be known about the relative importance of sweetpotato diseases. CIP will conduct surveys to establish the priority of sweetpotato diseases, and studies of their epidemiology. Detection and classification will then be emphasized.

Viruses. At present, feathery mottle virus (SPFMV) is the most prevalent sweetpotato virus. Although most cultivars have some tolerance, SPFMV can interact synergistically with other viruses. CIP distributes polyclonal antisera for SPFMV, as well as for mild mottle virus (SPMMV), latent virus (SPLV), a caulimo-like virus (SPCLV), and a new virus coded C-2 to national programs. An ELISA (enzyme-linked immunosorbent assay) procedure using economical, easy-to-mail paper sheets has also been developed for detecting viruses, and work on nucleic acid probes is well advanced. CIP intends to give immediate priority to screening for genetic resistance to SPFMV.

Storage rots. Several fungi, such as soft rot (*Rhizopus stolonifer*), Java black rot (*Diplodia gossypina*) and *Fusarium* rots, cause severe storage losses in many countries. The CIP germplasm collection will be screened for resistance to these diseases. Research on storage techniques will also be initiated.

Black rot. In China, black rot (*Ceratocystis fimbriata*) is the most damaging fungal disease of sweetpotato. It causes severe losses in plant beds and in storage. CIP will collaborate with national programs in China for the adaptation and application of integrated control programs currently used in industrialized countries, in combination with the use of resistant cultivars.

Bacterial wilt. This disease affects sweetpotato only in southern China, and to a great extent it is being controlled with resistant cultivars. Since the disease is severe, collaborative research will continue to be conducted with partner programs in southern China to prevent its spread to other geographical areas.

Scab. A foliar disease known as scab (*Elsinoe batatas*) is severe in areas where damp weather predominates, especially in Asia.

Selection and breeding for resistance to scab will be initiated according to the completion of surveys to determine precise needs.

Other diseases. Recent surveys in the highlands of Central Africa indicate that leaf spot and stem blight caused by *Alternaria* species are damaging sweetpotato diseases. Dry rot (*Phomopis* spp) of fleshy roots is significant during storage. Further surveys will be conducted to establish the relative importance and research priorities for these diseases.

Chlorotic leaf distortion, caused by *Fusarium lateritium*, can present quarantine problems because of seed transmission. Contract research will aim at developing techniques for its rapid identification. Research on other *Fusaria* that reportedly cause wilt, root rot, stem canker, surface rot, and fibrous root rot will be considered following the completion of surveys.

Thrust Priorities by Agroecology

POTATO

Semiarid Tropics
- *Potato tuber moth.*
- *Aphids.*
- *Leafminer fly.*

Humid Tropics
- *Potato tuber moth.*
- *Aphids.*
- *Root-knot nematode.*

Subtropical Lowlands
- *Potato tuber moth.*
- *Root-knot nematode.*

Arid and Mediterranean
- *Potato tuber moth.*

Highlands
- *Cyst nematode.*
- *Andean weevil.*

Temperate
- *Aphids.*
- *Cyst nematode.*

SWEETPOTATO

Semiarid Tropics
- *Surveys.*
- *Weevils.*
- *Root-knot nematode.*

Humid Tropics
- *Surveys.*
- *Weevils.*
- *Root-knot nematode.*

Subtropical Lowlands
- *Weevils.*
- *Surveys.*
- *Root-knot nematode.*

Arid and Mediterranean
- *Weevils.*
- *Root-knot nematode.*
- *Surveys.*

Highlands
- *Weevils.*
- *Surveys.*
- *Root-knot nematode.*

Thrust 4: Insect and Nematode Management

Thrust Outputs

- *Cultivars with resistance or tolerance to insects, nematodes, and mites.*
- *Biological and agronomic control methods.*
- *Integrated insect and nematode management measures.*
- *Information on the inheritance and durability of insect, nematode, and mite resistance.*
- *Information on the distribution, identification, and occurrence of insects, nematodes, and mites.*

In this thrust, components for the integrated management of potato and sweetpotato insect and nematode pests are developed, combined, tested, and transferred to national programs, according to the specific needs of the ecoregions in which they operate. These components include improved, resistant germplasm, as well as biological and agronomic measures. As with disease management, the integration and evaluation of component technologies for specific agroecologies will be accomplished in Thrust 1, in close collaboration with farmers and partners in CIP's client countries.

Potato

Potato tuber moth (PTM). Tuber moth (*Phthorimaea operculella*) is highly destructive and widely distributed in CIP's client countries, particularly in warm environments. High priority will be given to its control. Existing control measures, including resistance, pheromones, and biological control, will be evaluated in selected ecoregions. Emphasis will be placed on on-farm trials. Breeding will include the incorporation of new genes for resistance. For instance, collaborative research will aim at transforming commercially grown potato cultivars using *Bacillus thuringiensis* (BT) toxin genes, which are active against this insect in its larval stages. Glandular trichomes are also being incorporated into selected breeding populations to provide resistance to PTM.

Temperate
- *Rot nematode.*
- *Surveys.*
- *Root-knot nematode.*

Andean potato weevil complex. The Andean potato weevil complex (*Premnotrypes* spp) is a series of five closely related pests found in the high-altitude Andean tropics (above 2,000 m). Weevils are exceptionally destructive, and because of misuse, insecticides are often ineffective in their control. CIP's operational strategy for the Andean potato weevils will be similar to the approach developed for potato tuber moth. The integrated use of cultural control practices, biological control using an insect-killing *Beauveria* spp fungus, resistant cultivars, and postharvest management methods, will be emphasized.

Other insects, mites. In the warm tropics, aphids, leafminer flies, thrips, whiteflies, and mites are of particular importance. Aphids act as vectors of potato viruses, and at least ten potato viruses are aphid-transmitted. Leafminer fly is the most important dipteran attacking potato in warm, tropical regions of Latin America and Africa. Thrips, mites, and whiteflies are becoming increasingly important in many countries. CIP will focus on continued development of germplasm with broad-based insect resistance using glandular trichomes, complemented by research on host-plant resistance and biocontrol.

Nematodes. Of the many races of root-knot nematode (*Meloidogyne incognita*) that attack potatoes, five are of global importance. Root-knot nematodes undermine resistance to bacterial wilt by opening wounds for entry. CIP will focus on combined host-plant resistance and biological and cultural methods of control. Resistant genes found in some wild species will be transferred to widely accepted cultivars.

Significant annual yield losses in potato-producing countries are also caused by two species of the potato cyst nematode, *Globodera pallida*, and *Globodera rostochiensis*. Resistance to *G. pallida* and its major races has been developed at CIP. Research is needed, however, to keep abreast of the appearance of new races due to extensive, continuous use of resistant cultivars. Emphasis will be placed on the distribution of improved cultivars and the transfer of existing technology. Future research on these nematodes will be conducted at collaborating institutions through special projects and contracts. CIP will also play a catalytic role in the transfer of existing information for the management of the false root-knot nematode (*Nacobbus aberrans*).

Sweetpotato

CIP will promote the development of a sweetpotato insect management network in collaboration with national programs of Asia, Africa, and Central and South America, to focus on key components such as host-plant resistance, cultural practices, and biological control methods. Surveys and on-farm research will be important in facilitating research planning and evaluation.

Sweetpotato weevil complex. The principal source of insect damage to this crop is the sweetpotato weevil complex (*Euscepes* and *Cylas* spp), a group of four pests found in the Americas, Africa, and Asia. These weevils are high on CIP's list of priorities. Collaborative research will be conducted in the regions for the control of localized species.

In Asia, CIP's weevil research will be strengthened through the posting of an IPM specialist, and selected pest management strategies will be evaluated in different parts of the region. In East Africa, the development of integrated methods for the control of local weevil species will be done in collaboration with national and international organizations. In Africa and the Middle East, surveys will be conducted to identify the relative importance of this pest; CIP's entomologists located in the region will play a key role in the implementation of this work. In Latin America, CIP will continue current breeding for resistance, and will seek complemetary funding to implement further research as necessary.

Nematodes. Several species of root-knot nematode are distributed throughout the tropical, subtropical, and warmer temperate regions of the world. Root-knot nematodes interact with other pathogens to develop disease complexes. Resistance to *Meloidogyne incognita* has been identified in the CIP sweetpotato germplasm collection, and will be combined with resistance to other pests and pathogens. Other strategies for controlling these nematodes, including biological and cultural control practices, will be transferred to national programs.

One species of rot nematode is reported as a serious obstacle to sweetpotato production throughout China. Resistance to this nematode has been found in the CIP sweetpotato germplasm collection, and will be used for breeding by the national program and the universities of China.

Studies will be conducted in collaboration with national programs to determine the importance of other insects and nematodes to sweetpotato production. Necessary research for their control will be done through location-specific projects, in collaboration with national programs.

Thrust Priorities by Agroecology

POTATO

Semiarid Tropics
- *Propagation and crop management practices for areas susceptible to bacterial wilt.*
- *Seed schemes for areas of high virus spread.*
- *Self-sustained schemes for production of quality planting material.*
- *Improved TPS lines, production methods, and agronomy for extensive use.*
- *Water management, heat stress.*

Humid Tropics
- *Propagation and crop management practices for areas susceptible to bacterial wilt.*
- *Potato propagation methods adapted for high temperature/humidity.*
- *Improved TPS lines, production methods, and agronomy for extensive use.*

Subtropical Lowlands
- *Locally adapted propagation methods for use in clonal seed production schemes.*
- *Improved TPS lines, production methods, and agronomy for extensive use.*
- *Adverse temperature, drought stress, soil nutrient deficiency, and salinity.*

Thrust 5: Propagation and Crop Management

Thrust Outputs

- ***Worldwide distribution of pathogen-tested materials.***
- ***Techniques for the maintenance of basic stocks of planting materials.***
- ***Methods for the propagation of healthy clonal and true potato seed in diverse agricultural systems.***
- ***Methods for true potato seed utilization in diverse agricultural systems.***
- ***Improved true potato seed parents and progenies.***
- ***Physiological and agronomic methods for the management of abiotic stresses.***
- ***Nutrient management information and methods.***

Elimination of pathogens from desirable genetic material will continue to be an essential activity of this thrust, since susceptibility to some pests and diseases depends on whether or not a cultivar is virus-infected. Also, cultivars selected for distribution must be pathogen-tested, to prevent the spread of diseases. Lastly, the clean-up of locally adapted materials can result in significantly improved yields. CIP will also continue to emphasize the development of pathogen-elimination capabilities in national programs.

Potato

Lack of quality seed has been identified as a key constraint to increased potato production in CIP's client countries. CIP will concentrate on two major alternatives for improving national seed production: true potato seed (TPS); and simple, low-cost clonal propagation methods.

Approximately 35-40% of the potatoes produced in CIP's client countries are grown in warm tropical areas during the cool season. It is in these areas where the largest increase in potato cultivation has occurred in recent years. Nonetheless, production in these climates often depends on seed imports, which raise production costs and may also result in the introduction of new pests to a region. One of CIP's highest priorities is to contribute to the generation of low-cost propagation schemes for these agroecologies.

Arid and Mediterranean
- *Seed schemes for areas of high virus spread.*
- *Self-sustained schemes for production of quality planting material.*
- *Improved TPS lines, production methods, and agronomy for extensive use.*
- *Water management, heat stress.*

Highlands
- *Improved efficiency of seed production systems and components.*
- *Physiological basis for improved tolerance to frost.*

Temperate
- *Improved efficiency of seed production systems and components.*
- *Physiological basis for improved tolerance to frost.*

SWEETPOTATO

Semiarid Tropics
- *Crop management practices for more efficient use of soil moisture.*
- *Efficient field propagation methods.*
- *In vitro propagation and maintenance.*
- *Methods for production and maintenance of virus-free materials.*

Humid Tropics
- *Acid soils, heat stress, water-logged soils.*
- *Efficient propagation methods.*
- *Crop management practices for the prevailing agricultural systems.*

Propagation with true potato seed. TPS has potential as an extremely cost-efficient, flexible means of propagating potatoes. This seed is much easier to transport than tuber seed because of minimal space and perishability problems. Also, when TPS is used tubers normally saved for seed can be consumed, storage problems are reduced or eliminated, and seed is available year-round. Few diseases are known to be transmitted by TPS. In areas subject to bacterial wilt infection, for example, the use of TPS prevents the spread of this disease which can be carried in the form of latent infection in seed tubers. TPS can reduce dependence on costly seed imports. However, further refinements in available populations are required to make TPS suitable for widespread adoption.

TPS technology development will be increasingly focused at the country level. Special attention will be directed to breeding for improved TPS parents and progenies adapted to conditions in short-day, warm environments. Resistances to local pests will be combined with these traits. The objective will be to achieve large-scale production of selected TPS cultivars for wide distribution. Both open-pollinated and hybrid lines will be tested for appropriateness, according to agro-climatic and social conditions. The recurrent use of seed from improved progeny will enable farmers to produce their own seed with minimum need for disease-free maintenance of parental lines. To heighten farmer participation, extensive on-farm testing will be conducted.

Clonal seed schemes. CIP will continue to give high priority to strengthening the capabilities of national clonal seed production programs. Many of the clonal seed schemes developed by CIP have proven to be effective. The center will aim at further improving these schemes and promoting their integral adoption, as well as the introduction of useful components within the informal seed schemes that predominate in the center's client countries. Improved maintenance, multiplication, and propagation efficiency will be sought so as to reduce the number of generations needed for producing healthy seed.

Because of the location-specific nature of clonal propagation for warm tropical regions, this research will be conducted entirely through collaborative arrangements with partners in Africa, Asia, and Latin America.

Subtropical Lowlands
- *Efficient propagation methods.*
- *Crop management for improved response to high temperature.*

Arid and Mediterranean
- *Crop management practices for more efficient use of soil moisture.*
- *Efficient field propagation methods.*
- *In vitro propagation and maintenance.*
- *Methods for production and maintenance of virus-free materials.*

More than 60% of the potatoes produced in CIP's client countries are grown in traditional potato-growing environments, where quality seed is usually available. Therefore, in these highland temperate growing areas the major need is to develop and introduce seed technologies that can improve the efficiency and/or the output quality of the existing propagation and seed supply systems. The participation of social scientists, both from CIP and national programs, will be important for the analysis of institutional and policy constraints involved in seed program operations. Collaboration with private seed companies will be sought to support national efforts where appropriate.

PRUs. CIP's propagation and redistribution units, located in key continental locations, will facilitate the testing and introduction of low-input, sustainable, cost-effective propagation methods. At the same time, they will:

- provide sustainable supplies of quality planting materials;
- coordinate and monitor propagation and training activities;
- maintain and distribute pathogen-free materials adapted to specific ecoregions;
- coordinate TPS production and distribution.

Nutrient management. After seed, fertilizer contributes more to the total cost of potato production than any other item. Also, available cultivars have usually been selected under high rates of fertilizer applications, and therefore respond with high productivity levels only when grown under these conditions. Since high fertilizer application is costly and often environmentally harmful, CIP will increase the attention given to clonal performance in high and low fertility production environments. Nutrient management studies will also be added to the center's research agenda.

Abiotic stress. A more exacting approach will be adopted for the evaluation of agronomic practices that can mitigate the effects of the prevalent abiotic stresses in a given area. Insufficient water availability, for instance, has different effects according to agroecologies. Stress from adverse temperatures during the many stages of the crop cycle will also receive special attention. Studies on the physiological basis for improved response to stresses in different genotypes will provide breeders with support for the identification of advanced materials.

Sweetpotato

In the tropics, sweetpotato is grown throughout the year and is usually propagated continuously from cuttings. Gradual losses of productivity frequently result from build-up of pests. Though information is not currently available on the potential economic impact of organized distribution systems, improvements in productivity resulting from the use of healthy seed stocks and cuttings can bring important gains in land-use efficiency. CIP will give priority to developing information on and procedures for pathogen elimination and maintenance of basic stocks of clean sweetpotato planting materials. Micro- and macropropagation techniques will be developed. Collaborative research will be conducted in the regions on:

- the degeneration rates of planting stocks and their relation to climate;
- sanitary standards;
- the economic importance of improved planting materials;
- improved propagation methods and schemes.

The strengthening of national capabilities to maintain and multiply sweetpotato germplasm will be fundamental. The PRUs will progressively undertake research and development tasks for sweetpotato propagation.

Abiotic stress. Drought, particularly at planting, has been identified as a particularly important abiotic stress for sweetpotato production in Asia and sub-Saharan Africa. Poor soil fertility limits sweetpotato production in all agroecologies, but it is especially important in Asia. Though CIP will emphasize screening for tolerance to these stresses, agronomic practices will also be developed for their control, following research to establish priorities.

Thrust Priorities by Agroecology

POTATO

Semiarid Tropics
- *Alternative markets.*
- *Ware potato storage techniques.*
- *Improved cultivars for processing.*

Subtropical Lowlands
- *Ware potato storage techniques.*
- *Market studies.*
- *Seed potato storage techniques.*
- *Improved cultivars for processing.*

Arid and Mediterranean
- *Ware potato storage techniques.*
- *Seed potato storage techniques.*
- *Alternative markets.*

Highlands
- *Market studies.*
- *Seed potato storage techniques.*
- *Ware potato storage techniques.*
- *Improved cultivars for processing.*

Temperate
- *Market studies.*
- *Alternative markets.*
- *Ware potato storage techniques.*
- *Improved cultivars for processing.*

SWEETPOTATO

Semiarid Tropics
- *Market, technology, and policy assessment.*
- *Utilization for products for human consumption, feed, and starch.*

Thrust 6: Postharvest Management, Marketing

Thrust Outputs

- *Cultivars with improved processing quality.*
- *Storage technologies.*
- *Improved and new processing methods for potato and sweetpotato.*
- *Information on methods of sweetpotato utilization for horizontal transfer.*
- *Information on marketing, consumption, nutrition, and demand.*
- *Socio-economic methods for assessing markets, storage, processing and related government policies.*

Postharvest research includes diverse activities such as storage, processing, and marketing. Their effect before, during, and after the crop cycle strongly influences overall needs, priorities, and operational steps in other research areas. Postharvest and marketing research will include a strong policy component, to analyze the relationships between government and national program policy, and CIP's research efforts and their application.

Potato

Marketing. Price instability and inadequate market supply are significant constraints to potato utilization in CIP's client countries. This is compounded by the absence of trained researchers capable of analyzing marketing problems on a regular basis in the vast majority of national potato programs. Postharvest research at CIP will give immediate priority to regional workshops designed to improve national programs' capabilities to evaluate the complexity of marketing and supply problems, the alternatives available, and the relevant experiences of other countries. Methods for addressing these issues will be explored in cooperation with national scientists. The results of existing marketing studies will be synthesized for use in these workshops.

Storage of ware potatoes. The perishability of potato contributes to seasonal availability and resulting price movements. Shrinkage losses due to dehydration and spoilage are also

- *Improved cultivars for processing.*

Humid Tropics
- *Market, technology, and policy assessment.*
- *Utilization for products for human consumption, feed, and starch.*
- *Improved cultivars for processing.*

Subtropical Lowlands
- *Market, technology, and policy assessment.*
- *Utilization for products for human consumption, feed, and starch.*
- *Improved cultivars for processing.*

Arid and Mediterranean
- *Market, technology, and policy assessment.*

Highlands
- *Market, technology, and policy assessment.*
- *Utilization for products for human consumption, feed, and starch.*
- *Improved cultivars for processing.*

Temperate
- *Market, technology, and policy assessment.*
- *Utilization for products for human consumption, feed, and starch.*
- *Improved cultivars for processing.*

problematic. CIP will emphasize the development and diffusion of techniques for longer-term and more efficient rustic storage of ware potatoes. Highest priority for this research will be given to South Asia (India and Bangladesh) where the problems of seasonal supply and ambient temperature changes are most acute and the potential impact from the adoption of rustic storage technology is greatest. Through the active participation of social and biological scientists, technical and socioeconomic results of ware potato storage research in East and Southern Africa will be synthesized. This research will incorporate results from studies on potato tuber moth control, propagation of cultivars suitable for rustic storage, and marketing.

Seed storage. By reducing storage losses, diffused-light storage (DLS) lowers the cost of seed potatoes, consequently lowering production costs and the retail price paid for potatoes by consumers. It also provides growers with flexibility in planting dates, reducing the seasonal nature of production and the resulting off-season prices.

A more thorough assessment of the role of existing diffused-light storage technology and its derived benefits to farmers and consumers will be conducted. Impact studies and analyses of existing research should help to highlight the factors (design, government credit policy, training, extension) that have proven crucial to the success of DLS. This information will be used by CIP to promote continued adoption.

Processing. CIP will document current potato utilization by the convenience food industry, as well as the potential for expansion. A synthesis of existing market studies on products processed with village-level techniques will also be conducted. These will help to better program the breeding of improved cultivars. CIP will focus on the horizontal transfer of existing potato processing technology. A database will be established for potato processing techniques and products, including information on international trade of processed potato products.

Sweetpotato

Limited demand for fresh roots and lack of alternative markets are the most important constraints to sweetpotato production. However, little information is currently available about sweetpotato marketing, processing, and storage in CIP's client

countries. This is an area of high priority, and substantial resources will be allocated to it.

Marketing. CIP will conduct a series of case studies to assess the potential market for processed sweetpotatoes, and to evaluate current processed products and processes, and the role of government policy. The immediate result of the case studies will be a set of policy and research recommendations regarding the development of alternative markets for sweetpotatoes. Improved marketing is especially important for growing urban populations, given the high perishability of sweetpotatoes.

Processing. Sweetpotato postharvest research at CIP will give priority to the horizontal transfer of existing processing practices. This will involve increased collaboration between CIP scientists and national researchers in countries where relevant knowledge is available. Sharing of scientific information among national program scientists will be promoted through CIP-sponsored workshops, seminars, and scientist exchange.

CIP will also give priority to applied research on processed sweetpotato products for feed and human consumption that offer high potential for increasing demand. Initial research will emphasize the technical and socioeconomic aspects involved in using sweetpotato for animal feed. Parallel work will focus on research for the use of processed sweetpotatoes for human consumption and starch. CIP will develop a cadre of postharvest scientists to carry out sweetpotato research in Asia in collaboration with local institutions. The CIP networks will also play an important role in the transfer and development of sweetpotato processing technology.

Breeding priority will be given to selection for high dry-matter content, to provide improved eating and processing quality. Research on starch properties and trypsin inhibitors will be conducted to improve the digestibility of sweetpotatoes. Genetic selection for reduced perishability will also be conducted.

International Cooperation

CIP has consistently supported national programs in achieving self-sufficiency in the adaptation, application, and development of germplasm and technologies. The center's catalytic role aims at the progressive transfer of responsibilities to national systems through cooperation in research, training, and information dissemination.

Client-Oriented Research

Decentralization allows CIP to work closely with national researchers and to adapt research and evaluate technologies on site (Figure 16). Close collaboration with national colleagues also provides valuable input for research planning, monitoring, and evaluation. This function will be strengthened in the future through increased integration of decentralized activities in the regions and at headquarters (see Implementation).

CIP's strategy for maximizing impact in farmers' fields includes an emphasis on the introduction of techniques and germplasm directly to farmers, who can then carry out trials to determine their appropriateness and effectiveness under local conditions. National program colleagues play a primary role in this process. The approach will be extended to include collaboration in pilot production programs, and will involve expanding collaborative linkages to include national institutions specialized in extension.

CIP will emphasize systematic impact assessment to help set priorities more accurately in response to its clients' needs. Furthermore, by improving the integration of research, training, and information activities, CIP will be able to move research results to the field more quickly and effectively.

National Program Strengthening

The fuller integration of headquarters and regional research will provide a special challenge for CIP, since regional scientists also participate directly in national program strengthening. In this respect, CIP will give careful consideration to the distribution of responsibilities of its staff located in the regions. The

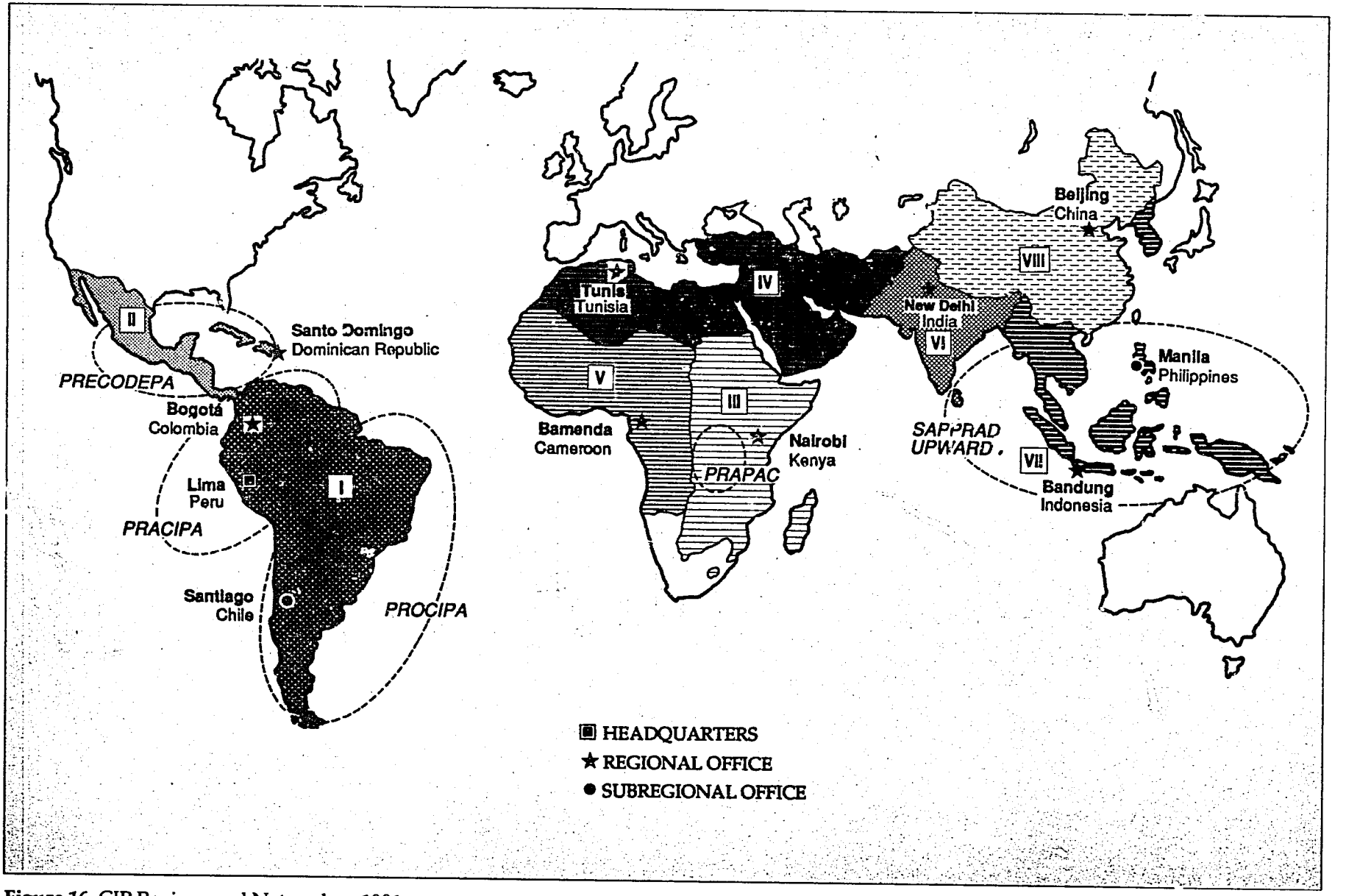


Figure 16. CIP Regions and Networks – 1991

composition and location of regional multidisciplinary teams will be based on national program capabilities in each region.

Complementary, special country projects provide an important mechanism for generating technical guidance in the implementation of available technologies within a given country. These projects are developed in direct response to clients' changing needs and capabilities. CIP will continue to encourage donors to fund special country projects for consolidating national capabilities and infrastructure in key locations.

Regional Consolidation

To increase efficiency in managing a growing number of regional activities, the number of CIP regions will be reduced (from eight to four or five) to cover major continental areas. The consolidation of regional activity will involve many factors, including:

- reduction of costly travel from headquarters to supervise activities;
- increased multidisciplinary expertise in each major geographical area;
- effective sharing of skills and coordination of activities within and among regions;
- more efficient use of local expertise;
- centralized germplasm distribution, in coordination with CIP's continental distribution units.

This regional consolidation, complemented by increased agroecological analysis in CIP's research, will provide more effective transfer of technology across and within ecoregions.

A senior staff member will be appointed to each region to coordinate research, training, and information activities in the area, and between the region and headquarters. Though the majority of regional staff will be grouped in a centralized location, some scientists will be located in other areas of the region where their expertise is required for solving priority problems.

CIP will study the evolution of regional offices and responsibilities carefully, to ensure that headquarters and regional administrative roles are properly balanced.

Networks

CIP's networks are fundamental vehicles for implementing research and disseminating its results among the center's clients. CIP's network model is based on sharing responsibilities among countries within a geographical area to economize on the costs of certain priority research. The senior policy-making body of each network is comprised of appointees of the member countries, with CIP representation. Coordination of network activities is usually the responsibility of the participating countries, and CIP gives technical guidance on request. The current networks and their members are as follows:

- PRECODEPA (Programa Regional Cooperativo de Papa): Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama
- PRACIPA (Programa Andino Cooperativo de Investigación en Papa): Bolivia, Colombia, Ecuador, Peru, Venezuela
- PROCIPA (Programa Cooperativo de Investigaciones en Papa): Argentina, Brazil, Chile, Uruguay, Paraguay
- SAPPRAD (Southeast Asian Program for Potato Research and Development): Indonesia, Malaysia, Papua New Guinea, the Philippines, Sri Lanka, Thailand
- PRAPAC (Programme Régional d'Amélioration de la Culture de Pomme de Terre en Afrique Centrale): Burundi, Rwanda, Uganda, Zaire
- UPWARD (User's Perspective with Agricultural Research and Development): Indonesia, Nepal, the Philippines, Sri Lanka, Thailand, Vietnam

Other countries will be encouraged to join the existing networks, and additional networks may be established to service new regions and countries as needed.

CIP-promoted networks initially focused on the horizontal transfer of technology for potato production. Over the past five years, this approach has been broadened to include social science and food systems (PRACIPA and UPWARD) as well as sweetpotato research (PRAPAC and SAPPRAD).

In the future CIP will strengthen its participation in the networks, when appropriate, for:

- on-site adaptive research;
- redistribution of germplasm;
- training;
- development of training materials and databases;
- needs and impact assessment.

CIP's financial contribution to the networks in the short term will be primarily in the form of continued assistance in identifying sources of funding. In some cases, network research that can complement CIP priority research will be funded from the core budget. CIP will also provide the networks with assistance in developing innovative methods of self-financing.

Should it prove necessary in the long term, CIP will consider a more direct role in coordinating the networks to ensure that their basic activities of technology and germplasm exchange are ongoing. The balance of activities between CIP's regional offices and the networks will be carefully analyzed, to avoid duplication of efforts and increase efficiency.

Continuing cooperation will be sought with other networks, such as the existing ties with the East and Southern Africa Root Crops Research Network (ESARRN) for sweetpotato research.

Professional Associations

Regional professional potato associations have been established in Asia, Latin America, and Africa. They hold triennial meetings, which serve as a forum for scientists, extensionists, policy makers, and private sector representatives to interact and exchange information. The associations in Asia and Latin America have journals, enabling researchers to publish their work and thus providing them with valuable professional recognition.

CIP will encourage the incorporation of sweetpotato into the existing associations, or the development of separate associations for this crop. Center staff will be encouraged to attend association meetings, and to publish research results in their journals.

Training

To date, CIP has trained close to 9,000 researchers, educators, and extensionists (Figure 17) who now form part of a global network for exchange of knowledge and germplasm. Annual figures include close to 70 undergraduate and 20-40 graduate students, and between 400 and 700 participants in group training.

To achieve more focus and impact, CIP's training priorities are now aligned directly with thrust research priorities. The Training Department will develop a five-year plan based on a cross analysis of research needs in each thrust, and national research and training needs as reported by the regional program. The plan will include specialized and production courses, advanced-degree and mid-career training, and postdoctoral

TOPIC	1972-1990 TRAINEES *	1972-1990 %	PROJECTED %
AGRONOMY	34	0.4	6
BREEDING & BIOTECHNOLOGY	122	1.4	12
GERMPLASM MANAGEMENT	368	4.2	10
IPM **	483	5.5	11
ON-FARM RESEARCH	121	1.4	3
PATHOLOGY	497	5.7	10
POSTHARVEST	605	6.9	12
GENERAL PRODUCTION **	3,000	34.4	8
RESEARCH, TRAINING & COMMUN. SKILLS	133	1.5	4
SEED PRODUCTION **	2,750	31.5	10
SOCIO-ECONOMICS	183	2.1	4
TPS	435	5.0	10

Figure 17. CIP Trainees by Topics

Note: * Total number of trainees between 1972 and 1990 – 8,731.

**Areas in which strong training capabilities will be developed in national programs.

fellowships. Most activities will be implemented by research staff using project facilities. In this way, training becomes a more integral part of research.

CIP will distribute future training efforts in the priority thrust areas (see Figure 17) according to comparative advantage and national program needs and capabilities. Much potato production training, for instance, can now be carried out by national programs and networks. The majority of training for the transfer of existing knowledge will be done in the regions, in direct collaboration with national programs. In these activities, farmer participation in germplasm and technology evaluation will be encouraged. Training for sweetpotato processing, utilization, and production will be supported by tapping the expertise of countries that have relevant experience.

Specialized training aimed at transferring specific skills and research capabilities is usually done at headquarters. This type of training will receive increasing emphasis, especially in areas such as breeding and germplasm management.

CIP will continue to promote self-sufficiency in partner countries through advanced training for M.S. and Ph.D. degrees at local universities. The number of Ph.D's trained on the job in association with CIP will be increased. Mid-career (6-12 months) and postdoctoral (1-2 years) training for scientists from developing countries will be conducted at headquarters and in appropriate locations in the regions.

Follow-up of trainees will receive high priority. The monitoring of participants' post-training activities will help in reorienting priorities and in avoiding duplication of efforts. Due to its multiplier effects, training of trainers will also receive priority.

Collaboration with other international agricultural research centers and advanced research institutions will be pursued in areas such as biotechnology, in which CIP presently has limited strength. Training collaboration with sister centers will also continue in selected areas such as root and tuber crop management, integrated pest management, social sciences, information, and research methodology and management.

Information

CIP's decentralized operations require an innovative communications strategy to ensure integration and consolidation of efforts. Information originating at headquarters, for instance in seminars and internal meetings, must be systematically collected and distributed. Knowledge gathered in the regions concerning technology performance, production systems, and the needs of national research programs must also be analyzed, documented, and fed back to each thrust and to other regions. At the regional level, CIP often acts as a catalyst, promoting information generation and exchange within and among networks and regional associations.

These diverse information activities require careful analysis and planning of information services, especially given the rapid advances of communications technology and the demands these can make on CIP and its partners.

CIP's six research thrusts now include information generation as a program function. The inclusion of information activities in each thrust will be accompanied by the development of a CIP-wide information plan to ensure the timely, program-related production of priority information. This five-year plan will include budgeting and production of materials and services.

The vehicles for management and exchange of thrust-generated information include CIP scientific publications for many audiences (scientists, science managers, extension staff, trainees, policy makers, and donors) as well as training materials, audiovisuals, and videos.

Potato and sweetpotato databases provide easily accessed and integrated information systems for use by headquarters and regional staff, and partners worldwide. The CIP germplasm databases include passport, characterization, and evaluation data, as well as pathogen-tested lists. In the future, these databases will go on-line and will include a mechanism for data interchange based on research evaluation. The CIP bibliographic database is the major source of computerized searches and selective dissemination of information for partners. This database also assists the thrusts with topic-specific bibliographies and searches. It provides references to all documentation

in the library, as well as access to all major bibliographic databases for potato and sweetpotato information. Project management databases, country files, and potato mapping systems allow users to access data on crop production, marketing, and consumption, classified by thrust and by region according to the indicators defined within the research projects.

CIP will emphasize the improvement of its databases for heightened research management and impact assessment capabilities in key areas such as germplasm tracking and follow-up of trainees. Databases to facilitate access to pertinent information on world geography as well as on processing techniques and opportunities are also being developed.

These activities are combined with selective training for national program partners, including hands-on training in the use of software and hardware. Learning modules for in-service training of partners and staff will be used to boost skills in information generation, media production, and accessing databases. Aside from these services, CIP will continue to provide assistance in research design, analysis, and presentation for headquarters and regional staff.

The unique challenges associated with CIP's highly decentralized information needs will be supported by a range of complementary management procedures, including:

- regional contracting of communication and production skills;
- co-publishing;
- exchange of databases;
- increased coordination with training in thrust priority areas;
- supporting national programs' organization of documentation centers.

The application of electronic networking and other new technologies such as electronic bulletin boards, computer conferences, user groups, electronic mail, and facsimile will require careful analysis of comparative advantage in the development and design of information systems. Some examples of new technologies already in use include CD-ROM for germplasm information and on-line searching via satellite of major thrust and administrative databases.

CIP plans to establish an internal advisory panel to aid in center-wide information and communications planning. It will

review total allocation of staff and resources for information management on an annual basis, and will assist in updating the thrusts' five-year information plans.

Resource Allocation

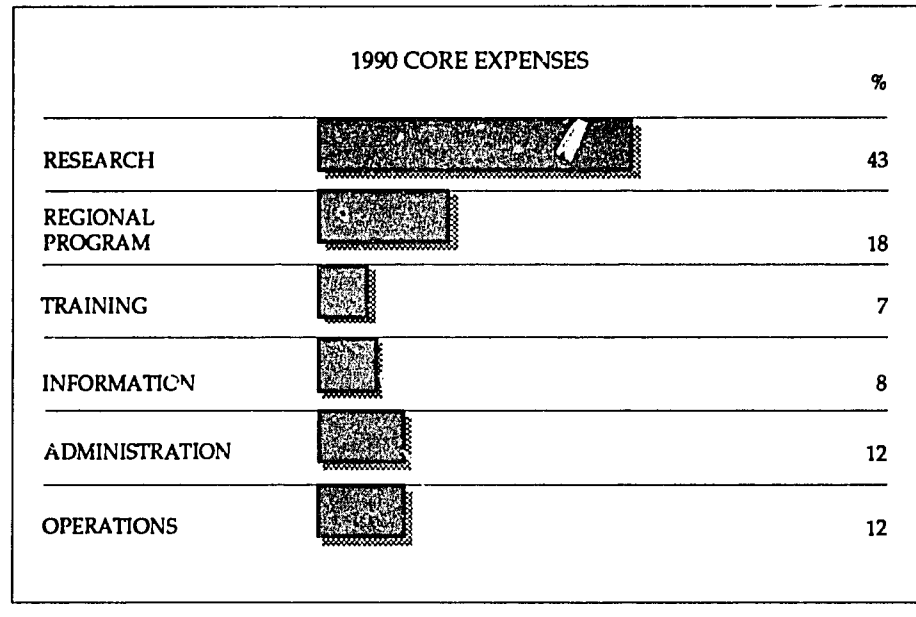
CIP continues to stress the importance of unrestricted core funding, to allow the center to respond effectively to clients' needs and make the most of opportunities. In 1990, core funding amounted to US$16.764 M, including US$0.440 M in restricted core projects. The center received US$3.006 M in support of complementary activities: US$0.270 M for research, US$1.026 M for network support, and US$1.710 M for national research system capability building. Figure 18 shows the distribution of CIP's core expenses in 1990.

CIP's allocation of resources for the future is based on many complex factors involving:

- assessment of the relative potential for impact of each of the center's mandate commodities;
- priority ranking of CIP's research activities with relation to potential impact;
- evaluation of the needs and opportunities in each of the regions CIP serves;
- CIP's and its clients' comparative advantage.

The Commodities: Between Potato and Sweetpotato

Since sweetpotato was added to the center's mandate in 1986, CIP has steadily increased its investment in research and training for this crop. Presently, sweetpotato accounts for about 30% of the center's research budget. The strategic target is a 60-40 budgetary split between potato and sweetpotato respectively. This is congruent with projections of the relative importance of these crops in CIP's client countries, if present trends continue. By 2010 the existing 50-50 share of potato and sweetpotato in total value of production should be 60-40 in favor of potato (Figure 19).



RESEARCH	Disciplinary Departments Research Support - Experiment Stations Conferences / Seminars / Workshops
REGIONAL PROGRAM	Office of the Director of the Regional Program Seed Program Regions
TRAINING	Training Department Training - Regions
INFORMATION	Information Unit Communication Unit Computer Unit Statistics Unit Public Awareness Unit
ADMINISTRATION	Board of Trustees Office of the Director General Office of the Controller Office of the Executive Officer Logistics Unit Local-Hire Personnel Unit
OPERATIONS (Lima)	Motor Pool Maintenance Security General Services

Figure 18. Distribution of CIP's Core Resources – 1990

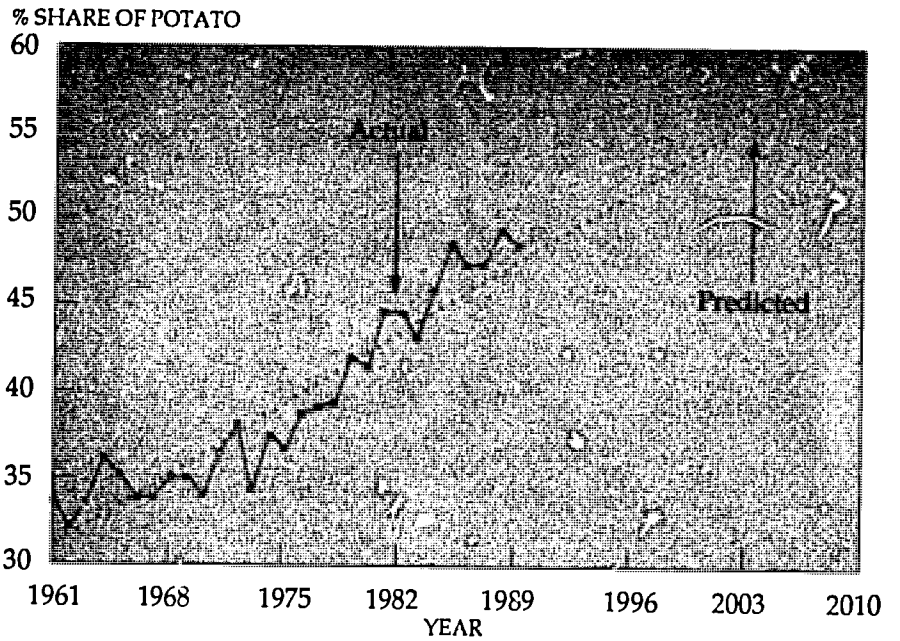


Figure 19. Share of Potato (%) in the Total Value of Production of Potato and Sweetpotato in Developing Countries

Note: Average prices in US$/t were 142 for potatoes and 89 for sweetpotatoes for all years.

Source: Constructed from *FAO Production Yearbooks, 1961-1989* and unpublished FAO estimates of farmgate prices.

Based on equity considerations and on relatively low investments in sweetpotato in the past, one could argue for an equal allocation for the two crops, or even for more weight for sweetpotato. However, current demand constraints rule against such a move. Moreover, the relative importance of reducing the use of purchased chemical inputs in potato production – as compared to sweetpotato cultivation, where their use is limited – increases the importance of potato research in responding to environmental concerns.

The Research: Among Thrusts

Weights for resource allocation across the six thrust areas are given in Table 1. In the future CIP will invest about 45% of its resources in integrated pest management (Thrusts 3 and 4). This emphasis reflects the global importance of late blight, bacterial wilt, potato tuber moth, and sweetpotato weevil. Thrusts 2, 5, and 6 will have equal claims on core resources, though some work will be done with complementary resources

Table 1. Indicative Resource Allocation (%) by Thrust for Potato and Sweetpotato

Thrust	Estimated 1991*	Future Potato	Future Sweet potato	Future Total
1. Production Systems	12	6	4	10
2. Germplasm Management & Enhancement	36	9	6	15
3. Disease Management	29	20	5	25
4. Insect & Nematode Management	14	10	10	20
5. Propagation, Crop Management	15	10	5	15
6. Postharvest Management, Marketing	4	5	10	15
Total	100	60	40	100

* Based on total 1991 research allocation.

or through cooperation with national programs, especially in Thrust 2.

Compared with the recent past, the weights in Table 1 imply a notable increase in the relative importance of postharvest research. This arises from the importance of addressing demand constraints on increased sweetpotato consumption.

The Regional Program: Among Regions

When viewed from the reference point of global production values, the center's regional program presently over-invests core funds in sub-Saharan Africa and Latin America and under-invests in Asia (Table 2). Percentage shares of core funds in North Africa and West Asia are reasonably proportional to their importance.

Although sub-Saharan Africa accounts for only 4% of the potatoes and sweetpotatoes produced in developing countries, CIP will continue to invest about 30% of its core regional resources there. This is justified by the region's expanding potato cropping area, declining per capita food production, and high incidence of poverty, as well as by the importance of sweetpotato as a source of food security for small farm households in selected areas. In North Africa, core investment will remain virtually unchanged.

In contrast to the apparent over-investment in sub-Saharan Africa, under-investment in Asia can no longer be justified.

Table 2. Value of Production of Potato and Sweetpotato in Relation to CIP's Regional Resource Allocation (%)

Region	Value of Production of Potato and Sweetpotato		Regional Resource Allocation* – 1991 Budget			
	Including China	Excluding China	Core	Networks	Special Projects	Total**
Latin America	10	25	28	50	80	47
N. Africa and W. Asia	8	20	8	0	2	4
Asia	78	44	37	17	6	24
Sub-Saharan Africa	4	11	27	33	12	25

* Includes regional program and training.

**Core, networks, and special projects.

Even excluding China, Asia's share in global production values for potato and sweetpotato is 44%, and CIP's present core allocation to this region only 37%. Potato cropping area is still increasing in Asia, and the importance of this continent in sweetpotato production is paramount. Also, the incidence of poverty remains high, particularly in South Asia. In the future, about half of CIP's core regional resources will be directed to Asia. The search for more effective ways to catalyze spill-over benefits from China and India to the rest of the region will represent a major challenge.

CIP balances regional allocation of core funds with complementary funding for network and special project activities where required. For instance, to accommodate the increasing emphasis on Asia, allocations from core to Latin America will be reduced. This is possible because some Latin American research networks, such as PRECODEPA, are now mature. Also, several Latin American countries have strong, well developed potato programs. Moreover, CIP has many complementary special projects in this geographical area (see Table 2).

Though Latin America is the only continental region that has not experienced sustained growth in area of potato production since the early 1960s, potato is very important there as a basic food. Sweetpotato also has great potential as a source of nutrition in many subsistence areas in Latin America, and both crops can generate income and employment. Continuing regional needs in Latin America will be coordinated by headquarters staff

in Lima, Peru and Quito, Ecuador, with a special emphasis on the Andean ecoregion.

CIP's regional budgetary targets are based on several assumptions. For instance, that headquarters activities in Peru are likely to benefit the four continental areas equally and that there will be no differential spill-over benefits among regions. However, these assumptions do not always hold. TPS breeding in Chile, for example, directly benefits several of the other regional programs. Also, per capita consumption factors may at times outweigh production value as criteria for resource allocation. Ongoing resource allocation will be continually evaluated, and adjustments will be made, when necessary, to provide the maximum impact in responding to CIP's changing environment.

Implementation

The report of the 1989 CIP External Management Review cited several principles that guide CIP's modes of operation. To quote the EMR,

many of these relate to organizational structures or processes. The list includes the following:

- *establishing quality collaborative relationships with institutions in developed and developing countries instead of working in isolation;*
- *extensive use of contract research in place of conducting the research in house;*
- *being close to clients by establishing regional offices (in association with other institutions with suitable infrastructure);*
- *establishing and facilitating the running of country research networks;*
- *organizing international planning conferences;*
- *involving social scientists in CIP's research teams;*
- *maintaining a low profile, with modest facilities and low cost overhead;*
- *establishing and maintaining a department/thrust matrix research structure;*

Major External Management Review Recommendations

Follow-through on the self-study and change plan with:

- *continuous internal management and operations review;*
- *Board of Trustees involvement in policy making, oversight of administration, and operations.*

Strengthened role of the Board in strategic concerns.

Leadership of the new Director General in drafting the strategic plan.

Modified organizational structure, including:

- *Deputy Director General of Research;*
- *strong commodity orientation;*
- *reduced number of thrusts and departments;*
- *budgetary authority to thrust and project leaders.*

Integrated performance and planning review system to replace annual evaluation process.

Yearly auditing of regional offices.

- *organizing annual internal reviews that are open to clients and collaborators;*
- *locating core scientists outside of headquarters;*
- *critically reviewing itself through a self-study.*

The External Management and Program Reviews, together with the self-study process, have been valuable in reinforcing these guiding principles. As the strategy evolves to meet new challenges and opportunities, they will continue to be applied. However, many specific management functions will be modified and fine-tuned to allow CIP to continue to fulfill its mission in the changing environment. These functions fall into two basic categories: research, and administrative. This process of change and adaptation will result in a strengthened center, whose operational modes are, to a large extent, its very structure.

The Program Matrix

CIP's department-thrust matrix is used to organize research activities into interdisciplinary problem-solving teams that address major production and utilization constraints. The focusing of the center's research agenda into fewer thrusts will be accompanied by streamlining of the basic research management structure. Regional collaborative projects, previously managed through an essentially separate program, are now also an integral part of thrust activities. Increased effectiveness of program review will be emphasized, in direct alignment with priority setting. CIP's linkages for cooperation will also be notably expanded.

Research Management

CIP will implement a project-based management system. This system is designed to provide:

- fuller disciplinary as well as regional and headquarters integration of the research program;
- an output-driven focus, with better capacity to respond to clients' needs and priorities;
- increased planning and priority-setting capability for management transparency;
- improved ability to monitor achievement and impact.

CIP's department-thrust matrix will remain the basis for research management. Departments will continue to provide disciplinary strength and scrutiny of the research agenda. Research activities will be grouped into a reduced (close to 50) number of projects, and resource allocation will be linked directly to their priority. Each project will include a clear definition of coverage, activities, and estimated time of impact.

Each project will have a leader who will be responsible for:

- project planning, development, monitoring, and reporting;
- budget preparation and management;
- supervision of time frames and objectives;

- impact assessment;
- participating in fund raising.

The thrusts will formulate the projects deemed necessary, and for which funding is available, to achieve their objectives. Thrusts will be the principal administrative and budgeting units for CIP activities. Thrust leaders will be responsible for:

- reviewing projects in the light of established thrust objectives and priorities, as well as available resources;
- coordinating thrust projects and distribution of resources;
- procuring the required resources and collaboration from the departments;
- assessing progress of thrust activities;
- reporting on thrust progress and impact achieved;
- participating in fund raising.

Every three to five years the center will review the overall objectives of each thrust in the light of new priorities and the completion of existing projects. The position of thrust leader will normally be rotated every three to five years.

Ad hoc working groups will be established as needed for general commodity-related issues. They will analyze constraints and reassess research priorities within the prevalent production systems for each crop.

Departments will continue to serve as the center of disciplinary debate, discussion and support. Projects developed to achieve thrust objectives will be reviewed by department heads to ensure that methodologies and research protocols meet the center's standards of excellence. Hiring will also be accomplished at the department level.

The department head's responsibilities will include:

- reviewing – with project and thrust leaders – requirements for staff support;
- effectively allocating departmental, human, and physical resources in response to thrust needs;
- promoting the professional development of staff and national scientists;
- monitoring compliance with disciplinary standards of research.

Despite the project-based budgeting system, CIP will also aggregate requirements by department for resource allocation purposes.

Each CIP scientific staff member, whether stationed at headquarters or in the regions, will belong to a disciplinary department and will participate in one or several thrusts, by project. All regional projects will form part of this research management system, whether they involve national program scientist collaborators or not.

Regional scientists can be project leaders, and as such will be responsible for the corresponding procedures. CIP's decentralization, with critical mass of expertise located in the regions according to areas and needs, will be fundamental to making this system operative. Training and capability building aimed at fortifying national programs will be included at the project level.

CIP's consolidation of its regions into four or five major groupings by areas or continents will provide more effective integration of headquarters and regional activity. The head of each of the regions will be responsible for:

- coordinating the interdisciplinary activities of the regional team;
- managing the regional budget (For efficient budgetary management at the regional level, the aggregate cost of all projects at any location will appear in the total regional budget.);
- ensuring that research and training activities are compatible with the region's needs;
- promoting transfer of results for impact at the farm level;
- coordinating activities and services between CIP and the network(s) in the region;
- coordinating interaction with any special country project team located in the region.

The regional head will directly supervise activities related to capability-strengthening projects.

Special country projects are an important operational approach used by CIP to fortify national capabilities and support transfer of technology in selected areas. Though these projects are funded complementarily, CIP scientists assigned to them are considered full regional scientists. Administration of these projects is conducted in conjunction with the national program involved.

Research Planning and Review

CIP's move to project-based management will result in corresponding changes in the center's mechanisms for project planning and review. The project-driven management system will heighten CIP's ability to focus its agenda accurately on the priority needs of its clients and beneficiaries. At the same time, improved impact assessment will sharpen the design of projects and will contribute to setting standards for their review.

Impact Assessment

CIP's strategy to enhance the farm-level impact of its germplasm and production methods involves a careful analysis of impact indicators, which can be calculated in the form of improved or increased:

- **area from**
  increased cropping diversity leading to
  augmented harvested acreage
- **yield from**
  quality seed
  disease resistance
  insect and nematode resistance
  nutrient management
  enhanced yield potential
- **cost effectiveness from**
  new planting methods/materials
  nutrient management
  disease resistance
  insect and nematode resistance
  pest management
- **storage efficiency from**
  disease resistance
  insect and nematode resistance
  pest management
  new or improved storage techniques
  production and market integration
  expanded processing

- **value of production from**
  expanded processing
  other demand-increasing efforts

Indicators will be defined to formalize the measurement of impact across the center's research areas, focusing on targeted clients, ecologies, and socio-economics. Before extending the application of these indicators to all areas, CIP plans to sample a few projects for in-depth study. This will allow the center to determine the relevance and feasibility of alternative approaches for *ex ante* and *ex post* assessment. The initial trials will be core-funded. However, special project funding will be sought for ongoing research on impact methodology.

Steps will also be taken to enhance the center's tracking of advanced genetic materials. A current database system gives detailed analysis of the cultivars sent to national programs, both on a country/region and a trait-specific basis. CIP will dedicate more resources to collaboration with partners for following up on use of breeding material, both as potential varieties and as progenitors. New collaborative projects will be developed to build a database on germplasm utilization at the research, seed program, and farmer levels. CIP's regional staff will play an important role in this activity.

Further efforts will be dedicated to monitoring the uptake of new technologies in national programs. Databases are already in place to track the distribution of trained personnel as well as technological tools such as serological detection kits. *Ex post* case studies of technological change attributed to collaboration between national programs and CIP will be emphasized. Priorities will include studies on the production of quality planting materials, and on integrated management of potato tuber moth and other pests. In addition to documenting the returns on research, results from these studies will point out areas in need of strengthening and approaches requiring adjustment.

The move to project-based management within the thrusts will include an emphasis on *ex ante* impact assessment for research formulation and evaluation. Impact assessment will be the responsibility of each thrust, and all scientific staff will be involved. CIP will also tap the expertise of outside specialists and will continue to participate in wider CGIAR initiatives for refining impact assessment methods.

Interdisciplinary Project Review

The complexity of CIP's decentralized research structure implies high interdependence among a large number of participants. In order to maintain efficiency in administering research, the center's methods for evaluating and reassessing priorities must be enhanced. At the same time, this process will be reflected in the research activities and in resource allocation.

Periodic reviews will be conducted for each project or, when appropriate, will cut across projects to explore a particular theme. These in-depth evaluations will involve the entire team of the project(s) under consideration, and will be based on expected and reported impact. Though the project reviews will be predominantly internal, outside experts may also be invited to participate.

Annual Program Reviews

CIP's annual program reviews will continue to bring together staff from around the world to evaluate research results, as necessary. Future reviews will focus on selected areas of relevance or need. The annual meetings are open forums for debate and constructive criticism of the center's global activities. External participation by CIP's collaborators from developed and developing countries is encouraged, since their presence helps in the identification of client priorities.

International Planning Conferences

International planning conferences play a key role in CIP's implementation of research. Outstanding scientists from partner countries are invited to participate in them to evaluate each new area of research concentration as it is identified. Together with CIP staff, the invited experts identify areas of comparative advantage and elaborate a five-year plan of action, evaluating CIP's activities in the light of work being accomplished elsewhere.

The recommendations derived from planning conferences are thought of as essential guidelines for research and program development, and as a basis for alignment of research staffing, funding, and time frames. For continuing research, conferences

are held at approximately three to five year intervals to monitor progress, reorient research according to changing needs, and assess ongoing and potential impact.

Modes of Collaboration

CIP's participatory mode of operation is based on the belief that the center's greatest effectiveness in fulfilling its mandate can be achieved through collaboration and team work with scientists, institutions, and farmers worldwide. Collaboration provides opportunities to combine comparative advantages, thus increasing cost-effectiveness, avoiding duplication of efforts, and extending benefits to a wide range of clients and partners.

Public and Private Sector Linkages

In recent years, public and private sector collaboration in the industrialized countries has led to a general division of labor based on comparative advantage. Agricultural research appears to be moving towards unifying its attempts to solve major problems. For example, in many industrialized countries the majority of breeding work is carried out by the private sector, with basic research and regulatory backup from public sector institutions. Collaboration is particularly prevalent with the new tools and products of biotechnology.

CIP will continue to seek association with the private sector in various ways, including membership on its board of trustees, cooperative research projects, scientist exchanges, and private funding of center projects, within the following guidelines:

- The strategies developed must ensure that unfair profits are not made at the expense of the producers and consumers of CIP's client countries. National programs will be involved in project planning and implementation, and whenever possible a portion of contract research and its financing will be assigned to national scientists.
- There must be no distortion of program objectives and priorities as a result of private sector funding or collaboration.
- Property rights and ownership of products resulting from joint ventures with the private sector must be carefully managed to protect the ready flow of information and technology to partner

country institutions. Appropriate policies will be developed and action will be taken, should the need arise, to safeguard free and ready access by national programs to cooperative research products.

In its client countries, CIP will seek private sector involvement in areas where there is a specific comparative advantage in doing so, such as seed production and processing research.

As CIP continues to explore these possibilities, special attention will be given to catalyzing direct linkages between CIP's national system clients and private sector institutions within their own countries and elsewhere. This will include diverse activities, from technology transfer and implementation with local companies to advanced training at specialized institutions.

Contract Research

The term contract research refers to a range of cooperative research agreements developed over time with advanced national and international institutions. Most contracts are cooperative agreements in which both partners carry the cost of their contribution. A small number are substantially funded by CIP. Contract research has a high success rate and is cost-effective. It allows CIP to take advantage of installed capabilities existing elsewhere that can complement its own.

Many technologies developed under contract have been widely disseminated and are now in routine use in CIP's client countries. Cooperation with molecular biology laboratories allows center scientists to remain at the forefront of biotechnological advances without investing in costly infrastructure. Contracts also open up important opportunities with advanced national systems, allowing CIP to draw on their experience and research capacities in selected areas of expertise.

Contracts will continue to be developed by CIP as a key element of the center's participatory strategy, to make effective use of the complementarity of capabilities of research institutions worldwide.

Inter-Center Collaboration

In the future, CIP will seek closer collaboration with other centers, particularly in the areas of farming systems, sustainability,

institution strengthening, and resource management. This approach will help to optimize resources and address the need for more environmentally sound production systems.

For instance, potato and sweetpotato can be grown extensively in cereal-based cropping systems. Potential collaboration includes research areas such as:

- sequential cropping with rice, in collaboration with the International Rice Research Institute (IRRI) and the Centro Internacional de Agricultura Tropical (CIAT);
- intercropping with maize, in collaboration with the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT);
- alternative cropping for marginal irrigation systems, with the International Irrigation Management Institute (IIMI);
- economic and policy research, with the International Food Policy Research Institute (IFPRI) and the International Service for National Agricultural Research (ISNAR).

Sweetpotato is common in agroforestry systems. Collaboration with ICRAF and CIAT will be important for exploring the crop's potential in those areas.

Cooperative studies with ICRAF and the International Board for Soil Research and Management (IBSRAM) will be sought for the erosion-prone production areas associated with both potato and sweetpotato production. Research cooperation for CIP's heightened focus on the Andean ecoregion will draw heavily on pertinent work being carried out by centers such as CIMMYT, CIAT, ICRAF, and ILCA, as well as by institutions specializing in mountain production systems, such as the International Center for Integrated Mountain Development (ICIMOD).

Inter-center collaboration will continue to be used to increase research efficiency in topics of common interest such as bacterial wilt, viruses, and planting materials, as well as biotechnology. An example of such collaboration is the work being carried out jointly with the International Center of Insect Physiology and Ecology (ICIPE) for the control of key insect pests.

To promote more efficient technology transfer and institution strengthening, CIP will continue current collaboration for training and information with root and tuber crop centers such as CIAT and IITA. Further collaboration with these centers will include processing studies.

Strong support will also be sought to help CIP keep abreast of rapidly advancing communications technology. The greater use of tools such as electronic conferences and bulletin boards will be explored, in collaboration with specialized institutions and with sister centers.

Administration

The effectiveness of CIP's changing research structure will depend on appropriate administrative measures to provide efficiency in carrying out an increasingly complex task. As CIP's modes of operation evolve to respond to the challenges and opportunities of the future, center administration must keep pace. This will require carefully balancing and coordinating the many areas of CIP's activity. It will also involve close attention to the center's institutional culture, to ensure that all staff are fully involved in the process.

CIP recognizes the importance of efficient management and will continue to provide training in this area for staff whose functions involve a strong administrative role. At the same time, staff participation in center management will be encouraged. The organizational structure will be modified to accommodate CIP's growing operational complexity, and to support fuller research integration.

Board of Trustees

CIP's Board of Trustees is responsible for the overall direction and performance of the center. Its members include scientists and research managers from partner countries, each of whom serves in a personal capacity. Three members are selected by the Consultative Group on International Agricultural Research. There are two Peruvian representatives, one selected by the National Agrarian University and the other by the Ministry of Agriculture. The Director General serves as an ex officio member. Board business is routinely handled through the Executive, Program, and Audit Committees.

To ensure continuity and to accommodate the added demands of the mandate for sweetpotato, the Board expanded in 1989 from 10 members to 12. Recently it completed a self-study, restructured its committees, and revised its by-laws. The Board's self-study focused on improving its effectiveness and strengthening its role in guiding and supervising the center's activities.

Organizational Structure

CIP has carefully considered the recommendations of the External Management Review in formulating a management structure that can help to effectively implement the programs and institutional linkages foreseen in this strategy. Though many of the details for the center's future organizational structure are still under discussion, the key points are as follows.

CIP will create two Deputy Director General (DDG) positions, one for administration and one for research. The center will maintain a balance between the responsibilities of these positions. The DDG for Administration will deal with personnel,

finance, operations, logistical support to programs, and international relations. The DDG for Research will focus on CIP's research at headquarters and in the regions, including networks and other collaborative research components.

Training, information services, and research support are activities that relate closely to both administration and research, combining elements of both. CIP management is studying these areas to improve their organization. The functions of public relations and donor coordination will be strengthened.

CIP will move to project grouping within six programs that will replace the present thrusts. The programs will integrate research, information, and training activities within a systems focus.

While the final definition of the organizational structure is still evolving, many relevant staffing and organizational changes will be presented in CIP's next five-year plan (March 1992).

Staff

CIP's institutional culture is based on a philosophy of making the most of opportunities through collaboration among many partners, within the institution as well as outside. The international nature of CIP's staff contributes to a rich, cross-cultural working environment.

CIP's spirit is manifested in a willingness to try new methods before they are standard elsewhere, as exemplified by many of the center's early approaches, including a strong regional emphasis; the participation of social scientists in the research program; decentralized cooperative training; and an emphasis on institutional impact, among others. The success of these approaches has resulted in a general sense of self-confidence, and has reaffirmed the center's values.

Currently, a large part of CIP's internationally hired staff is stationed outside of headquarters. In the future, close to half of CIP's staff will be located in the regions to aid in the easy transfer of technology and research responsibility. The objective is to group expertise in key geographical areas in accordance with clients' needs.

Staffing will be increased in areas of signalled priority where there is the need to expand capabilities. Examples are the social sciences (for postharvest and impact research) and physiology (for resource management). The details of these changes will be presented in the next five-year plan.

About 8% of CIP's internationally hired staff is female, and there have consistently been women members on the Board of Trustees. Over time, CIP will increase the number of women working at the center at all levels, including senior management, and will address their conditions of employment to ensure equity.

Headquarters Infrastructure

CIP's emphasis on low-profile facilities helps keep maintenance costs low and allows the center to maintain compatible working relationships with its national system colleagues. CIP's principal headquarters facilities are at the La Molina experiment station in the coastal desert near Lima (240 m). CIP has four more experiment stations, which represent the major climatic conditions of its client countries (Figure 7).

There are two sites in the Amazon area, one in the mid-elevation jungle of San Ramon on the eastern slopes of the Andes (800 m), and the other in the hot, lowland jungle of Yurimaguas (180 m). Research at these two sites is focused on warm-climate potato and sweetpotato production. Work in Yurimaguas is conducted at CIP sites and also at the INIAA research station. CIP has two Andean highland stations, one in Huancayo (3,260 m) and another in Quito, Ecuador (2,900 m). CIP headquarters personnel in Peru and Ecuador comprise approximately 50 internationally hired and 550 locally hired staff.

To meet working requirements at the La Molina station, CIP will address continuing needs in the following areas:

- **Land.** At the La Molina station land is intensively used, and demand for field space usually exceeds the land available. There was no increase in land area accompanying the incorporation of sweetpotato research into CIP's activities. Furthermore, sweetpotato has a longer growing season than potato, and therefore cropping cycles are often incompatible. For

these reasons, local sweetpotato field research takes place off-station on land (roughly 5 ha) contracted from other institutions or farmers.

- **Water.** Because of the lack of rain on the Peruvian coast, all agriculture at the La Molina station is irrigated using underground water. Though growing urbanization in the surrounding area makes the domestic use of water a first priority, it may in the long run favor municipal efforts to seek new sources of water supply. CIP has initiated measures to provide more effective use of water in its research, to help in preventing future shortages.
- **Facilities.** The implementation of biotechnological research at headquarters will require enhanced laboratory space (growth facilities for testing of transgenic plants). Initial efforts will be made to satisfy needs through redistribution of activities in the existing space, though some increased capital equipment will be required.

Experimental work at CIP's Huancayo station has been reduced to a minimum, for security reasons. Some highland research is conducted off-station in Cajamarca, in the northern Sierra of Peru (about 10 ha). For instance, most of CIP's in-field germplasm conservation and multiplication is conducted there. CIP's station in Quito, Ecuador complements the center's highland research facilities in Peru and offers security for the duplicate maintenance of CIP's genetic resources. Facilities there include screenhouses, 4 ha of field space, a tissue culture laboratory, and germplasm maintenance facilities.

Given the importance of the Andean production systems in CIP's strategy, management will carefully study needs for future implementation of research in that ecoregion. Details on these decisions will be contained in the next five-year plan.

Finance

CIP has a good financial record. The center's low profile and its cost-effective approach to research collaboration are attractive to donors, and allow CIP to work effectively within its means. However, recent economic circumstances in CIP's host country have adversely affected the center's finances.

Costs of headquarters operations increased sharply during 1989 and 1990, because of 7,650% inflation in Peru which was not compensated by devaluation of the national currency (3,483% over the same period). For example, the cost in US dollars of gasoline and electricity increased by 418% and 450% respectively. The greatest impact was felt in local-hire salaries, which rose by 2,051% in 1989 and by 3,158% in 1990. This, however, was not nearly enough to compensate for the increased cost of living: 2,778% and 7,650% for those two years respectively. Expressed in dollar terms, salary raises for 1989 and 1990 were 29% and 31% respectively. Inflation for the same years,also in dollar terms, was 333% and 120%, resulting in a serious reduction of purchasing power.

CIP's future funding requirements are foreseen to be similar in constant dollars to those budgeted for 1992, the last year of our present medium-term plan. A one-time, compensatory price increase of 10% above normal operating costs requested for 1993 is to compensate for increased costs at headquarters and to permit overdue replacement of equipment.

In terms of capital expenditures, no major expansion is foreseen at headquarters. However, to respond to new research activities in biotechnology, CIP plans to construct a biosafety facility and provide the necessary associated laboratory space.

The Way Ahead

This strategic document provides a vision of the direction CIP is taking to fulfill its mission into the 1990s and beyond. It describes how we are evolving to adapt to our challenges. Our research, training, and information activities will be integrated and focused. At the same time, their reach will be expanded as we continue to decentralize. In this way, we will become, more and more, a center without walls. The sharing of capabilities for research and information exchange with many partners on a global basis will, as always, be the foundation for our operations.

As we move into the future, the mechanisms for ensuring that we meet our goals and objectives will be continually reviewed and refined. The philosophical and practical guidelines that have been presented in this document will steer the process. Their implementation and definition will be updated progressively in our future five-year plans, and above all, will be assessed and adjusted in our day-to-day relations with our partners throughout the world.