IDRC-219e

Social Scientists in Agricultural Research

Lessons from the Mantaro Valley Project, Peru

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Postal Address: Box 8500, Ottawa, Canada K1G 3H9
Head Office: 60 Queen Street, Ottawa, Canada

Horton, D. E.

IDRC-219e

Social scientists in agricultural research: lessons from the Mantaro Valley Project, Peru. Ottawa, Ont., IDRC, 1984. 67 p.: ill.

/Interdisciplinary research/, /on-farm research/, /social sciences/, /natural sciences/, /scientists/, /potatoes/, /Peru/ — /farm size/, /agricultural engineering/, /research methods/, /research results/, /project implementation/, /crop yield/.

UDC: 63.001.5:3-051 ISBN: 0-88936-400-1

Microfiche edition available

Il existe également une édition française de cette publication

La edición española de esta publicación también se encuentra disponible

IDRC-219e

SOCIAL SCIENTISTS IN AGRICULTURAL RESEARCH

Lessons from the Mantaro Valley Project, Peru

Economist, International Potato Center (CIP), Lima, Peru.

Résumé

L'intérêt des sciences sociales pour la recherche agronomique est nouveau, et les études produites ne sont pas reconnues au même titre, par exemple, que celles des biologistes. De 1977 à 1980, le Centre international de la pomme de terre (CIP) a mis en oeuvre un programme de recherche pluridisciplinaire sur la ferme, dans la vallée du Mantaro, sur les hautes-terres du Pérou, associant anthropologues, économistes, sociologues, phytophysiologistes, agronomes, pathologistes et entomologistes. Le programme visait à: 1° sensibiliser le CIP et les scientifiques des programmes nationaux à la valeur de la recherche sur la ferme même; 2° créer et tester sur le terrain des méthodes de recherche sur la pomme de terre, et 3° former les effectifs des programmes nationaux aux techniques de recherche sur la ferme. Cette monographie expose brièvement les expériences réalisées dans la vallée du Mantaro et les résultats obtenus.

Resumen

Los científicos sociales están recién llegados a los programas de investigación agrícola y la mayoría de instituciones consideran su trabajo como de importancia secundaria en relación con el de los científicos de la biología. Sin embargo, de 1977–1980, el Centro Internacional de la Papa (CIP) llevó a cabo un programa de investigación interdisciplinaria a nivel de finca en el Valle del Mantaro en la sierra Peruana, en el cual participaron antropólogos y entomólogos. El programa tenía tres objetivos centrales: (1) sensibilizar al CIP y a los científicos del programa nacional respecto de la investigación en fincas, (2) desarrollar y probar en el campo de procedimientos para la investigación en fincas con papa, y (3) capacitar personal de programa nacional en el empleo de las técnicas de investigación en fincas. Esta monografía ofrece un resumen de la experiencia y resultados del Proyecto del Valle del Mantaro.

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Foreword

In September 1977, the International Development Research Centre (IDRC) approved a grant from its Social Sciences Division to enable the Socioeconomics Unit of the International Potato Center (CIP) to undertake a program of research on the agroeconomic constraints to potato production and postharvest technology. The research project was carried out in the Mantaro Valley of Peru. The research team included economists, anthropologists, and sociologists working in collaboration with their biological and agricultural engineering colleagues.

At the time the project began, there were few social scientists, most of these economists, working as regular staff of the International Agricultural Research Centres (IARCs), of which CIP is one. Much of the research carried out by these social scientists was ancillary to the work of those IARCs, whose primary objective is to conduct research and develop technology to improve the productivity of the particular agricultural commodities covered by their respective mandates. The research program at CIP, therefore, was most unusual with respect to the central role given to social scientists on the research team. The team's goal to identify existing technologies being used by potato farmers and farming systems that could serve as the basis for technological innovations and, hence, productivity improvements was largely achieved.

Although farming systems research incorporating agricultural economists into interdisciplinary research teams for technological development is now more common, they still include few other social scientists. A key element in CIP's approach and the successes of the project was the role played by anthropologists and sociologists on the research teams.

This monograph focuses on the approach adopted by CIP for using social scientists on agricultural research teams. The effectiveness of the approach and the difficulties and delays in institutionalizing interdisciplinary collaboration between social and biological scientists should be of major interest to researchers, administrators, and funding agencies of both international and national agricultural research centres.

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Director
Social Sciences Division
International Development Research Centre

Acknowledgments

The Mantaro Valley Project was funded, in large part, by a grant from the Social Sciences Division of the International Development Research Centre (IDRC). Financial support was also provided by the International Potato Center (CIP), Rockefeller and Ford Foundations, and Inter-American Development Bank.

This monograph, which attempts to synthesize the lessons of the project, reflects the creative efforts of many individuals. In particular, I wish to acknowledge the substantial intellectual contributions made by Primo Accatino, Robert Booth, James Bryan, Gelia Castillo, Roger Cortbaoui, Efrain Franco, Anibal Monares, Robert Rhoades, Roy Shaw, and Robert Werge. Useful comments on earlier versions were received from D. Boynton, S. Bradfield, K. Brown, D. Dalrymple, J. Dillon, A. Hibon, R. W. Hougas, C. McClung, O. T. Page, J. Pino, S. Poats, R. L. Sawyer, G. Scott, F. Tardieu, N. Takase, J. Thomas, M. Twomey, M. Umaerus, D. E. van der Zaag, D. Winkelmann, W. F. Whyte, and H. Zandstra. I would also like to express my appreciation to Mariella Altet and Lilia Salinas for their excellent work and patience in preparing innumerable drafts of the manuscript.

Finally, I would like to thank the staff of IDRC's Social Sciences Division, and in particular Garv Costello, David King, and M. S. Rao, for their encouragement, guidance, and unfailing support in planning and executing the project and preparing this final report.

Summary

From 1977–1980, the International Potato Center (CIP) implemented a program of interdisciplinary farm-level research in the Mantaro Valley of highland Peru. Anthropologists, economists, sociologists, plant physiologists, agronomists, pathologists, and entomologists were involved. The three main objectives of the program were to (1) sensitize CIP and national-program scientists to the value of on-farm research, (2) develop and field test procedures for on-farm research with potatoes, and (3) train national-program personnel in the use of on-farm research techniques.

This monograph presents a summary of the experiences and results of the Mantaro Valley Project. On-farm research is now embraced by CIP's management and working scientists as an integral part of the institution's research and technology-transfer system. A range of survey and experimental techniques for on-farm research were developed and are now routinely employed in CIP's programs. During the project's implementation, a number of developing-country professionals were trained and since then a rapidly growing number of training activities conducted by CIP, national research organizations, and international agencies have adopted the philosophy and procedures of interdisciplinary, farm-level research that were developed under the project.

The major findings of the project can be grouped under two headings: empirical research results and methodological lessons.

Empirical Research Results

Literature on potato production and use in developing countries is scarce. The Mantaro Valley Project generated a large body of new knowledge on the socioeconomic and technological aspects of Andean potato agriculture. Much of this is embodied in the publications listed in the Appendix. Six major empirical findings are highlighted in this report.

(1) *Ecology and farm type influence the technological requirements of farmers.* The project documented graphically how ecology and farm type influence farming systems and the technological needs of potato farmers. It also illustrated how taking these factors into account can significantly improve the effectiveness of agricultural research and development efforts.

(2) *Small-scale farmers are open to change and new technologies.* Small-scale farmers are often viewed by policymakers and technologists as being isolated from markets and passive or resistant to change. This view was found to have little validity in the area under study. On the contrary, most small-scale farmers were found to be well integrated into input and product markets and eager to adopt new farming practices if they offered clear

advantages over their current practices.

(3) *Farmers rarely adopt complete technological packages.* Most agricultural-development projects are based on the assumption that a large pool of superior technology exists that can be readily transferred to needy farmers in well-designed technological packages. This technological-package approach to agricultural extension was found to be inadequate, however, for two major reasons. First, the packages tested did not perform well, neither agronomically nor economically, because some costly elements of the packages (e.g., improved seed) did not perform as expected. Second, very few farmers "adopted" the technological packages. Instead, most farmers incorporated one or more of the component technologies into their existing cropping system, often "adapting" the components to fit their particular needs.

(4) *Farmers' technologies are, in many cases, equal or superior to recommended practices.* Most production specialists assume that "traditional" production systems are characterized by low yields and economic inefficiencies that can be overcome if farmers adopt recommended practices. In the Mantaro Valley Project, poor-quality seed was considered to be the major yield constraint. It was believed, therefore, that the use of "improved seed" would be highly profitable. Research showed, however, that the seed available from registered seed producers was very costly and yielded little more than that commonly used by the farmers. Hence, use of improved seed reduced the farmers' net return. Two factors accounted for this surprising result. First, farmers successfully use numerous strategies to obtain and maintain good-quality seed. Thus, the seed available through the farmers' informal seed system is better than production specialists previously assumed. Second, the improved seed, produced and distributed through a formal government-regulated system, is not as good as it had been assumed to be.

(5) *Technical knowledge is available to solve many farmers' problems.* Based on the poor performance of the technological packages, it should not be concluded that the technology to solve farmers' problems is not available. On the contrary, one of the most positive results of the project was the finding that seed-potato storage can be improved through the application of the well-known principles of seed-tuber physiology. Careful problem identification and on-farm testing, involving the active participation of farmers, led to practical application of improved, low-cost storage technologies in Mantaro Valley. Further use of the same farmer-oriented approach led to widespread application of the same principles elsewhere in Peru, the Philippines, Sri Lanka, Colombia, and Guatemala. It is felt that the success achieved with seed storage was not a mere stroke of luck but the result of successful interdisciplinary teamwork that would be repeated in many other areas.

(6) *Technology cannot be "transferred," but must be adapted to local conditions.* It was found that little technology could be "transferred" to Mantaro Valley farmers without subjecting it to local refinement through adaptive research. Few farmers "adopted" the technology as presented to them in recommendations or prototypes; instead, they selected and "adapted" technologies to fit their specific needs and resource endowments. Researchers in the project learned much from farmers' creative

adaptations. Hence, it is concluded that agricultural research and development models involving active farmer participation are more likely to be successful than those based on the "top-down" or "technology-transfer" approach.

Methodological Lessons

The methodological lessons learned from the Mantaro Valley Project, which have had a substantial impact on CIP's research program and regional networks, are summarized as follows.

(1) *Interdisciplinary on-farm research requires flexibility and adequate resources.* The on-farm research was more difficult and costly than originally anticipated for two principal reasons: (a) the disciplinary boundaries separating natural and social scientists (as well as scientists within these two groups) and (b) the logistical problems associated with conducting farm surveys and experiments in highland Peru.

Barriers between scientific disciplines, rooted in academic specialization, often make interdisciplinary teamwork more difficult and subject to conflict for professionals than work conducted among professionals within the same discipline. In the Mantaro Valley Project, it was found that the use of specialized professional jargon hampered communication across disciplines and often led to apparent differences of opinion when, in fact, little substantive disagreement existed. The professional incentives of team members also posed obstacles to the establishment of common goals and conceptual frameworks. This was especially the case with young professionals who were conducting thesis research (the final product of which had to meet the approval of a university committee, with its narrow disciplinary criteria of scientific excellence) or who wanted to publish articles in prestigious scientific journals. A third problem involved the degree of mutual respect and joint decision-making within the project teams. Whenever decisions made by members of one discipline were imposed on members of another discipline, resentments built up that threatened morale and productivity. Thus, experience indicates that productive interdisciplinary teamwork required special efforts to (a) communicate clearly and (b) provide team members with enough freedom to pursue their own professional interests and, at the same time, promote joint decision-making and responsibility to achieve the final product of the research effort.

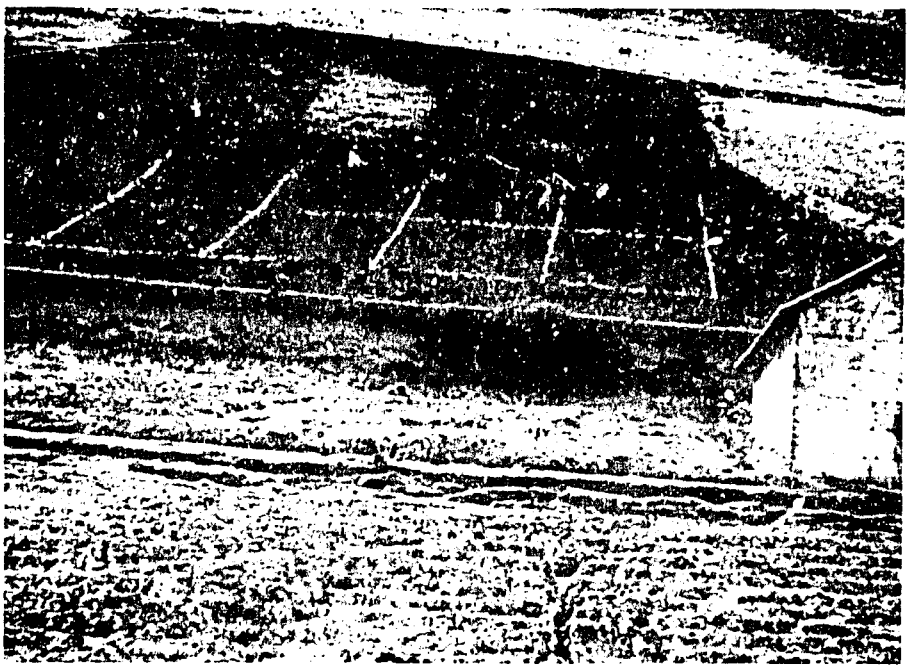
Transportation and logistical requirements make on-farm research costly in terms of operating capital. The mix of resources needed for on-farm research is radically different from that required for conventional laboratory or experimental station based agricultural research. It requires little on-station capital, which most agricultural research institutes have, but requires funds for operating vehicles, per diems, and hiring temporary personnel, which many institutes do not have or have not allocated for this purpose.

(2) *On-farm research has far-reaching benefits.* The long-term institutional benefits of the Mantaro Valley Project far exceeded initial expectations. In the project, on-farm research was used to achieve three distinct goals: (a) the ex post evaluation of technology, (b) to facilitate the transfer of technology, and (c) to develop new technology. Conceptual and pro-

cedural innovations were made in each of these areas. Perhaps the most important achievement of the project, however, was to demonstrate how social scientists can contribute not only to the transfer and ex post evaluation of technology but also to the design of new technology. The successful development and diffusion of low-cost seed-storage technology led to the formulation of the "farmer-back-to-farmer" model for generating and transferring agricultural technology. This model is now being applied in other areas of CIP's research program, such as the development of technology for farmer use of true potato seed.

(3) *Informal surveys and simple on-farm trials have many advantages.* When confronted with a need for information on farming practices, researchers have a strong urge to apply formal questionnaire-type surveys. When technologies are to be tested on farms, researchers generally opt for complex, replicated field trials. Experience, however, has pointed out several advantages of informal surveys and simple, unreplicated trials.

An informal survey or *sondeo* (sounding) carried out by an interdisciplinary team ensures that researchers of different disciplines gain personal familiarity with the area and problem under study. This is generally not the case when formal questionnaire-type surveys are used. Questionnaires are often designed in offices by people who have little knowledge of the area to be surveyed or the problem under study. Responsibility for planning and executing questionnaire-type surveys is often assigned to social scientists. Although biologists may have some limited input into the design of the questionnaire, they seldom participate in the fieldwork. As a result, questionnaires are seldom successful in obtaining relevant or sufficiently precise technical information for pinpointing production problems. Also, results of



Layout of an on-farm trial in the intermediate zone.

questionnaire-type surveys often take many months, or years, to analyze and publish. Applied research programs can seldom afford such delays.

An advantage of an informal survey that is seldom appreciated is that the interaction of those researchers carrying out the survey initiates and helps consolidate a spirit of cooperation among the scientists from different disciplines and with the farmers. This cooperation, in turn, is beneficial in terms of overall research productivity.

The current project also illustrated the value of well-planned but simple on-farm trials. Complex trials are extremely management intensive and are generally beyond the capacity of most small-scale farmers. They may also be beyond the capacity of many research teams, particularly those just entering into on-farm research. Therefore, a research team can handle fewer complex trials than simple ones. In many cases, a larger number of simple trials provides the team with more, and better quality, information on farming problems and the performance of technologies than a small number of complex trials. A second, and very important, reason to opt for simple trials is that it allows researchers to establish a useful dialogue with farmers concerning the pros and cons of the technologies being tested.

(4) *Anthropologists and sociologists can play useful roles in agricultural research.* All agricultural research institutes employ biologists, most now employ economists, but very few employ anthropologists or other sociologists. It is generally assumed that on-farm research requires the participation of biological scientists and economists but that anthropologists and sociologists are needed only under special conditions. In the Mantaro Valley Project, anthropologists and sociologists proved to be extremely effective in delimiting agroecological zones, classifying farm types, appraising the socioeconomic viability of alternative technologies, and conceptualizing new approaches to research and training. It is concluded, therefore, that an individual's success in applied, interdisciplinary agricultural research rests primarily on his or her flexibility and willingness to adapt methods to the technological/on-farm challenge at hand.

(5) *Many results can be extrapolated.* A common argument against farm-level research, especially at the International Agricultural Research Centres (IARCs), is that results are location specific and cannot be extrapolated to other areas. On the basis of this reasoning, on-farm research should be in the domain of national programs and the IARCs should limit their involvement to training and backstopping (preferably through special funding). The experience of the Mantaro Valley Project does not support this view. On the contrary, the principal research results and methodological lessons of the project have proven to be valid over a very wide range of developing-country conditions, e.g., the problems related to "improved seed" encountered in Mantaro Valley are common elsewhere; the solution to these problems — designing new systems based on farmers' existing channels — offers great promise. The low-cost storage technologies developed with Mantaro Valley farmers have proven to be successful in many other areas. The simple farm-survey and experimental procedures used have also been applied successfully by several national programs.

Technologies must ultimately be adapted to specific locations. For this reason, on-farm research is advocated as a diagnostic tool but not one appropriate for designing new cropping systems or determining optimal

input levels. Testing new technological packages and cropping systems can play a useful role in a farming-systems program, but greater attention should be paid to identifying and solving key problems rather than attempting to change the whole system.

I. INTRODUCTION

Street vendors selling potatoes and other Andean tubers in Huancayo.

In the wake of the widely publicized release and spread of high-yielding varieties of wheat and rice in the 1960s, agricultural research and technology transfer moved centre stage in the international community's campaign against hunger and poverty in the Third World. Through the joint sponsorship of the Food and Agriculture Organization of the United Nations (FAO), World Bank, and United Nations Development Programme (UNDP), a network of International Agricultural Research Centres (IARCs) was established to develop and transfer improved technology for food crops and livestock. This network, coordinated by the Consultative Group on International Agricultural Research (CGIAR), now includes ten commodity-oriented centres that conduct multidisciplinary research on crops and livestock, which account for three-quarters of the total food supply of the developing countries. Three other CGIAR institutes are responsible for aspects of plant genetic resources, food policy, and assistance to national agricultural research programs (Table 1). Following the example of the IARCs, several national programs now organize their research programs along commodity, rather than disciplinary, lines (CGIAR 1980; IADS 1982).

Table 1. International Agricultural Research Centres (IARCs).

Institute within CGIAR[a]	Year of establishment	Location of headquarters	Principal commodities or programs
IRRI	1960	Philippines	Rice
CIMMYT	1966	Mexico	Wheat, maize
IITA	1966	Nigeria	Grains, legumes, roots and tubers, systems
CIAT	1968	Colombia	Cassava, beans, beef cattle and pastures
WARDA	1971	Liberia	Rice
CIP	1971	Peru	Potatoes
ICRISAT	1972	India	Sorghum, millet, dry-land systems
IBPGR	1974	Italy	Genetic materials
ILRAD	1974	Kenya	Selected animal diseases
ILCA	1974	Ethiopia	Livestock production systems
IFPRI	1975	United States	Food policy
ICARDA	1976	Syria	Mixed animal-crop production systems
ISNAR	1980	Netherlands	Strengthening national agricultural research systems

[a]IRRI: International Rice Research Institute. CIMMYT: International Centre for the Improvement of Maize and Wheat. IITA: International Institute of Tropical Agriculture. CIAT: International Centre for Tropical Agriculture. WARDA: West Africa Rice Development Association. CIP: International Potato Center. ICRISAT: International Crops Research Institute for the Semi-Arid Tropics. IBPGR: International Board for Plant Genetic Resources. ILRAD: International Laboratory for Research on Animal Diseases. ILCA: International Livestock Centre for Africa. IFPRI: International Food Policy Research Institute. ICARDA: International Centre for Agricultural Research. ISNAR: International Service for National Agricultural Research.

Social scientists are latecomers to agricultural research programs and in most institutes their work is considered to be of secondary importance relative to that of biological scientists. When Vernon Ruttan joined the staff of the International Rice Research Institute (IRRI) in 1963, he was the first economist in what has become the CGIAR-sponsored complex of IARCs (Ruttan 1982). Over the years, Ruttan and his successors developed an Agricultural Economics Department that has carried out a substantial amount of high-quality research and has served as a model for other agricultural research institutes (World Bank 1973). In other CGIAR-sponsored centres and most national research institutes, however, agricultural economics came later and, with some important exceptions (e.g., Internatioal Centre for the Improvement of Maize and Wheat (CIMMYT), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and Instituto de Ciencia y Technología Agrícolas (ICTA)), has been less successfully integrated into the overall research program.

All but one of the IARCs (i.e., International Laboratory for Research on Animal Diseases (ILRAD)) and most national research institutes now employ economists, but few have anthropologists or rural sociologists on their staff. Van Dusseldorp (1977) has estimated that for every thousand scientists in agricultural research centres only one is a permanently assigned sociologist or cultural anthropologist.

Economists and other social scientists have played a number of roles in the IARCs. The available literature indicates that most have chosen or been assigned to (1) conduct ex post studies on farmer adoption and the impact of new technologies (e.g., Colmenares 1975; Demir 1976; Gafsi 1976; Gerhart 1975; Vyas 1975; Winkelmann 1976a; IRRI 1978), (2) investigate the factors responsible for continuing low farm yields (e.g., IRRI 1978), or (3) work at the national level in projects designed to facilitate the transfer of technology or intensify local farming systems (e.g., Perrin et al. 1976; Byerlee et al. 1980, 1982).

In agricultural research institutes, few social scientists work directly with biological scientists in the development of new technologies (IRRI 1982). CIP represents an exception to this general rule by actively involving anthropologists, economists, and sociologists in technology development. The integration of CIP's biological and social scientists in problem-solving teams received its major impetus from experiences gained in the Mantaro Valley Project.

When the project began in 1977, little had been published on the role of social scientists in agricultural research programs or in agroeconomic, on-farm, or farming-systems research. The Puebla and Caqueza projects had been conducted (Winkelmann 1976a; Zandstra et al. 1979) and multidisciplinary, farm-level research was under way at IRRI, CIMMYT, the International Centre for Tropical Agriculture (CIAT), and a few other IARCs and in national research programs (e.g., those of Bangladesh, Colombia, Guatemala, and Mexico). Relatively few publications appeared, however, on the concepts, methods, or results of this work.[1] CIP had only recently been established and at the time had generated little technology that was

[1]Rather than present a literature review of farming-systems research and the experiences gained in the Puebla and Caqueza projects, the interested reader is referred to Casement et al. (1982), Gilbert et al. (1980), Norman et al. (1981), Shaner et al. (1982), and Whyte (1981) for additional information.

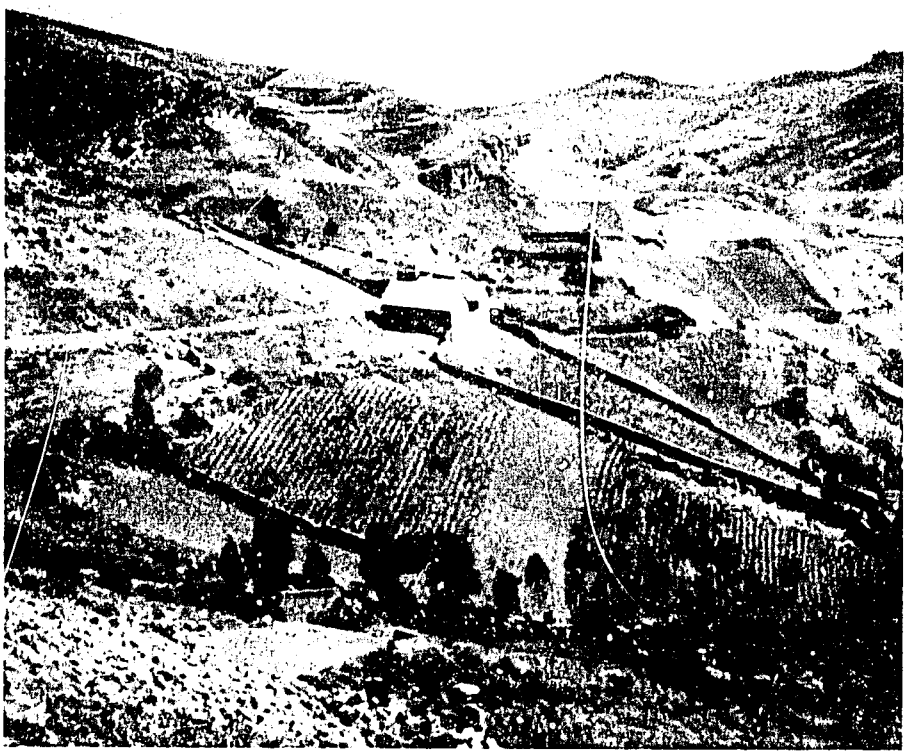
ready for farm-level testing; hence, the ex post "constraints" model developed by IRRI for measuring the gap between potential and actual farm yields was not applicable. In addition, in sharp contrast to the situation for cereal grains, there was very little socioeconomic literature on potato production and use in developing countries.

The Mantaro Valley Project, however, generated a substantial body of information on potato production and utilization in the Central Andes. Research results cast new light on four concepts that were basic to CIP's program and many other agricultural research and development programs: the concept of the small-scale farmer; the technological-package approach; the concept of improved seed; and the concept of technology transfer. Successful development and farmer adoption of low-cost storage technology also demonstrated how early and continuous social science input can improve the effectiveness of research and technology-transfer programs.

Until recently, few people outside CIP knew of the Mantaro Valley Project. This was illustrated by the fact that an authoritative review of farming-systems research at the IARCs stated that CIP was the only crop-improvement centre in the network that was not conducting any farming-systems research (CGIAR 1978).

This monograph presents a synthesis of the goals, implementation, and major results of the Mantaro Valley Project. Chapter II sketches the institutional setting and conditions that gave rise to the project; chapter III outlines the project's objectives and some aspects of its implementation; and chapter IV presents a brief overview of its accomplishments. Chapters IV and V present empirical research findings and methodological lessons that are of relevance to social science involvement in agricultural research and development programs. A list of publications, research reports, and training documents emanating from the project is presented in an Appendix.

II. SETTING



Typical farm on the steep slopes of the intermediate zone.

International Potato Center

The International Potato Center (Centro Internacional de la Papa (CIP)) is one of the 13 centres sponsored by the Consultative Group on International Agricultural Research (CGIAR). The goal of the centres is to develop improved agricultural technology that will increase food production and improve the welfare of poor people in developing countries.

CIP is a single-crop institute, with all activities focused on expanding the use of the tuber-bearing species of *Solanum* in developing countries. The centre was established in 1971 through an agreement with the government of Peru. The first funding, through CGIAR, was received in 1972.

CIP's two basic objectives are to increase the potato's yielding ability, stability, and efficiency of production in areas where it is now being grown and increase the potato's adaptability, enabling it to be grown more extensively in the cold high regions and hot, humid low regions of the tropics (Sawyer 1982). Research aims to develop potential new varieties, seed production and distribution systems, agronomic and pest-control measures, and postharvest technology that are appropriate for developing-country conditions.

The centre's two principal organizational components are the Source Research and Regional Research and Training programs (Fig. 1). Personnel and other resources of the Source Research Program are budgeted for and managed within the framework of five departments: breeding and genetics, nematology and entomology, pathology, physiology, and taxonomy. The basic units of source research are 67 research projects, which are grouped within 10 problem-oriented thrusts:[2] (1) maintenance and utilization of unexploited genetic resources; (2) production and distribution of advanced breeding material; (3) research on bacterial and fungal diseases; (4) potato virus research; (5) integrated pest management; (6) hot climate potato production; (7) cool climate potato production; (8) postharvest technology; (9) seed technology; and (10) potatoes in developing-country food systems.

CIP has four principal research sites in Peru (Fig. 2). These locations have growing conditions that are similar to those found in actual and potential potato-producing zones in many other developing areas (Rhoades 1982).

From its inception, CIP developed a regional network for adaptive research, distribution of technology to surrounding countries, and training. During its formative years, the Regional Research and Training Program concentrated primarily on development of regional bases and accumulation of knowledge about country interests, needs, and opportunities for potato improvement. Emphasis was placed on helping national programs

[2]Thrusts 1–9 were established in 1973. In 1983, in response to CIP's second quinquennial review, the problem areas covered by these thrusts were modified somewhat and thrust 10 was created.

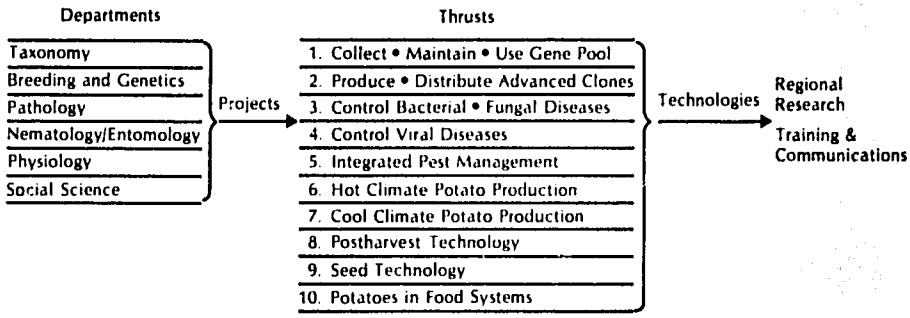


Fig. 1. CIP's organizational components.

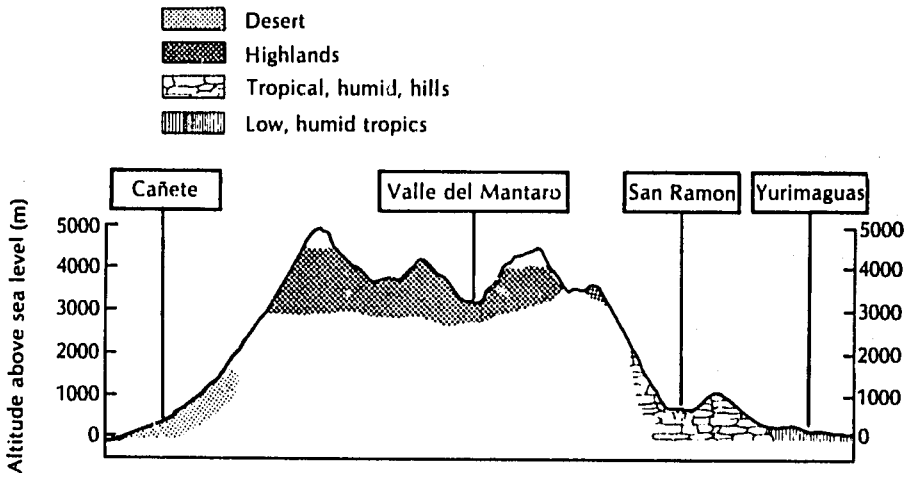
identify key research priorities and conduct production training using known technology. Gradually, the emphasis has shifted toward conducting more research at regional sites, in collaboration with national programs. In 1980, a position was created to coordinate research in the regions with that at headquarters and contract research sites. Thus, each regional team now submits a yearly work plan that is discussed with the source research scientists in Lima during the annual program review. Presently, 77 regional research projects are being implemented.

At present, seven regional offices (Fig. 3) are responsible for multiplication and distribution of genetic material, testing and adaptive research, and training. Regional activities aim to strengthen potato research and extension capacities in developing countries. Regional teams typically consist of one or two international scientific staff members supplemented with locally hired scientific and support personnel. One international scientist in each region is permanently funded; the others are supported by postdoctoral fellowships or special project funds. As more appropriate technologies become available and country-program demands on CIP services increase, regional staffing might also increase slightly. The scientists based at headquarters travel extensively in the regions and those scientists working on priority technologies are occasionally deployed to regional locations for extended periods of time to work closely with national programs in local testing and dissemination of results.

Social Sciences at CIP

CIP's social science program dates from late 1973, when economist Michael Twomey was assigned to the Outreach Program.[3] Over time, priorities for the social sciences have gradually shifted from support activities to research. In addition, the program has broadened its disciplinary base from agricultural economics to include anthropology, rural sociology, nutrition, and agronomy. These shifts in priorities and disciplinary mix, which were endorsed by Planning Conferences in 1977, 1978, and 1981 (CIP 1977, 1980,

[3]In line with a Planning Conference recommendation (CIP 1976), what was originally conceived of as an Outreach Program evolved into the present Regional Research and Training Program.



Characteristics	Cañete	Mantaro	San Ramon	Yurimaguas
Ecological zone	Arid coast	Tropical highland	Mid-elevation, humid tropics	Lowland, humid tropics
Farming system type	Irrigated commercial	Small-scale subsistence	Mixed-shifting cultivation and tropical estate agriculture	Shifting cultivation
Principal crops or crop types	Cotton, potatoes, maize	Andean tubers, grains, vegetables	Coffee, tropical fruit, cassava, maize	Rice, cassava, plantains
Method of land preparation	Plow cultivation	Plow cultivation	Clearing by fire, no tillage, plow cultivation on estates	Clearing by fire, no tillage, digging stick
Manuring or use of chemicals	Intensive	Intensive	Limited on small farms, widely used on estates	Extremely rare
Cropping pattern	Monocrop	Monocrop	Intercropping, relay planting	Intercropping, relay planting
Backyard garden	Well-defined, frequently fenced	Well defined	Dispersed tropical trees and yard plants, no fencing	Dispersed tropical fruit trees and yard plants, no fencing
Agricultural calendar sociocultural factors	Fixed dates, government regulated	Fixed dates, community and individual decision	Dates highly variable, individual decision	Dates highly variable, individual decision
Social unit of production	Cooperatives, individual households	Individual households	Cooperatives, individual households	Individual households
Present status of potato production on farms	Modernized, geared for export to urban areas	Traditional technology Advanced seed production	Experiments by farmers at elevations above 1000 m Geared for home consumption as supplemental vegetable	Nonexistent

Fig. 2. Cross section of Central Andes and characteristics of agricultural systems in four Peruvian regions (adapted from Rhoades 1982).

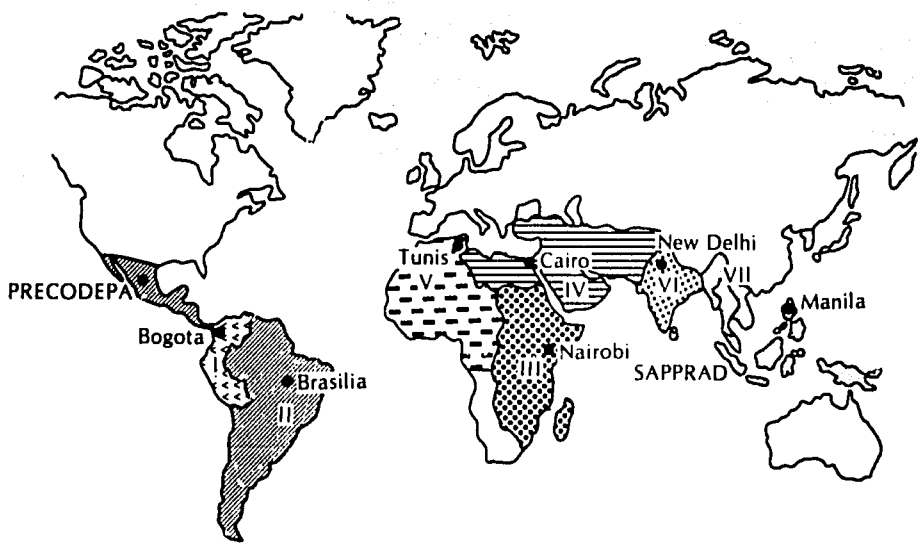


Fig. 3. Location of CIP regional offices and study areas. PRECODEPA (Regional Cooperative Project for Potato Development in Central America) and SAPPRAD (South Asian Program for Potato Research and Development) are acronyms for country research networks that CIP helped establish and works with.

1982a), were consolidated through implementation of the Mantaro Valley Project.

From 1973–1975, Twomey was the only social scientist at CIP. Having no research budget, he provided support to the Outreach Program through assistance in project development and training. In 1975, Twomey resigned and two new social scientists joined CIP: economist Douglas Horton and anthropologist Robert Werge. In mid-1976, a second economist, Anibal Monares, joined the staff. Initially, CIP's budget provided for only one position in economics. The second economics position, therefore, was funded by a 3-year special project grant from the Inter-American Development Bank (IADB) and the anthropology position was funded by a 2-year Rockefeller Foundation postdoctoral fellowship. In 1978, CIP's budget was expanded to provide long-term funding for all three positions.

In 1975, the Socioeconomic Unit began four activities: (1) bibliographic research on the socioeconomic aspects of potato production and use, (2) compilation and analysis of published national-level statistics, (3) a series of national-level studies on potatoes in developing countries, and (4) visits to potato-growing areas in Peru.

These activities led to the publication of bibliographies (Werge 1977; Mante and Blodig 1979); statistical compilations (Horton 1978; CIP 1978, 1982b); and country studies on Chile (Fu 1979), Ecuador (Valderrama and Luzuriaga 1980), and Kenya (Durr and Lorenzl 1980). In addition, these studies provided the empirical basis for the unit to identify three key technological areas for more intensive, future farm-level research: (1) agronomic constraints to potato production, (2) seed-potato systems, and (3) postharvest technology.

These were the three technological areas that appeared most consistently in the priority listing of production problems as perceived by CIP scientists

and national-program researchers and extensionists. Moreover, biological scientists felt confident that the technology existed to solve these problems. In their view, the main obstacles to expansion of potato production and use were problems of technology transfer and its use by farmers.

Given this definition of the problems and potential solutions, members of the Social Science Unit perceived an opportunity to learn a great deal about the potentials and processes of technological change by studying farmers' perceptions of problems, their actual production strategies, and the performance of recommended technologies under existing farming conditions.

It was not possible, at the time, to justify substantial use of staff time, vehicles, and financial resources for what was envisaged as needed farm-level research in Peru because few CIP scientists or administrators believed that farm-level studies would contribute significantly to achieving the centre's international mandate. Two reasons for this skepticism become apparent. First, most biological scientists believed that information generated from farm-level studies was valid only for the specific locale from which it was obtained. Second, most scientists were so confident of the superiority of the recommended technology over farmers' practices that they saw little reason for farm-level testing.

Members of the Social Science Unit believed that a program of farm-level research was essential if a better understanding of farmers' problems, with respect to potato production, was to be obtained and the most promising avenues for technological change were to be identified. For this reason, the unit began searching for external special-project funding for on-farm research.

III. PROJECT PROPOSAL, IMPLEMENTATION, AND OVERVIEW OF ACCOMPLISHMENTS

Farmer demonstrating the use of the Andean foot plow (chaquitaclla) *to trainees.*

Project Proposal

In May 1977, CIP's Socioeconomic Unit submitted a draft project proposal entitled "Agro-Economic[4] Research on Potato Production Constraints and Post-Harvest Technology" to IDRC's Social Sciences and Human Resources Division. In September 1977, IDRC approved a grant of up to $268 450 (Canadian) to enable CIP to conduct the proposed research and training activities. The proposal outlined a series of farm-level research and training activities with broad institutional goals, rather than a sharply defined research project to test specific hypotheses. As stated in the proposal, the central objective was:

> to enable CIP to conduct agro-economic research on potato production constraints and post-harvest technology, and specifically:
> (1) to sensitize CIP and national program scientists to the value of agro-economic research in the design and evaluation of potato technology;
> (2) to refine, adapt and test appropriate agro-economic procedures, including low-cost farm surveys and experimental techniques; and
> (3) through CIP's Training Program, to develop training materials and contribute to the training of national researchers and production specialists in the use of agro-economic techniques.

The underlying theme of the proposal was to develop a set of procedures for identifying major constraints to potato production and to field test these procedures in a representative area of the Andean highlands. The proposal outlined a sequence of farm-level surveys and experiments to be conducted in Peru's highland Mantaro Valley. Work elsewhere in Peru (Cuzco, Huaraz, Cañete) and in other countries was contemplated in the proposal but was assigned lower priority than activities focused on the Mantaro Valley. For this reason, the project became known as the Mantaro Valley Project.

Fieldwork in the Mantaro Valley was intended to generate information on Andean potato farming systems and field test procedures for farm-level research with potatoes. Training of agronomists was to be accomplished by linking the Mantaro Valley research with CIP's annual production course. Social scientists were to be trained through thesis research in the valley. Research results were to be presented at conferences and seminars and published in research reports. In addition, training documents were to be issued for use in CIP courses, both at headquarters and in the regions.

CIP's major contributions were to be the time and travel expenses of the three social scientists involved in the program. In addition, CIP was to provide a full-time secretary and all materials necessary for the implementation of the proposed research and training activities. IDRC provided funds

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[4]The term "agroeconomic," used in the proposal, gradually disappeared from common usage at CIP as the importance of nonagronomic and noneconomic aspects of farm-level research became appreciated.

for contracting an agricultural economist, an agronomist, and an anthropologist for the duration of the project. IDRC also provided travel funds for project staff and financed seminars and workshops, postgraduate training, the purchase of vehicles and equipment for fieldwork, and the reproduction and distribution of research reports.

Implementation

The Mantaro Valley Project was integrated into the programs of the Social Science Department, thrusts 7–9, and CIP's Regional Research and Training Program. Hence, it is impossible to draw a sharp boundary around the project's activities. Most IDRC funds were used for research and training in the Mantaro Valley, but even here major financial contributions were made by the Rockefeller Foundation (postdoctoral fellowships), IADB (postdoctoral fellowship), and CIP's budget. Several CIP staff members (primarily in the Physiology and Social Science departments) allocated a substantial portion of their time to the project. CIP's funds were also added to cover many of the costs of transport, training, seminars, and publications.

The survey phase of the Mantaro Valley Project was conducted jointly by CIP, CIMMYT, and Peru's National Maize and Potato programs. In 1977 and 1978, surveys of maize and potato growers were conducted in Callejón de Huaylas, Mantaro Valley, and Cuzco. The results, with respect to maize growers and their production problems, have been reported elsewhere (Byerlee et al. 1980; UNA 1979).

The Mantaro Valley Project was implemented within the existing organizational framework of CIP's research programs, departments, and thrusts. As noted earlier, the Socioeconomic Unit had, through its country studies and interactions with CIP scientists, identified three key technological areas for farm-level research: production constraints, postharvest technology, and seed systems.

In 1977, when the proposal was submitted to IDRC, social scientists were in the process of establishing working relationships with biological scientists in these areas of study. Following a recommendation of the August 1977 Social Science Planning Conference (CIP 1977), three interdisciplinary research projects were established. Each of these projects had as co-leaders a social scientist and one or more biological scientists.

It is important to note that these research projects were established within three separate research areas. The priorities and philosophies of the project leaders and the stage of technical research in each area influenced the development of the projects. Each team established its own specific objectives and work plan. The "production constraints team," operating on the assumption that potato farmers' yields and incomes could be significantly increased through better application of existing technology, aimed to develop and test procedures for identifying potato-production constraints and evaluating alternative technologies on farms (Accatino and Horton 1978, 1980). In contrast, the "postharvest team" had as its main objective the development of simple storage and processing technologies appropriate for small-scale farming conditions (Rhoades et al. 1982). The "seed systems team" had yet another objective. It attempted to find answers to the questions of why seed-potato certification programs have not been more suc-

cessful in developing countries and how the use of certified seed could be expanded (Monares 1981).

In the original project proposal, it was envisaged that a single field team would conduct all farmer surveys and on-farm experiments. The establishment of three independent teams, however, made this impossible. Some survey activities were carried out jointly, but all experimental work was conducted independently by the three different teams.

During implementation of the Mantaro Valley Project, conflicts between research teams and between disciplines occurred. At the time, these conflicts were seen as negative aspects of the project. In retrospect, however, one of the most positive aspects of the project was its plurality: the experimentation of the three independent research teams and their "constructive conflict" (Rhoades et al. 1982) generated more useful results than could have been produced by a single team with a common conceptual/methodological framework.

Interdisciplinary teamwork involving social and biological scientists and farm-level research has played a vital role in some of CIP's most successful regional programs. The Programme National de l'Amelioration de la Pomme de Terre (PNAP), Rwanda's National Potato Program, for example, was established in 1979 with the financial support of the Belgian government and technical/organizational backstopping of CIP and is generally considered to be the country's most successful commodity program and a model for development projects in Rwanda and abroad. PNAP is a small program, in comparison with most commodity programs, but it has been exceptionally successful in achieving a significant production impact at the farmer and consumer levels.

Several factors account for the success of the program, including the commitment of national policymakers to potato improvement, generous external funding, and the high calibre and motivation of the program's staff — both Rwandan and expatriate. The key to PNAP's success, however, is the program's "client-oriented research phi'osophy." PNAP based its initial research priorities on observations and conversations with farmers in major production zones — an "informal survey" conducted by the newly formed team of production specialists. Information generated in this baseline survey was supplemented by a general study of potato production and use, conducted by an agricultural economist in 1979 (Durr 1983), and consumption surveys conducted by an anthropologist in 1980 (Poats 1981).

Since that time, PNAP's staff has maintained close ties with farmers and consumers. It is the concerns of these groups that have guided PNAP's research program. In this context, it is important to note that CIP does not consider Rwanda as a test site for its technology. Instead, PNAP looks to CIP, as well as other sources of technical support, for potential solutions to the country's production problems.

Overview of Accomplishments

Laying the Groundwork for Interdisciplinary Teamwork

A stated objective of the project was to sensitize biological scientists to

the value of on-farm research. In actual fact, the project succeeded in sensitizing both biological and social scientists to the value of interdisciplinary teamwork, not only at the farm level but also throughout the research/transfer process. After an initial period of skepticism, and at times rejection of early research findings, most scientists close to the work — both at CIP and in collaborating national programs — have become strong advocates of interdisciplinary farm-level research. This is, indeed, one of the most striking results of the project. Thus, CIP has adopted on-farm research as a major component of its regional testing strategy and involves social scientists in several of the centre's research thrusts.

Source Research

In thrust 8, interdisciplinary research and training is conducted on both seed- and consumer-potato storage, as well as on potato processing. In thrusts 7 and 9, interdisciplinary research on potato seed systems has been conducted in three areas: (1) In response to national program requests, seed-certification systems have been evaluated, farmer demand for certified seed has been estimated, and networks of on-farm trials have been established to monitor seed quality. (2) Studies of two particularly successful seed production and distribution systems (those of Tunisia and Rwanda) have been conducted. (3) Socioeconomic research on an entirely new technology, true potato seed (TPS), has begun. In this third area, social and biological scientists interact in establishing priorities for research both on and off the experimental station, conducting farm-level surveys and experiments, and planning and executing training courses.

This case of interdisciplinary research on seed illustrates how ex post evaluations of a recommended technology — improved seed — led to an awareness of the limitations not only of the technology itself but also of the developed-country institutional model being used to generate the technology — the seed-certification program. This awareness led to three new areas of research: (1) ex ante evaluations of the potential demand for and social benefits of seed-tuber multiplication systems; (2) designing innovative seed-tuber multiplication schemes based on the existing farmers' informal seed systems; and (3) research aimed at developing TPS technology components and systems that are viable under developing-country conditions. Early farm-level research in the design of this new technology helped guide on-station work. It was quickly learned, for example, that farmers were more concerned with seedling vigour and less concerned with the uniformity (colour, shape, and size) of the potatoes produced than had been assumed previously. Biologists have used information provided by farmers, therefore, to reorient their research priorities.

Recently, scientists working on thrust 6 (nematology and entomology) have requested the involvement of social scientists in their research projects to help determine the relative importance of different pest problems and to test and monitor the effectiveness of new pest-control measures. An agricultural economist has been contracted to work full time in this important area.

Regional Research and Training

Over time, demands for greater social science involvement in farm-level research have increased in regional and national programs. An agronomist

was assigned for a 3-year period to CIP's region VII team in the Philippines (Fig. 3). The region VII office has prepared a proposal for special-project funding of a social science position in the region. The Swiss and Nepalese governments are exploring avenues for increasing the social science input in the Nepalese potato program. In a recently activated Swiss-funded potato-improvement program in Pakistan, two of the three staff positions are for economists: one for marketing and one for farm-level research. In a major proposal from Peru's National Agricultural Research and Promotion Institute (INIPA) to the World Bank, funding was requested for a farming-systems research program to capitalize on the work begun by CIP in Mantaro Valley. In 1982, INIPA requested that CIP organize a 6-week course on farming-systems methods. This course was organized by an economist and an anthropologist, both ex-CIP staff members with extensive experience in farming-systems analysis in Mantaro Valley. In a major Peruvian seed-production project activated in 1983, an anthropologist was contracted to conduct an 8-month study of existing seed systems. This diagnostic study, the first of its kind, provided baseline information for planning and implementing the seed project. Two economists are employed full time to work with biologists in institutional design, monitoring, and evaluation.

A number of other examples could be cited, but suffice it to say that once the value of social science input in interdisciplinary research was demonstrated a strong demand was created for such expertise.

Developing Procedures for On-Farm Research

Considerable time and effort was invested in the Mantaro Valley Project in developing and testing procedures for use by national potato programs with limited personnel and financial resources. Several of these procedures have been documented in working papers, special publications, and training documents issued by the Social Science Department.

In evaluating procedures for farm-level research, high priority has been placed on: (1) clear problem identification through the use of well-planned, informal surveys conducted by interdisciplinary teams and (2) simple experimental designs that incorporate the farmer's technology as the control treatment, evaluate well-defined changes in the cropping system, and involve the farmer in both the management and evaluation of the trials. This approach has produced very high returns in both the design and transfer of technology.

As the Mantaro Valley Project evolved, it became increasingly clear that there was considerable scope for social science involvement not only in regional and national programs but also within CIP's research thrusts. Increasing involvement of social scientists in CIP's research has led to the application of a wide range of micro- and macrolevel analytical procedures. Beginning with farm-level evaluations of seed and postharvest technology, studies have evolved in the directions of broader farming-systems analysis, marketing, and nutrition. Procedures for conducting these studies have been documented by Rhoades (1982), Poats (1982), and Scott (1984). Beyond the procedures themselves, the farmer-back-to-farmer model provides a framework for guiding interdisciplinary teamwork through the entire research/transfer process.

Trainees in a farming-systems course.

Training

Of the three original objectives of the Mantaro Valley Project, the training objective was the most difficult to achieve. There were four main reasons for this: First, plans to introduce farm-level research methods into CIP's annual production course, held in Peru, failed to materialize when the course was terminated in 1978.[5] Second, during the early years of the project's implementation, training materials for course work on farm-level research were inadequate. Third, CIP's scholarship policy, geared to the needs of agronomy students conducting thesis research at CIP headquarters, was found to be inadequate for social science thesis fieldwork in the provinces. CIP's scholarships made no allowance for travel and the additional living expenses associated with fieldwork. In addition, the level of scholarship payments was inadequate to attract top students in the social sciences. Finally, given the interdisciplinary nature of the Mantaro Valley research, it was difficult to provide students with thesis topics and methodologies that were acceptable to their thesis committees, which were oriented toward specific scientific disciplines.

In spite of these difficulties, a considerable amount of training was conducted. This proved to be useful not only for the trainees but also for the project staff. Involvement in training made the staff aware of the ambiguous or impractical aspects of the procedures being proposed for use in national programs. Thus, a number of specialized training courses on farm-level research have been held since 1978 that have drawn heavily upon the data

[5]Since that time, all general production training has been conducted by CIP's regional staff in association with national programs. Increasingly, national programs are conducting this type of training with little dependence upon CIP.

and experiences gained in the Mantaro Valley Project. The courses held in Peru have all involved fieldwork in the Mantaro Valley. In most cases, this has been complemented with fieldwork in other ecological zones of the country. In courses conducted outside of Peru, training materials based on the Mantaro Valley research have been used extensively. As more experience was gained in other areas, such as in the Philippines and Rwanda, training materials began drawing upon these experiences.

Six thesis research projects were conducted by students in conjunction with the Mantaro Valley Project. To compensate for the inadequacies of CIP's scholarship policy, several students were hired on fixed-term contracts to conduct their thesis research. For this reason, the number of theses completed under the Mantaro Valley Project exceeds the number of scholarships granted.

In addition to the thesis research projects conducted by students during the project's implementation, students and staff of Peru's National Agrarian University, Catholic University, and Pacific University have frequently drawn on data compiled in the Mantaro Valley surveys and experiments for their own independent research projects. Over time, interest in this information has increased. Hence, the data bank established is a valuable resource that is likely to be exploited by researchers for years to come.

Two recent developments facilitate institutionalization of training in farm-level research at CIP. First, the postharvest thrust uses the farmer-back-to-farmer model as the overall framework for its numerous, and highly successful, training activities. Second, the Training and Communications Department has recently embraced on-farm research as a central component of its production training and a manual is being prepared for regional production courses that reflects this new orientation.

In conclusion, it can be said that, even though the project's training objective was more difficult to achieve than the other two objectives, considerable progress has been made in training both agronomists and social scientists. The importance of interdisciplinary teamwork is now formally recognized by CIP's Training and Communications Department and approaches and procedures for farm-level research are now being included in the centre's major training activities.

Project-Related Activities not Contemplated in the Proposal

The Mantaro Valley Project stimulated a great deal of farm-level research and training outside of the valley. Most of this work was funded through CIP's budget, but it was also supported by grants from the Ford and Rockefeller Foundations, IADB, the governments of Switzerland and Belgium, and other donor institutions. Highlights of these activities follow.

1978

A survey of maize and potato farmers was conducted in Cuzco in conjunction with CIMMYT. Training courses in postharvest technology were carried out. Farm-level research on seed systems was initiated in the Cañete Valley of Peru's Central Coast and in highland Ecuador and Colombia.[6]

[6]This research was partially funded by the Ford Foundation.

The production constraints team developed a farm-level research approach — first termed "maximizing potato productivity in developing countries" and later "optimizing potato productivity (OPP)" — for use by CIP's regional scientists and national-program workers in identifying potato-production constraints and evaluating potential technological solutions under farmers' conditions (Accatino and Horton 1978, 1980). Beginning in 1978, a number of training courses, workshops, and seminars were organized to familiarize regional and national scientists with the OPP approach and procedures for conducting farm-level surveys and experiments.

The postharvest team began a series of training courses designed to motivate national programs to focus their storage and processing programs on farmers' problems. Over time, the postharvest team developed an interdisciplinary model for generating and transferring technology, termed the "farmer-back-to-farmer" model (Rhoades et al. 1982). Although the OPP approach provided an effective means of bridging the traditional gap between research and extension, the farmer-back-to-farmer model encompassed the entire research-transfer process. These two complementary approaches are now being applied by CIP in both its headquarter's research and in a number of regional and national programs.

1979

The Social Science Department established a "Working Paper Series" to encourage debate, the exchange of ideas, and the advancement of social science knowledge about potato production and use. R. Rhoades, who joined CIP on a postdoctoral fellowship from the Rockefeller Foundation, began a comparative study of potato farming systems in four Peruvian ecological zones: highlands, coast, and high and low jungle. The Social Science Department assisted with farm-level testing of "Molinera," a new Peruvian potato variety resistant to late blight and bacterial wilt. In response to a request from Ecuador's National Agricultural Research Institute (INIAP), CIP assisted in planning and carrying out a farmer survey and planning a series of on-farm trials in northern Ecuador.

Two short courses were held on farm-level research in Peru, with trainees from Bolivia, Chiie, Colombia, Ecuador, Mexico, and Peru. Two workshops were also held on farm-level research: one in Peru and the other in Costa Rica.

In 1979, two agronomists joined the Social Sciences Department: one had responsibility for coordinating CIP's farm-level research and training activities for a 2-year period; the other was posted in the Philippines for a 3-year period to conduct farm-level research with the National Potato Program (Potts 1983). The postharvest team initiated a study of farmer adoption of simple seed-storage technology in the Philippines and intensified its training and technology-transfer activities in several countries.

1980

The Social Science Department initiated its "Training Document Series" and a number of courses and workshops were organized. Several national programs initiated farm-level research on potatoes. The major programs were in the Philippines, Rwanda, and Tunisia. Farm-level research on potatoes was also conducted in Algeria, Colombia, Ecuador, Guatemala, Nepal,

Pakistan, Peru, and Turkey. Throughout the year, intensive research continued to be conducted in the Mantaro Valley.

Post-1980

The scale of activities in the Mantaro Valley was reduced after 1980 and the emphasis shifted to institutionalizing farm-level research in CIP thrusts and regional and national programs. A number of training documents and publications have been issued that reflect experience gained not only in the Mantaro Valley but also in CIP's collaborative work outside of Peru.

IV. EMPIRICAL RESEARCH RESULTS

Applying pesticides in an on-farm trial in the intermediate zone.

Research Phases

It is not possible to do justice in a single report to all of the research connected with the Mantaro Valley Project. Therefore, this report concentrates on the major results of the four research activities listed in the original proposal: literature review; baseline survey of ecology and agriculture; single and multiple-visit producer surveys; and on-farm potato experiments.

Although an attempt has been made to provide a balanced report on the three interdisciplinary projects conducted under the umbrella of the Mantaro Valley Project, the agronomic constraints project, of which the author was co-leader, is treated more extensively than the other two. Research on postharvest technology and seed is more adequately covered in Rhoades et al. (1982), Rhoades and Booth (1982a,b), and Monares (1981, 1982). Additional research on folk taxonomies and potato marketing, carried out in the Mantaro Valley, are reported on by Brush et al. (1981) and Scott (1981). A study comparing farming systems in Mantaro Valley with those in three other Peruvian locations is being prepared (Rhoades, in preparation).

Selection of the Research Site

The Mantaro Valley was chosen as the principal research site for three reasons: First, CIP's highland experimental station and the headquarters of Peru's National Potato Program are located in the valley. Hence, the site offered valuable opportunities for interaction between project personnel and potato specialists. In addition, the infrastructure for research and training was far superior to that available in other highland locations. These factors were considered to be crucial for achieving two of the project's goals: sensitizing biologists to the value of on-farm research, and training. The second reason for choosing the Mantaro Valley is that it is the most important potato-producing region in Peru's Central Highlands. The final reason for the selection of this site is that ecological conditions in the valley are representative of conditions in many other highland potato-producing regions in the Andes and elsewhere in the developing world, thus allowing extrapolation of results (Posner and McPherson 1982; CIP 1980). For these reasons, it was felt that this site offered better conditions for achieving the goals of the project than any other.

Literature Review

The Mantaro Valley is one of the most intensively studied regions in the highlands of Peru and potatoes are its major crop. A great deal of biological research has been conducted on potatoes in the valley over the years and several classics of Peruvian social science literature are based on fieldwork in the valley. Available studies provide surprisingly little empirical data on

farmers' production and postharvest technology (as opposed to recommended technology), however, or on the performance of new technologies under representative farming conditions (Werge 1977; Mayer 1979). Hence, available literature was found to be of little direct use for identifying farmers' production problems and selecting technologies for on-farm testing. Nevertheless, maps, published statistics, and studies of the region's geography and agriculture were quite useful for planning surveys.

Baseline Survey

Based on 2 months of fieldwork in the valley and a review of topographical maps, aerial photographs, census figures, and published reports, Mayer (1979) applied a natural-ecological scheme to produce land-use maps and a descriptive analysis of the valley's agriculture. Major agroecological zones, subzones, and types of producers were defined. The results of this "informal" survey were later used for planning and executing "formal" surveys and on-farm experiments.

Single- and Multiple-Visit Surveys

Based on Mayer's (1979) findings, two formal questionnaire-type surveys were used to generate detailed information on potato production and use. In September 1977, 260 farmers were interviewed at points randomly selected throughout the valley (Franco et al. 1979). From October of the same year until June 1978, a series of weekly visits were made to a subset of 53 producers (Horton et al. 1980). Information generated from the single-visit survey was used to refine the agroecological zonation and quantify important aspects of potato production and use (e.g., average farm size, crop mix, market orientation, and use of traditional and modern inputs). The multiple-visit survey, observations, and direct field measurements provided a check for estimates obtained from the single-visit survey and generated information on production costs, returns, and technical aspects of crop production and postharvest practices.

On-Farm Experiments

A number of technologies were evaluated in experiments conducted on farms. The farmer's own technology served as the "control" or "check" treatment in each experiment. The production constraints team, which tested a number of inputs and packages under a range of conditions, conducted 30 farm-level experiments in Mantaro Valley during the 1978/1979 crop year and 35 in 1979/1980. The postharvest team, which experimented with fewer variables and placed strong emphasis on frequent interaction with farmer collaborators, conducted four experiments in 1978/1979, six in 1979/1980, and six in 1980/1981. For reasons outlined below, the team researching seed systems conducted experiments on the Peruvian coast and in the highlands of Ecuador and Colombia rather than in Mantaro Valley.

Research Results

The Mantaro Valley Project generated a wealth of empirical information — both technical and socioeconomic — on Andean potato agriculture. The

research demonstrated how land use and agricultural technology are influenced by two key factors — ecology and farm type — beyond the immediate control of farmers. The research also provided new perspectives on four concepts that are central to the philosophy of CIP's research and transfer program and, in fact, to most agricultural research and development programs. These are the concepts of the small-scale farmer, the technological package, improved seed, and technology transfer.

Agroecological Zones and Farm Types

Mantaro Valley is one of Peru's largest and most fertile highland agricultural areas. The city of Huancayo, in the southern part of the valley, is the most important commercial centre in the Central Highlands. Agriculture, mining, livestock, and commerce are important sources of regional employment and income.

Agroecological Zones

The valley's cropland can be divided into three agroecological zones: the relatively flat land of the "low zone" along Mantaro River, ranging between 3200 and 3450 m above sea level (asl); the sloping land of the "intermediate zone" between 3450 and 3950 m asl; and the more steeply sloping fields of the "high zone" between 3950 and 4200 m asl (Fig. 4). In the puna lands above 4200 m asl, no crops are grown and agricultural land use is limited to pasturing for sheep, llamas, and alpacas. Of the valley's 150000 ha of cropland, approximately 50% is in the low zone, 40% in the intermediate zone, and 10% in the high zone.

Planting dates for most crops grown in the valley are determined by seasonal patterns of temperature and rainfall. Most crops are sown in October and harvested in May.

Cropping is most intensive in the low zone, particularly on irrigated fields. A wide range of food crops is grown, the most important of which is maize. As one ascends into the intermediate and high zones, fewer and fewer crops can be grown and fallow becomes more important in the rotation cycle. In the high zone, a large proportion of the land is permanent natural pasture. Maize is seldom found above 3450 m asl. Tubers (mainly potatoes) predominate on the humid eastern slopes of the intermediate zone; small grains (mainly barley) predominate on the drier western slopes. In the high zone, where only the hardiest of plants survive the cold and frost, potatoes are the dominant crop (Fig. 5).

Nearly 90% of the valley's potatoes are produced in the low zone and on the eastern slopes of the intermediate zone. Seventy-five percent of the valley's potato producers live in these two agroecological zones, where 80% of the land is seeded with potatoes. In the high zone, the potato is the most strategic crop in the farming system, but this zone accounts for only a small proportion of the valley's total population and potato production. In recent years, large-scale farmers in the low zone have expanded production of seed potatoes for sale to the coast (Monares 1981). This lucrative business has contributed to an increasing concentration of land being devoted to potatoes in large commercially oriented rental units.

Types of Farms

Small farms, which are in the majority throughout the valley, occupy

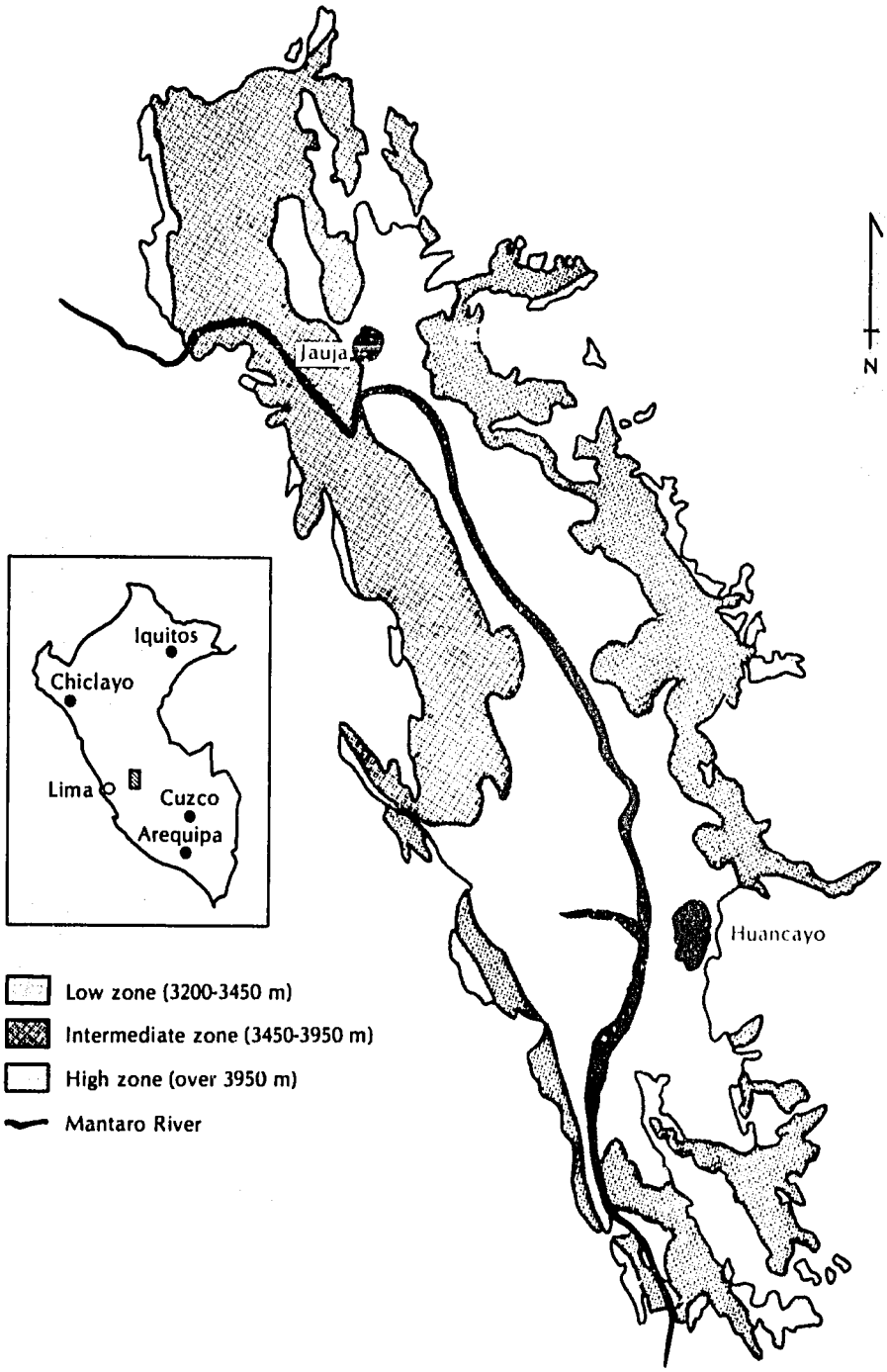


Fig. 4. Agroecological zones of Mantaro Valley, Peru (adapted from Mayer 1979).

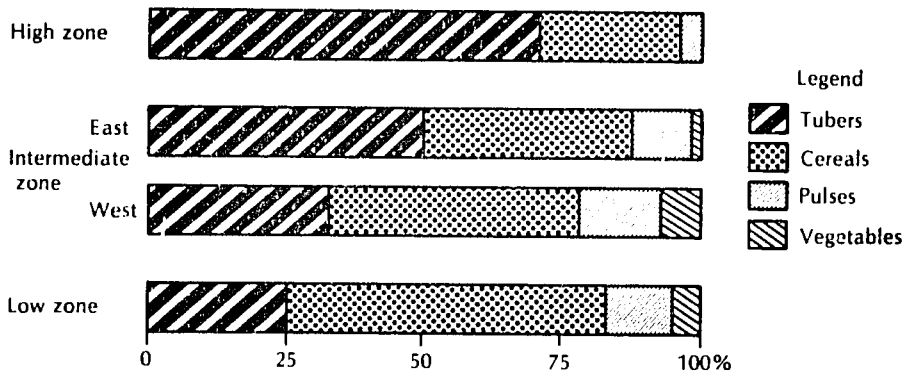


Fig. 5. Percentage of cropland in food crops in Mantaro Valley by agroecological zone (Franco et al. 1979).

every possible ecological environment. In contrast, large farms are found primarily in the low zone, where they occupy the valley's best cropland, and in the high grazing lands of the puna.

In the low zone, a fundamental difference is observed between large- and small-scale farmers. Large-scale farmers tend to specialize in commercial potato production, whereas small-scale farmers operate highly diversified, risk-averting, part-time farming systems and grow potatoes mainly for home consumption. This distinction is not so clear in the intermediate and high zones, where large-scale commercial farmers are virtually absent. In the intermediate zone, many small-scale farmers market potatoes and barley, crops that grow best in the area. In the high zone, most farmers derive their cash income from livestock and produce potatoes mainly for home consumption.

Nearly every farmer in Mantaro Valley produces potatoes, but most produce them on less than 1 ha of land. Potato production is concentrated on a few large farms (Tables 2 and 3). Ten percent of the valley's farmers produce over half of the potatoes and an even higher percentage of the marketed output. Moreover, in recent years the degree of concentration of potato production on large farms has increased, despite implementation of Peru's land reform (Caballero 1980). High production costs and risks are

Table 2. Number of potato producers, area, production, and yield by agroecological zone.

	Low zone	Intermediate zone East	Intermediate zone West	High zone	Total valley
Distribution (%)					
Potato producers	51	24	18	7	100
Area in potatoes	49	30	13	8	100
Potato production	55	31	7	6	100[a]
Area in potatoes as % of cropland	19	39	22	57	25
Yield (t/ha)	5.5	5.0	2.7	3.6	4.8

Source: Franco et al. (1979).

[a]Due to rounding off, the potato-production values do not total 100.

Table 3. Selected characteristics of Mantaro Valley potato farms.

	Low zone			Intermediate zone		
	Large farms	Medium farms	Small farms	East	West	High zone
Average cropland (ha)	74.7	10.9	1.0	1.9	1.8	1.4
Average in potatoes (ha)	41.9	1.9	0.2	0.7	0.4	0.6
Farmers with off-farm jobs (%)	30	46	80	61	59	63
Potatoes marketed (%)	63	73	11	52	17	26
Inputs purchased (%)	75	61	59	36	27	25

Sources: Franco et al. (1979); Horton et al. (1980).

NOTE: Large farms are defined herein as those of large-scale seed growers and are registered by the Ministry of Agriculture. Medium-sized farms are those producing consumption potatoes on more than 0.5 ha of land. Small farms are those with less than or equal to 0.5 ha of land under potatoes.

forcing small-scale farmers to reduce planting, whereas large-scale growers, with their greater risk absorbing capacity and preferential financial and marketing arrangements, are expanding acreage to supply the growing coastal markets with seed and consumption potatoes.

The Concept of the Small-Scale Farmer

Many agricultural research and development programs assume, explicitly or implicitly, that small-scale farmers are isolated from input and product markets and are particularly resistent to change. In the context of the Mantaro Valley Project, it was assumed that small-scale potato producers grew mainly native varieties for home consumption and that they applied little or no fertilizer or pesticides. Surveys indicated that, although such traditional, subsistence-oriented small-scale farmers can be found, they are by no means the norm.

Market Integration

Although nearly all farmers in the intermediate and high zones are small scale, the smallest in the valley were found in the low zone (Table 3). These farmers are subsistence oriented in the sense that they keep a large proportion of their potato harvest for home consumption. They purchase most inputs, however, including labour, and most of them have off-farm jobs. They are, in essence, part-time farmers who are well integrated into the cash economy (Table 3).

Use of Purchased Inputs

In the low zone, fertilizer- and pesticide-application rates were found to be surprisingly high — often exceeding recommended levels — with even small-scale farmers applying, on average, over 100 kg N/ha (Table 4). In the intermediate and high zones, many small-scale farmers applied less chemical fertilizers and pesticides for two reasons. First, because the probability of crop loss from hail or frost is extremely high, farmers minimize financial risks by minimizing their use of purchased inputs. The second reason is that, because two-thirds of the zone's potatoes are planted after fallow, they require little fertilization and pest control. It is clear that the use of purchased inputs is not determined by culture, lack of knowledge, or lack of input supplies because the same farmers who used less fertilizer and pesticides in the high zone applied more fertilizer and pesticides on their fields at lower elevations.

Table 4. Use of chemical fertilizers, pesticides, and fallow.

	Low zone				
	Large farms	Medium farms	Small farms	Intermediate zone	High zone
% of potato fields with applications of					
Chemical fertilizer (N)	100	95	83	74	28
Soil pesticide	89	63	80	90	54
Nitrogen application (kg/ha)	212	124	108	85	148
% of fields planted after fallow	0	8	6	52	67

Sources: Franco et al. (1979); Horton et al. (1980).

Use of Modern and Native Varieties by Small-Scale Farmers[7]

Nearly all farmers, both large and small scale, grow modern varieties in the low zone, whereas most farmers in the high zone grow native varieties (Fig. 6). Native and bitter potatoes are grown at high altitudes because traditional producers prefer the culinary qualities of native potatoes (Carney 1980). A major reason that native and bitter potatoes are grown is that they are extremely well adapted to the production conditions of high Andean areas.

With present technology, modern varieties have a considerable yield advantage over native varieties in the low zone. This is not always the case, however, in higher zones (Table 5). Traditional varieties are highly resistant to frost and hail and produce reasonably well with low applications of chemical fertilizer and pesticides (Brush et al. 1981). Hence, their use allows farmers to minimize losses in an environment characterized by frequent crop failure. In addition, native varieties are now considered a luxury item in urban areas and fetch a higher market price than modern varieties. Given these conditions, in areas where native varieties yield the same or more than modern varieties — as they do in the intermediate zone — many farmers derive a substantial cash income from marketing native potatoes.

Potatoes play an important role in the diet of rural households in high areas due to limited cropping alternatives and the absence of retail food markets in these scarcely populated areas. Because native varieties store well, farmers can keep them for home consumption practically year round from one harvest to the next. Night frost and sunny days after harvest provide excellent natural conditions for transforming inedible bitter potatoes into *chuño* (Werge 1979; Christiansen 1977). *Chuño* plays a special role in the typical diet of this zone. Because it is light in weight, it can easily be carried by herders during their seasonal migration to high-altitude pasture lands. Also, because it can be stored for years, it provides them with a degree of food security in this uncertain environment.

[7]Modern varieties are defined herein as hybrids produced by Peruvian breeding programs. Native varieties are all others. Bitter potatoes are a subtype of native varieties that because of their high glycoalkaloid content are not eaten fresh but are processed into *chuño* — a traditional freeze-dried product that can be stored for years.

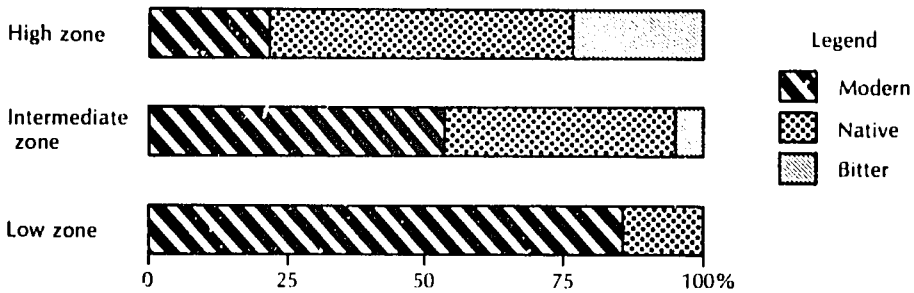


Fig. 6. Cultivation of modern and native potato varieties in Mantaro Valley by agroecological zone (Franco et al. 1979). (Bitter potatoes are native varieties that are not consumed directly but are processed into chuño.)

Economics of Small Farm Production Systems

Table 6 illustrates how a "traditional" low-input system can offer producers economic advantages over a "modern" higher input system. In the intermediate and high zones, the *ticpa* system, employing native varieties, no tillage prior to planting, hand power (using the *chaquitaclla* or Andean plow) for all cultivation and harvest operations, and very little chemical fertilizer and pesticides, was found to produce a higher net return than the *barbecho* system, which employed modern varieties, tractor power, and high levels of chemical fertilizer and pesticides. Both the yield and total input costs associated with the *ticpa* system were about 20% less than those associated with the *barbecho* system. The net return over direct input costs was higher in the *ticpa* system because higher valued native varieties were produced. Of equal, or perhaps greater, importance, is the fact that the *ticpa* system employs only about one-third of the value of purchased inputs compared with those used in the *barbecho* system. Hence, this "traditional" system exposes farmers to relatively little financial risk.

Table 5. Average yields and producer scores for modern, native, and bitter potato varieties.

	Low zone		Intermediate and high zones		
	Modern varieties	Native varieties	Modern varieties	Native varieties	Bitter potatoes
Average yield (t/ha)	5.7	3.7	4.8	4.7	4.9
Producer scores					
Culinary quality	87	96	76	95	67
Market price	76	84	82	87	58
Yield	80	68	82	73	85
Pest resistance	59	46	66	46	85
Frost resistance	49	35	49	43	91
Storability	65	72	69	85	84

Source: Franco et al. (1979).

NOTES: (1) Scores range from 0–100. A score of zero indicates that all producers considered the variety "bad." A score of 100 indicates that all producers considered the variety "good." Fewer than five farmers interviewed produced bitter potatoes in the low zone; hence, no scores are given. (2) Modern varieties are defined herein as hybrids released since 1950 by Peru's breeding programs. Native varieties are all those that have not originated in formal breeding programs. Bitter potatoes are native varieties that are not consumed directly but are processed into *chuño*.

Table 6. Yields, costs, and returns in two potato-production systems in the intermediate and high zones.

	Barbecho system[a] (*n*=8)	*Ticpa* system[b] (*n*=9)
Yield (t/ha)	9.4	7.3
Total returns (US$/ha)	1102	030
Direct input costs (US$/ha)		
Seed	278	235
Labour	186	218
Pesticides	67	14
Tractor/oxen	64	0
Chemical fertilizer	62	18
Manure	15	59
Total	672	544
(Purchased)	316	114
Gross margin (US$/ha)		
Total return - direct input costs	430	486
Total return - purchased inputs	786	916

Source: Horton et al. (1980).

[a]Modern varieties grown; tractor used for plowing.

[b]Native varieties grown with no tillage before planting; all cultivation done by hand.

These empirical findings were in sharp contradiction to the assumptions of many CIP scientists and development experts working in the Andes. They helped to destroy the myth that traditionalism among the small-scale farmers is a major barrier to the transfer of technology.

The Technological Package Approach to Agricultural Extension

Belief in technological packages is widespread in the development community. Based on the agronomic principle of input interaction[8] and on a superficial analysis of the "seed-fertilizer revolution" of the 1960s, many development experts and policymakers have concluded that agricultural improvement requires that farmers adopt complex technological packages. To cite just one example, a recent World Bank paper states that "the first requirement for successful innovation is the availability of a package of technical components that is complete, reliable, and suitably designed for the conditions within which it is to be applied" (McInerney 1978). Similar statements are found in documents of the Food and Agriculture Organization of the United Nations (FAO 1981a, b) and other development agencies. Indeed, it seems fair to generalize that the vast majority of crop-improvement programs in developing countries are based on the concept of the improved technological package.

When CIP's agronomic constraints work began in 1978, it was accepted that many small-scale farming practices were so rudimentary that a complete package of improved practices was needed to substantially increase yields and economic returns. Hence, technological packages were used for

[8]The combined effect on yield of applying several inputs jointly is greater than the sum of the effects of each applied separately.

Table 7. Average increase in yield and cost and net benefit/cost ratio of technological packages and single factors.[a]

	% increase in yield	Increase in cost (US$/ha)	Benefit/cost ratio
Technological packages			
1978/1979 (*n*=11)			
Low cost	1	48	-0.9[b]
Medium cost	17	165	0.7
High cost	53	252	3.1
1979/1980 (*n*=20)			
Low cost	8	10	20.2
Medium cost	32	306	2.2
High cost	59	457	2.8
Single factors			
Insect control (*n*=5)	16	48	7.1
Fertilization (*n*=4)	17	70	4.0
Improved seed (*n*=5)	17	223	-0.2[b]

Sources: Franco et al. (1980, 1981).

[a]Average increases in yield and cost are in relation to the farmer's technology (control treatment) for each experiment. Benefit/cost ratio is defined as (change in net returns - change in cost)/change in cost.

[b]Benefit/cost ratio is negative because cost increased but net returns decreased.

evaluating recommended technologies under farmers' conditions. In consultation with local production specialists, three packages were designed. A "low-cost package" was designed to increase yields and net returns without increasing costs and financial risks and "medium" and "high-cost" packages were designed to increase yields and net returns more significantly but at higher costs and risks to the farmer. Each of the packages included three recommended practices, the effects of which were believed to be complementary: improved seed, fertilization, and pest control. The levels and cost of these elements varied between the three packages. Performance of the individual elements of the packages was studied in single-factor trials in 1978/1979.

The package trials employed relatively large land parcels (150 m^2) with no replications. Single-factor trials used smaller parcels (75 m^2) with two replications. In all trials, the farmer's technology was used as the control treatment and all nonexperimental factors were kept at the farmer level. Based on the results of the first year's trials, package designs were modified somewhat for the 1979/1980 trials and single-factor trials were replaced by a factorial design.[9]

The on-farm trials and subsequent evaluation of farmer adoption in the area revealed four problems with the technological package approach: results were poorer than expected; an optimal package could not be identified; one key element of the packages performed poorly; and farmers did not adopt the packages.

On average, the high-cost package increased yields by 50–60% over the farmers' current level, the medium-cost package increased yields by 20–30%, and the low-cost package yielded about the same as the farmers' established technology (Table 7). These results were disappointing to production specialists who expected a doubling or tripling in yields.

[9]Designs and results of the on-farm experiments are detailed in Franco et al. (1980, 1981).

As indicated in Fig. 7, experimental results varied widely across farms. Within the intermediate zone, farmers' yields ranged from less than 5 t/ha to nearly 30 t/ha and the packages yielded from about 5 t/ha to more than 40 t/ha. These diverse yield levels reflect variations in soil fertility and weather conditions within the zone, coupled with differences in farmers' management practices (e.g., variety, tillage, and rotation). Clearly, no single package represented an economic optimum under the diverse farming conditions of this single agroecological zone.

Figure 7 illustrates graphically the risk of determining farmer recommendations based on aggregate, or average, results of on-farm trials. Behind such averages can be concealed an extremely high degree of variability. In this context, it is interesting to note that in conventional statistical terms the average yields of the medium- and high-cost packages were significantly higher than the average farmers' yield (at the 5% level of significance).

If more care had been taken in delimiting the zones or if numerous smaller "recommendation domains" (Perrin et al. 1976; Byerlee et al. 1980) had been identified, this variability might have been reduced. However, precision in zoning is costly. Hence, the variability shown in Fig. 7 illustrates a real problem faced by researchers and extensionists working in mountainous areas.

As noted earlier, one of the justifications for the technological-package approach is the generally accepted agronomic principle that the combined effect on yield of several improved practices applied together is greater than the sum of the effects of each applied alone. Results of on-farm trials in Mantaro Valley illustrate how this principle may be misleading in the context of agricultural extension. In the experiments, the combined effect on yield of recommended seed, fertilization, and insect control was slightly greater than the sum of the effects of the individual practices. However, economic analysis showed that adoption of either the recommended insect control or fertilization, alone, offered farmers higher rates of return than adoption of the complete package (Table 7).

The packages had one very weak component — improved seed — the use of which actually reduced net farm earnings. It is interesting to note that "improved seed" was the technology that most production specialists considered to be the single most important component of the packages. Hence, assumptions about the relative importance of production constraints and the economic viability of alternative technologies proved to be incorrect.

Surveys conducted after the experiments indicate that, although farmers are now using certain recommended practices, they have not adopted the complete technological packages.

The Concept of Improved Seed

Poor seed quality has been identified by many agricultural experts as the most critical factor limiting crop yields in developing countries. For example, Villareal (1980) states that "no input in the production of crops gives greater results with less effort than good seed." Seed quality is considered to be a more serious problem with potatoes than with most other crops due to the transmission of virus diseases in seed tubers (CIP 1974). A recent publication on potatoes in Peru states that 100% of Peruvian native potatoes are infected with virus diseases (Flores et al. 1980). Establishment of a viable

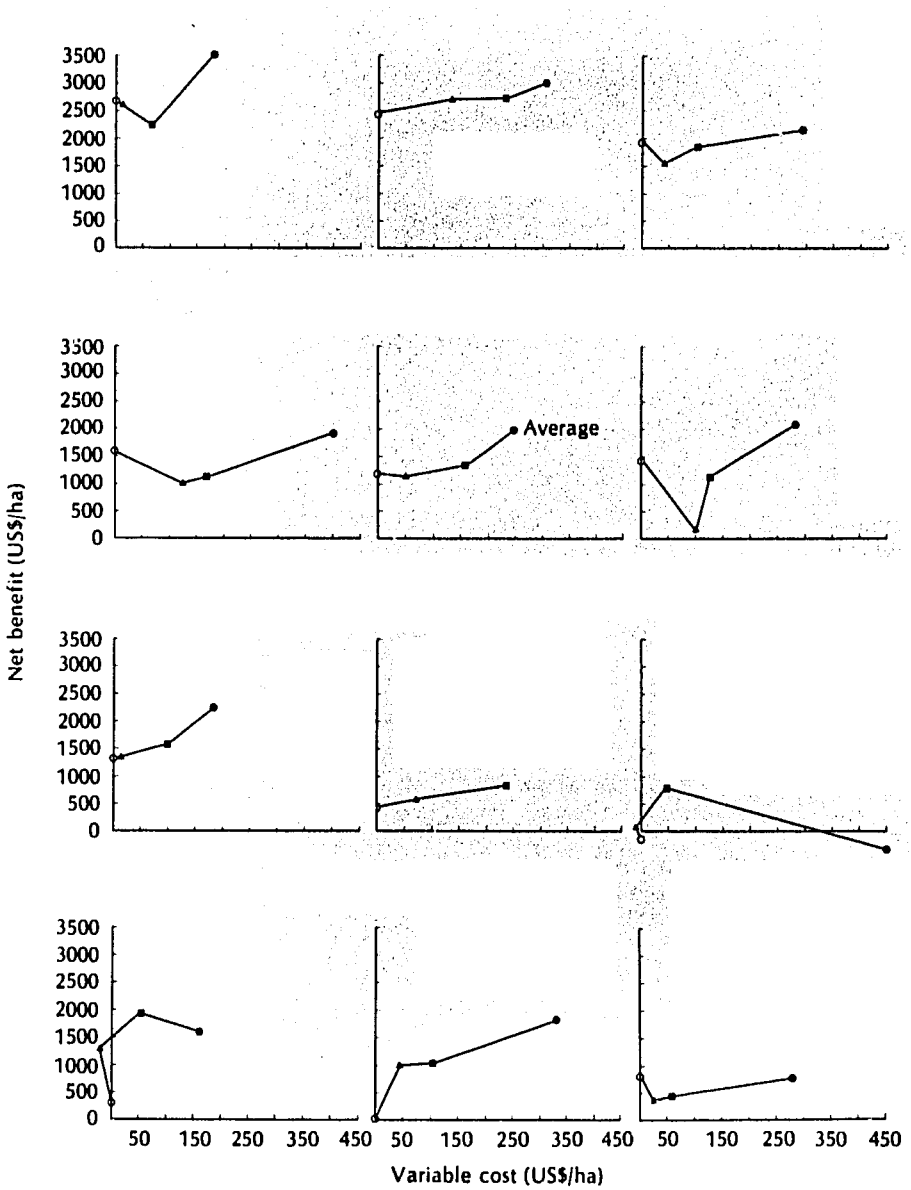


Fig. 7. Net benefit of four packages evaluated on 11 farms in the intermediate zone, 1978/1979. (Net benefit = total revenue − variable cost. Variable cost = cost of package − cost of farmer's practice.) ○, *farmer practice;* ▲, *low-cost package;* ■, *medium-cost package;* ●, *high-cost package.*

Table 8. Observed symptoms of virus diseases, farmers' average seed size, and percentage of farmers using their own seed.

	Low zone			
	Large farm	Medium farm	Small farm	Intermediate and high zones
Percentage using own seed	68	53	38	73
Plants with virus symptoms (%)		23		7
Average seed size (g)		47		43

Sources: Horton et al. (1980); Franco et al. (1980, 1981).

NOTE: Observations of virus symptoms and measurements of seed size were made in 12 fields in the low zone and 70 fields in the intermediate and high zones. Estimates are not available for large farms.

seed-certification system has been a high priority of Peru's National Potato Program for years.

Mantaro Valley farmers often consume or sell their largest potatoes and keep smaller tubers for seed. Production specialists fault this practice on the grounds that planting small tubers increases the spread of virus diseases and reduces yields. It is generally believed that if small-scale farmers would use certified or "improved" seed they could substantially increase their yield and income.

Surveys and on-farm experiments indicate that farmers' seed is not as bad as it is generally assumed to be and that for most farmers the use of presently available "improved" seed is uneconomical. Data recorded from farm-level experiments indicate that yield-reducing virus diseases are not as common as previously assumed (Table 8). There are two important reasons for this. First, farmers' native varieties are not as severely affected by yield-reducing virus diseases as are most modern varieties. Second, farmers' seed management practices tend to minimize the spreading of viruses.

Over a period of centuries, Andean farmers have developed sophisticated "informal" seed networks and management practices to cope with local diseases, including viruses. Farmers seldom plant seed tubers harvested from one crop in the same field the next year. Instead, they plant their seed in another of their own fields or exchange the seed with neighbours. Farmers generally select the fields from which they will keep seed based on the vigour and yield of the crop and the appearance of harvested tubers. When they consider the seed stock to be "degenerated," they consume or sell the harvest and acquire new seed. In the low zone, where virus infection is greatest, farmers replace their seed stock more often than farmers in the higher zones. Farmers also know where to acquire good seed, i.e., from higher areas where virus infection is lower (Monares 1981).[10]

In on-farm experiments, the use of improved seed increased yields on average by 15–20%. Due to the high cost of the improved seed, however, its use reduced farmers' net returns below the level obtained when using their own seed (Table 8).

[10]An extensive description of farmers' seed management practices and informal seed networks in central and southern Peru is in draft form (Franco 1983).

The Technology-Transfer Paradigm

In the conventional research-transfer paradigm, new agricultural technology is developed by researchers in laboratories and experimental stations and then "transferred" via extension services to passively recipient farmers (Whyte 1981). Some very optimistic and sweeping statements have been made concerning the amount of demonstrated technology awaiting transfer to needy farmers in developing countries. A special issue of *Scientific American* (1976), dedicated to food and agriculture, provides an example.

> By conservative estimates, presently demonstrated agricultural technology, if applied to all land now in cultivation could support a world population of 45 billion .... The transfer of modern agricultural technology from developed to underdeveloped countries is gathering perceptible momentum.

Based upon the assumption that developed countries and research centres have generated a large stock of appropriate technology, international development agencies are now looking for ways to speed up the transfer of research results to farmers. The "training and visit" extension system, promoted by the World Bank and implemented in over 50 developing countries, is based on the view that extension of known practices, with little or no local testing, can substantially and rapidly increase farmers' yields. A World Bank publication states:

> The extension services can take advantage of the gaps between existing agricultural practices and the backlog of research findings which already exist but which have not yet reached the farmers. Such gaps are now large .... Since these practices are normally quite well known and tested, they can be fed into the extension service quickly without requiring an elaborate, time-consuming screening and trial process (Benor and Harrison 1977).

In the Mantaro Valley Project, two things become clear: first, that there was little "demonstrated technology" that could be transferred directly to farmers without local refinement or adaptive research; and second, that farmers are not passive recipients of recommended technologies but active researchers and developers in their own right.

In contrast to this optimism concerning the transferability of superior technology stands the failure of many extension programs (Rice 1974) and the disrespect shown by many farmers for extension agents who, in the farmers' view, offer little or no technology that is viable under practical farming conditions.

Within the framework of the Mantaro Valley Project, an extension campaign was not conducted; however, many farmers showed an active interest in the research and began applying some of the practices tested on their farms. A 1982 survey of adoption indicated that very few of the farmers who tested technological packages adopted them, but more than half of the farmers reported taking advantage of one or more of the component technologies. In general, they adopted low-cost practices, such as the use of diffused-light seed storage, the selection of healthy seed, and improved insect-control measures. Very few began using costly certified seed or recommended fertilization levels (Table 9).

In most cases, farmers did not "adopt" the practices tested but "adapted"

Table 9. Percentage of farmers adopting the practices tested on their farms.

	Adopted	Not adopted	Number of observations
Technological packages	12	88	24
Seed management practices			
Diffused-light storage	58	42	19
Planting one large tuber per hill	36	64	28
Selecting healthy seed	56	44	18
Using certified seed	20	80	15
Fertilization practices			
Recommended levels	17	83	30
Split N application	29	71	31
Insect-control measures			
Foliar application	43	57	30
Soil application	60	40	30

them to fit their specific needs. The most striking illustration of farmer adaptation of a technology is that of diffused-light seed storage. This technique, which involves exposing stored seed potatoes to indirect sunlight to retard sprout elongation and green the skin, was tested on a number of farms by the postharvest team. In 16 trials, the average yield increase resulting from storing seed in diffused light, rather than in farmers' dark stores, was 20% (Booth et al. 1983). Careful observation indicates that "farmers did not copy the model store but began applying the principle of diffused-light storage in a wide range of innovative ways." Hence, the technology, as a physical entity or precise recommendation, was not transferred to farmers. Instead, farmers understanding the principle applied it to suit their needs. In most cases, rather than building an elaborate new store, the farmer modified existing stores to incorporate the diffused-light principle. The same type of farmer adaptation, with respect to seed-storage technology, has been observed in a number of other countries (Rhoades et al. 1983; Potts 1983).

V. METHODOLOGICAL LESSONS

Farmer's (control) treatment in an intermediate-zone trial.

In this chapter, the emphasis will shift from the empirical research results discussed in the previous chapter to the methodological lessons learned from the project. These have proven to be of importance to CIP's research and training program and it is felt that they may also be of value to other institutions — national or international — embarking on interdisciplinary farm-level research. Five general lessons are discussed: difficulties with on-farm research; benefits of interdisciplinary research; value of informal surveys and simple on-farm trials; contributions of social scientists; and extrapolation of research results.

Readers interested in more specific methodological lessons concerning farm surveys and on-farm experimentation should consult the reports and training documents listed in the Appendix.

Difficulties with On-Farm Research

When the Mantaro Valley Project began in 1977, the complexity of and difficulty with the proposed farm-level research was underestimated. On the other hand, the value of the results that would be obtained was also underestimated. The difficulty with and expense of the research resulted from two main factors: (1) conventional disciplinary boundaries separating the natural and social scientists, as well as scientists within these two groups, and (2) logistical problems related to conducting farm surveys and experiments in the Andes.

Disciplinary Barriers

CIP's research organization, with its problem-oriented thrusts, facilitates interaction and teamwork involving scientists of different disciplines. Nevertheless, in the Mantaro Valley Project it became clear that scientific specialization along disciplinary lines posed significant barriers to effective interdisciplinary research.

Communication

Specialization limits both the motivation and ability of scientists to communicate across disciplines. It was found, for example, that the term "improved seed" meant very different things to plant pathologists, physiologists, and economists. To pathologists, it meant disease-free seed; to physiologists it meant seed with higher yielding capacity. To economists, an "improved" seed was one which increased the farmers' net returns. During the course of the project, many time- and energy-consuming discussions and disagreements resulted from problems of communication. At the same time, however, cross-disciplinary dialogue helped to clarify important concepts and ideas. When the term "improved seed" is now used, scientists

of various disciplines are much more cognizant of its many facets than they were in the past. They realize that for a seed-improvement program to work, the seed produced must be better than the farmers' own seed based on the farmers' criteria of quality.

Professional Incentives

The present system of professional incentives was also found to inhibit interdisciplinary teamwork. This problem was especially critical in the case of university students and young professionals concerned with improving their professional stature through publication of their research results. As a rule, university thesis committees do not look favourably upon interdisciplinary research projects aimed at solving practical problems. Attainment of "high scientific standards" generally requires students to use sophisticated procedures that are often not suitable for use at the farm level. Hence, the quest for conventionally defined scientific rigour comes at the expense of relevance. The following two examples illustrate this point.

In one case, an agronomy student found that she could not use on-farm experiments for her thesis research because her committee required an experimental design of such complexity that it would not have been feasible to conduct the experiment in a farmer's field. It is interesting to note that even if the experiment had been conducted it would have been of little value to the interdisciplinary research team because there would have been no way to gauge the farmer's evaluation of the technology under study. The experiment would have been too complex to be managed or understood by the farmer. In the second case, the thesis committee of an economics student rejected his proposal to analyze a farming system using simple ("old fashioned") whole-farm budgeting procedures and insisted upon the use of computerized linear programing. Implementation of the linear-programing model was very complex and costly in terms of computer time. As a result, the student simplified the model to such an extent that it had little practical relevance to the problem under study.

Thus, experience indicates that agricultural research institutes with commodity or farming-systems programs provide an organizational structure and incentives that are more conducive to interdisciplinary research than is the case in most universities.

Mutual Respect and Joint Decision-Making

A third critical aspect of interdisciplinary teamwork is the need for mutual respect among professionals of different disciplines. Experience has shown that the productivity of interdisciplinary teamwork depends upon the extent to which team members of different disciplines function as equal partners with joint responsibility for the final product of the research. This requires that scientists of roughly the same calibre and experience be involved. This is particularly difficult to achieve in many national research institutes where social scientists tend to be few in number, young, and inexperienced. If members of one discipline are cast in the role of assistants to members of other disciplines, little can be expected from the joint effort.

Transportation and Logistics

Carrying out field research in mountainous areas such as the Andes is

extremely demanding in terms of transportation and logistical support. The trip from Lima to the Mantaro Valley takes about 6 hours in good weather on a road that goes from the coast to over 4800 m asl. During the rainy season, the trip is extremely hazardous and may take many hours (or days). Within the valley, distances are also great and public transportation is poor. For this reason, even though the project had three vehicles, it was impossible to maintain a schedule of weekly interviews with 30 farmers during the multiple-visit survey. Due to the fact that in most of the developing world potatoes are grown in mountainous environments, programs initiating farm-level research with potatoes should anticipate high transportation costs if a significant number of farmers are to be interviewed or farm-level experiments are to be conducted. Unless adequate resources are provided for transportation and field staff, the quality of the information obtained will suffer.

As a final point, it is important to recognize that on-farm research requires a mix of resources that is radically different from that required for conventional agricultural research. Most developing countries now have agricultural research institutes that have substantial investments in laboratory and experimental station facilities. However, these institutes often have severe budgetary limitations for operating expenses. Farm-level research requires little capital (aside from vehicles and, perhaps, computer equipment) but relatively heavy expenditures for travel, per diems, and temporary personnel for conducting surveys and on-farm experiments. These resources are in short supply in most developing-country research institutes.

Benefits of Interdisciplinary Research

In the Mantaro Valley Project and subsequent collaborative research with biological scientists in the Source Research Program and in regional and national programs, CIP social scientists have worked in three areas: (1) ex post evaluation of technology, (2) facilitating technology transfer, and (3) generation of technology. These three types of research and their benefits are illustrated by: (1) the research conducted on seed systems, (2) the "optimizing potato productivity" approach, and (3) development and application of the "farmer-back-to-farmer model" respectively.

Research on Seed Technologies and Programs

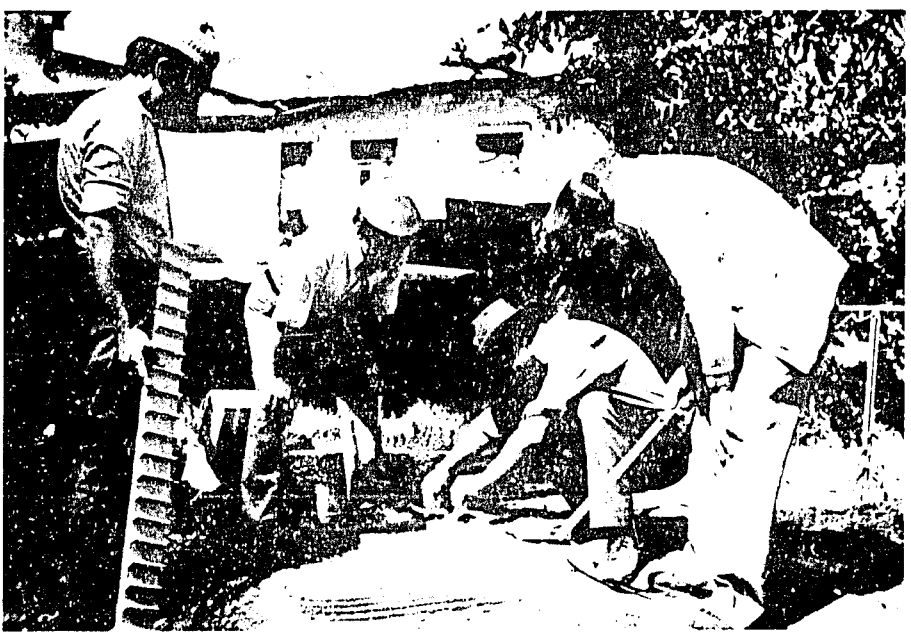
The role of the social scientist as an ex post evaluator is a familiar one. However, the use of such evaluations to improve the effectiveness of research and development programs (feedback) has seldom been exploited and even less often documented. Farm-level research on seed potatoes demonstrates how ex post evaluations can be used to improve the performance of seed programs. On-farm experiments in Peru, Colombia, and Ecuador indicated that farmer use of locally available "improved seed" was not profitable. As would be expected, this "negative" research result was initially rejected by biological scientists and national program leaders. The survey and experimental methods used in the research came under unusually close review and severe criticism. As supporting evidence was obtained, however, biologists became more deeply involved in the

research and the reasons — technical and socioeconomic — for the poor performance of the improved seed became known, the results became accepted, and, more importantly, means were sought to improve the design and performance of future seed programs.

In the design of new seed systems, social scientists have made two main types of contributions. They have provided expertise in planning and conducting surveys and farm-level experiments that help determine farmers' needs and the potential demand for certified seed. Such work has now been done in a number of countries including Chile, Colombia, Ecuador, Peru, Rwanda, and Tunisia. Their second contribution is that they have worked with biological scientists in devising seed schemes that complement, rather than compete with, farmers' existing seed systems. This input is illustrated by a seed-production program initiated in Peru in 1983 with CIP technical assistance. The first phase of this project's implementation was a detailed diagnostic survey of farmers' seed-management practices and "informal" seed networks (Franco 1983). The project team is now using these survey results to select varieties to be multiplied, areas for multiplication, and potential farmer collaborators, and to establish a system for monitoring and evaluating seed produced by the project and measuring the project's impact.

The Optimizing Potato Productivity Approach

The "optimizing potato productivity" (OPP) approach, tested and implemented in the Mantaro Valley and in CIP's regional programs, aims to improve the transfer of potato technology by providing an intermediate step between the generation of technologies and their dissemination (Cortbaoui 1980). The ultimate goal is to identify production and postharvest



Establishing a seedbed in an on-farm trial utilizing true potato seed.

technologies that farmers can profitably incorporate into their production systems. The two basic assumptions of this approach are that to be adopted a technology must (1) be appropriate for the needs and resources of farmers and (2) increase returns enough to cover the costs and risks associated with its adoption. Ideally, this research should be conducted by interdisciplinary teams made up of social and biological scientists.

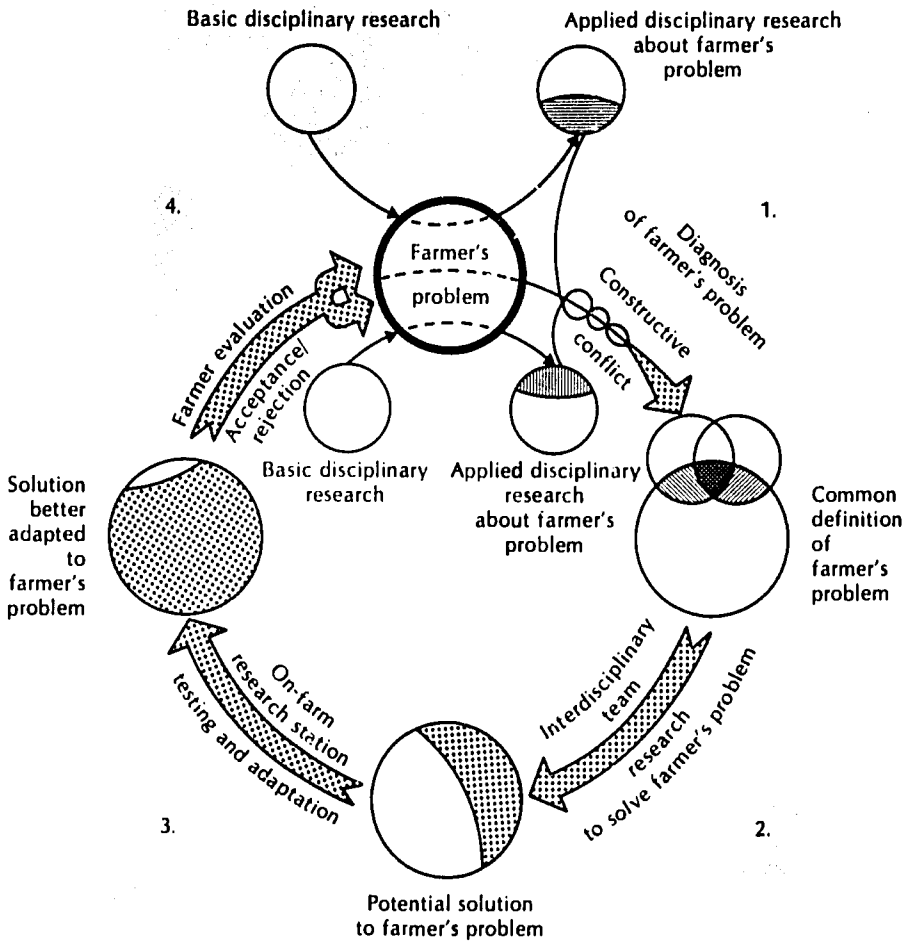
In practice, most OPP work outside the Mantaro Valley has been carried out by production specialists previously sensitized to and trained in the socioeconomic aspects of the approach. The OPP approach has been used by several developing-country programs, the best documented case being the Philippines, where a production specialist was assigned to conduct farm-level research in the mountainous potato-growing area of Northern Luzon (Potts 1983). Potts and his colleagues in the extension service quickly found that the extension effort was based on two false assumptions: (1) that farmers' yields were less than 10 t/ha and (2) that the recommended technological package could more than double yields and profits under most farmers' conditions. A careful survey demonstrated, however, that farmers' yields averaged 25 t/ha and on-farm trials showed that the complex, recommended technological package (with over 20 different elements) was both unworkable and uneconomical. Farmers did, however, adopt the improved seed-storage practices introduced into the area by CIP through the National Potato Program (Rhoades et al. 1983).

OPP work in Rwanda is less well documented than in the Philippines but it is, perhaps, more significant because the potato program in Rwanda (Programme National d'Amelioration de la Pomme de Terre (PNAP)) is based entirely on this farmer-oriented research approach. Informal farmer surveys and observations that began in 1979 guided PNAP in testing technological alternatives in farm-level trials. As a result of the effectiveness of this approach, PNAP is now considered to be one of the most successful commodity-improvement programs in Central Africa.

The Farmer-Back-To-Farmer Model

Based on their experiences in development and dissemination of postharvest technology in the Mantaro Valley and elsewhere, the postharvest team formulated the "farmer-back-to-farmer" model for generating and transferring agricultural technology (Rhoades and Booth 1982b). This model is based on the assumption that, to be effective, applied agricultural research and transfer should begin and end with the farmer and involve interdisciplinary teamwork in all phases of a continuous research/diffusion process. Although the model was developed during the adaptation of seed-storage principles to the requirements of resource-poor farmers, it is equally applicable to other areas of applied agricultural research. The model consists of a series of goals aimed at achieving acceptable solutions to farmers' problems that are linked in a circular form by a number of activities (labeled 1–4 on Fig. 8).

A proper diagnosis of problems (activity 1) is essential for efficient use of research resources. Initially, this may require that social and biological scientists make independent observations and studies. Subsequently, through a process of interdisciplinary dialogue and interaction with farmers, often characterized by debate and "constructive conflict," the dif-



Activities	Goals
1. Diagnosis of farmer's problem	Common definition of problem by farmers and scientists
2. Interdisciplinary team research to solve farmer's problem	Identify and develop a potential solution to the problem
3. On-farm testing and adaptation	Better adapt the proposed solution to farmer's conditions
4. Farmer evaluation	Understanding farmer acceptance or rejection of solution

Fig. 8. Farmer-back-to-farmer — a model for generating acceptable technology (adapted from Rhoades and Booth 1982b).

ferent diagnoses of social and technological perspectives are brought together to arrive at a common definition of the problem. During this phase, team members begin interdisciplinary research (activity 2) in an attempt to develop potential solutions to the problem. Armed with a potential solution, the team proceeds, as in the OPP approach, to the testing and adaptation (activity 3) phase, usually started at the research station and followed by on-farm testing. In cooperation with the farmer, potential solutions are compared with existing farming practices. It may be necessary to repeat stages 2 and 3 (research, testing, and adaptation) several times before reaching a solution adapted to the farmer's needs and resource endowment. The farmers, in cooperation with scientists, make a final evaluation (activity 4) of the technology under existing farm conditions using their own resources and management. Eventually, the farmer accepts or rejects the technology. If rejected, further research determines the reason for rejection and may find ways to improve the performance and acceptability of the technology. If the technology is accepted and used by farmers, scientists monitor the farmers' modifications, which can often be incorporated into prototypes for introduction elsewhere. The impact of the technology is also monitored to determine if and how it is beneficial for farmers and consumers.

The farmer-back-to-farmer model is the focus of CIP storage courses. Although complete monitoring of farmer adoption has not been possible, it is known that the storage principles have been adopted by large numbers of farmers in Peru, Colombia, Guatemala, Sri Lanka, and the Philippines. The storage case illustrates how early and continuous input from social scientists can contribute to the efficient development and dissemination of technologies adapted to the needs and resources of small-scale farmers.

Value of Informal Surveys and Simple On-Farm Trials

Surveys

When microlevel information is needed for planning or evaluating development programs, formal questionnaires are usually applied. Experience with a range of survey procedures has led to the conclusion that, in many cases, informal surveys or *sondeos*, as described by Hildebrand (1981) and Rhoades (1982), are more time and cost effective than formal survey techniques. This is not to say that formal survey techniques are no longer used or recommended, but it is believed that informal surveys have far greater value for research and development programs than has been realized to date.

At this point, it is important to clarify what is meant by informal surveys or *sondeos*. They may have many purposes and use different procedures, depending upon the goals, local conditions, and resources available. Their common elements, however, are that (1) they are problem oriented; (2) they employ informal conversations rather than written questionnaires; (3) they are ideally conducted by interdisciplinary teams; and (4) as the survey evolves, the team focuses increasingly upon specific problem areas.

In what is believed to be the ideal farm-level research sequence, an interdisciplinary team first conducts an informal survey of farmers, market agents, ministry officials, and other key informants. This phase of the research is designed to identify major agroecological zones and farm types

and establish tentative rankings of production problems and potential solutions. The informal survey is then followed by a single-visit survey of farmers, which is focused on the key technological and socioeconomic areas identified in the informal survey. Both of these surveys should be completed within a relatively short period of time, leading up to the planning and installation of on-farm experiments. A multiple-visit survey of farmer collaborators and their neighbours is then conducted during the execution of the on-farm trials.

In collaborative research projects with national institutes, it has been noted that most researchers, i.e., both social and biological scientists, have a strong preference for formal questionnaire surveys over the informal survey approach. They generally believe that the "hard" data generated from a questionnaire is more valid and useful than the impressionistic results of an informal survey.

Several problems have been noted with questionnaires that can be avoided with informal surveys. First, there is a tendency to produce the questionnaire in the office and delegate to hired enumerators or extensionists responsibility for conducting the fieldwork. Often, the data gathered are of poor quality and do not provide a solid basis for planning on-farm trials. In many cases, better results could have been obtained if the project leaders had spent a few days in the field.[11] Second, in multidisciplinary projects, responsibility for questionnaire surveys is often delegated to social scientists who have little understanding of production technology. Hence, the survey results are too general to be useful to production specialists or data have not been obtained on key technical variables. Third, timely planning and implementation of formal surveys and analysis of the results can be extremely time consuming. Researchers can easily lose enthusiasm for a questionnaire survey if the results are not ready in time for planting the next season's crop. A major advantage of the informal survey is that it can be conducted and analyzed quickly, allowing experiments to be installed before the on-farm research program loses momentum.

A final very important but seldom appreciated point is that the interaction of researchers carrying out the informal survey initiates or helps consolidate a spirit of cooperation and understanding among scientists and with farmers.

On-Farm Trials

A number of types of trials have been proposed for on-farm research ranging from complex, replicated factorial trials (De Datta et al. 1978) to simple demonstrations. Although most farming-systems researchers would agree that some attempt should be made to compare alternative technologies with current farmers' practices, there is no general agreement on how this should be carried out. In some cases, an attempt is made to simulate each of the farmer's practices in each trial. In others, some notion of "average" or "representative" farmers' practices are included in all trials as a standard control treatment. In other cases, the results of the technology being tested are compared with the results in another part of the farmer's field that is outside of the experimental plot layout.

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[11]A recent study by Franzel (1983) concludes that relatively little is learned from a formal questionnaire survey after a well-conducted informal survey.

In the Mantaro Valley Project and subsequent on-farm research, each of these variants has been used, the conclusion being that each type of trial and each way of representing the farmer's current technology has a role to play in on-farm research. In general, most trials are kept simple and in each the farmer collaborator manages the control treatment in the trial as much as possible. This approach offers five advantages over the use of more conventional, replicated designs with uniform control treatments. (1) It forces the team to think hard, establish priorities, and focus research on what it considers to be the few most critical factors to be improved. (2) Simple trials are subject to lower measurement error, which is a major problem in on-farm work. (3) A research team can successfully manage a larger number of simple trials than complex ones. In most on-farm research situations, this is desirable (Gomez 1977). (4) Because complex, replicated trials take more field space than small trials and require closer management on the part of researchers, their use encourages research teams to work with relatively large-scale farmers whose fields are easily reached by road. For a number of reasons, the results of trials on these fields may not reflect the performance of technology on small farms located in more isolated areas. (5) Most farmers find it difficult to understand complex trials. Hence, to the extent that farmers' perceptions of technology are sought, trials should be kept simple.

A research program needs a range of types of experiments of varying complexity. However, in the research process complex trials should not necessarily come first and simple ones later, when the basic technology is "worked out" and ready for "packaging" or "transfer." In recent research with an entirely new technology, true potato seed (TPS), for example, some very simple on-farm trials have provided researchers with crucial information for orienting on-station work. Initially, it was believed that heterogeneity of tuber colour, shape, and other characteristics would be a major factor limiting the farmer's use of TPS. Early farmer reaction, however, indicated that seedling vigour was a much more important problem. This information has helped guide research at CIP and in national institutions.

Contributions of Social Scientists

A number of widely circulated publications on farming-systems research consider economists as necessary team members, whereas anthropologists and other social scientists are unnecessary or may merely be consulted when sociocultural problems need special attention (CGIAR 1978; CIMMYT 1981).

Experience from the Mantaro Valley Project does not support this view, however, and anthropologists' contributions to interdisciplinary teams were found to be no less important than those of economists or biological scientists. The holistic ecological framework and rapid, effective survey methods employed by the researchers were extremely useful throughout the research process. The publication by Mayer (1979) on land use in the Andes and the farmer-back-to-farmer model developed by R. Rhoades and R.W. Werge (anthropologists) in collaboration with R.H. Booth (pathologist) and R. Shaw (physiologist) represent two extremely valuable contributions to farming-systems literature. A comprehensive statement on the role of anthropologists at CIP is in preparation (Rhoades 1983).

Extrapolation of Research Results

As noted earlier, a common argument against farm-level research by the international centres is that the results are location specific. Prior to the Mantaro Valley Project and subsequent involvement with regional and national programs on farm-level research, there was no evidence to support or refute this point. It was found, however, that many of the results of the Mantaro Valley research — both empirical and methodological — were valid for other developing areas as well.

It is significant that the empirical evidence generated in the Mantaro Valley, with respect to the small-scale farmer, technological packages, and technology transfer, has been found to be relevant to CIP's work throughout the developing world. This is not to say that seed-potato programs have not worked anywhere, but in most developing areas they have encountered problems because the seed distributed was not always clearly superior to the seed available from existing sources. As well, it does not mean that technological packages never work or are never adopted by farmers, but to date there are extremely few cases in which packages have been adopted successfully.[12]

In the realm of methodology, it has been found that the farmer-back-to-farmer approach, first applied to storage problems in Mantaro Valley, is equally valid for other research problems. CIP is now using this model in its program to develop and transfer technology for producing potatoes from true, or botanical, seed (Monares et al. 1983). The concepts "agroecological zone" and "farm type," which were found to be useful for grouping potato farmers, understanding their farming systems, and evaluating alternative technologies, were later found to be equally valid in other research sites ranging from Yurimaguas in the Peruvian jungle (Bidegaray 1981) to Mountain Province in the Philippines (Potts 1983).

The research results that were found to be difficult to extrapolate were the estimated optimal levels and combinations of inputs. The optimal point on a given production function is highly location specific and can be expected to vary greatly over both space and time. For this reason, farmers reach their decisions on input levels on the basis of their own experimenta-

[12]Given the high response of dwarf wheat and rice varieties and the fact that farmers adopting the new varieties also increased their use of chemical fertilizer, it has become conventional wisdom that no single innovation is likely to be adopted by cultivators unless complementary inputs are also provided in a "package." As early as 1971, however, IRRI economist Randolph Barker noted that "the so-called package of inputs (including the seed itself) is still very much in the development stage.... Even at present, it is difficult to describe a precise package of inputs associated with the high-yielding varieties" (Barker 1971). Later IRRI studies documented that farmers were not adopting complete packages and that they were applying much less fertilizer than the levels predicted by either agronomic or economic analysis (IRRI 1978). CIMMYT economist Donald Winkelmann noted in 1976 that farmers were not adopting improved wheat and maize technologies as a package (Winkelmann 1976a,b). Based on extensive fieldwork in Turkey, Rockefeller Foundation economist Charles Mann concluded that farmers were adopting improved wheat practices in a sequence, depending on their expected benefit/cost ratio, rather than as a complete package of practices (Mann 1978). Farmers have reportedly adopted technological packages with hybrid maize in Kenya but, as Gerhart (1975) notes, the conditions surrounding this adoption were quite unusual. Walker (1981) presents an interesting perspective on the pros and cons of "package" versus "gradient" approaches.

tion. They often select what both biological and social scientists perceive to be nonoptimal input levels, but a growing body of farming-systems literature and many examples from the current work indicate how such sub- or supraoptimality in one component of the farming system may be consistent with optimality at the whole-farm or household level.

Present experience leads to the conclusion that applied research teams can maximize their contribution to development by discovering what principles can be applied to solve problems rather than attempting to determine optimal input levels and combinations. Unfortunately, most guidebooks on farming-systems or on-farm research offer procedures that are designed for estimating economically optimal input quantities rather than for problem identification or qualitative evaluation of alternative technologies (Perrin et al. 1976; De Datta et al. 1978; Zandstra et al. 1981; Shaner et al. 1982, Chapter 7).

Specific cropping systems are highly location specific. For this reason, there is little confidence in research that aims to design new cropping systems. In agreement with Ruttan (1981), it is concluded that the main contribution of interdisciplinary farm-level research is to provide information on the need for, and value of, improved components of existing farming systems.

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Appendix: Additional Research Reports, Publications, and Training Documents Resulting from the Project

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