A Decade of Learning

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

Agriculture, Food and Nutrition Sciences Division: The First Ten Years

The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activity is concentrated in five sectors: agriculture, food and nutrition sciences; health sciences; information sciences; social sciences; and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America, and the Middle East.

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

IDRC, Ottawa CA

IDRC-170e

Decade of learning : International Development Research Centre : Agriculture, Food and Nutrition Sciences Division : the first ten years. Ottawa, Ont., IDRC, 1981. 180 p. : ill.

/IDRC publication/, /IDRC/, /agriculture/, /food/, /nutrition/, /agricultural research/, /applied research/, /work programme/, /developing countries/ — /research projects/, /forestry research/, /fishery research/, /nutrition research/, /post-harvest systems/, /training/, /Canada/, /research centres/, /future/, /publications/.

UDC: 63.001.5 ISBN: 0-88936-297-1

Microfiche edition available

Il existe également une édition française de cette publication.
La edición española de esta publicación también se encuentra disponible.

IDRC-170e

A Decade of Learning

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE
Agriculture, Food and Nutrition Sciences Division:
The First Ten Years

To our friends in many lands whose good works
are pictured within

Contents

Preface

The international development community of today is filled with the rhetoric of concern for the problems of food, poverty, environment, etc., that plague the developing countries, but precious little of that rhetoric ever gets translated into specific actions that actually go toward the improvement of rural people's lives. *A Decade of Learning* is a synthesis of how the Agriculture, Food and Nutrition Sciences (AFNS) Division of IDRC has put this concern into operation in 400 research projects in 70 countries. The subjects have been diverse, including elephant grass, cassava, cowpeas, mussels, and village woodlots; the projects have spanned the globe and have been carried out in a manner that lends substance to IDRC's philosophy — to contribute but not to govern.

Unlike many other development-oriented publications, this one speaks of deeds and little of intentions for Joe Hulse, Director of the AFNS Division, and his staff have earned the rare credentials of having done it. They helped build research capacity and at the same time produced research results in some of the less likely places. In the past ten years they lavished attention on neglected crops, neglected lands, and neglected peoples by investing in the creation of new research structures dedicated to these areas of neglect, nurturing research networks across countries and continents, and tapping Canada's human research resources to backstop budding Third World scientists and their projects. The latter has been achieved unobtrusively and without the usual "pains" that accompany collaboration between the "haves" and the "have-nots." Although never loud on the virtues of the multidisciplinary approach, research projects have a built-in multidisciplinarity because they are conceived with social sensitivity and rooted in the farmers' system, which holds no academic boundaries. What better way is there of spending $73 million where it matters most?

This book comes at a time of growing consensus on the need to build research capacity in developing countries as a lasting answer to our continuing problems. For those who are engaged in this very difficult task, whether North or South, *A Decade of Learning* is a must for it is the voice of experience. As they say: "You name it, Joe Hulse and his staff have done it or at least have tried it." And if one can read beyond the pages, there is a special dose of personal commitment that does not readily translate into words but, hopefully, it will inspire those it touches.

Gelia T. Castillo
Professor of Rural Sociology
University of the Philippines at Los Baños

Foreword

In all things we learn only from those we love
— Goethe

In 1977, the International Development Research Centre published *Agriculture, Food and Nutrition Sciences Division: The First Five Years* (IDRC-089e), a review of all that the AFNS Division had attempted and accomplished between 1970 and 1975. *The First Five Years* turned out to be one of the Centre's most sought-after publications. Now that another 5 years have passed and IDRC's 10th anniversary has been celebrated, it seems timely to revise the earlier publication and bring it up to date.

The earlier publication followed the sequence of the Division's program of work and budget, the projects being presented under the Division's five program groups: Crops and Cropping Systems, Fisheries, Animal Sciences, Forestry, and Postproduction Systems. In this publication, the format has been changed and the projects and other activities are reviewed according to the geographical region in which they took place. The text is presented in four chapters: History, Philosophy, and Style; A Review by Geographical Region; What Has Been Learned; and The Future.

The first chapter gives a brief history of how the Division and its program developed; what have been its priorities; how these were chosen and pursued; the manner in which the Division's human, financial, and material resources were organized and managed; and the philosophy by which the program and the style of operation have been influenced and guided.

The second and longest chapter reviews the activities and projects supported in each of the principal developing regions: Africa, the Middle East and North Africa, Asia, and Latin America and the Caribbean followed by projects supported in Canada. Not every project is described in detail (a complete list appears in Appendix 1), but it is hoped that Chapter 2 will illustrate the scope and diversity of the program. Several projects have been reviewed more comprehensively than others to illustrate progress of particular interest or uniqueness.

The third chapter tries to answer the question: "What has been learned during the past decade?" It is the result of some soul-searching among the staff of the Division and includes a summary of written and verbal responses to the question addressed. On some issues there is a clear consensus, on others there is much difference of opinion. It will be helpful particularly to newcomers to international agricultural development but, being essentially a collection of subjective judgments, it is not offered as an infallible guide to the subject. It tries to look critically at what AFNS has done or left undone. It does not attempt a critical evaluation of individual projects or their leaders; these are best dealt with face to face.

The final paragraphs take a look into the future and attempt to foresee how the emphases and priorities may change and what are the various alternatives from which the architects of the next decade must choose. Clearly this final section must be regarded as speculative because it is the responsibility of IDRC's Board of Governors to decide upon the future program priorities and how the Centre's resources will be allocated.

Though this review deals with the program of work of the AFNS Division, tribute must be paid to the benefit and assistance that staff of the Division and the projects supported derive from other Divisions of IDRC and the Centre's Board of Governors.

Certain statements made in *The First Five Years* bear repetition: IDRC exists to encourage and support applied research, not itself to undertake research; the Centre may best be regarded as a catalytic agent and a provider of supporting services, services that help scientists in developing countries to define, plan, and direct applied research to improve the well-being of the rural poor.

Whatever has been attempted and accomplished is attributable to those scientists and institutions that it has been the Centre's privilege to encourage and support, and it is to them that this publication is dedicated.

The title *A Decade of Learning* seems appropriate because it is a record of what others have achieved and what the staff of the Division has learned by association with the scientists and technologists it has helped to sustain and from a continuing critical review of what others have described as IDRC's unique style of operation.

The text includes a synthesis of opinions and comments by AFNS staff and others with whom the program has been associated. I am grateful to all who have provided the material for this publication, but I accept personal responsibility for the final interpretation.

J.H. Hulse
Director
Agriculture, Food and Nutrition Sciences Division

Acronyms and Abbreviations

AEG — Agricultural Economics Group
AIT — Asian Institute of Technology
ALAD — Arid Lands Agricultural Development
ASEAN — Association of the South East Asian Nations
BARI — Bangladesh Agricultural Research Institute
BRRI — Bangladesh Rice Research Institute
CASAFA — Interunion Commission on the Application of Science to Agriculture, Forestry and Aquaculture
CATIE — Centro Agronómico Tropical de Investigación y Enseñanza
CGIAR — Consultative Group on International Agricultural Research
CIAT — Centro Internacional de Agricultura Tropical
CIBC — Commonwealth Institute of Biological Control
CIDA — Canadian International Development Agency
CIFRI — Central Inland Fisheries Research Institute
CIFT — Central Institute of Fisheries Technology
CIMMYT — Centro Internacional de Mejoramiento de Maíz y Trigo
CIMPA — Centro de Investigacion y Mejoramiento de la Producion Animal
CNRA — Centre national de recherches agronomiques
CRIA — Central Research Institute for Agriculture
CTCRI — Central Tuber Crops Research Institute
CUSO — Canadian University Service Overseas
EEC — European Economic Community
FAO — Food and Agriculture Organization of the United Nations
GASGA — Group for Assistance on the Storage of Grains in Africa
IADB — Inter-American Development Bank
IARC — International Agricultural Research Centre
IARI — Indian Agricultural Research Institute
ICA — Instituto Colombiano Agropecuario
ICAITI — Instituto Centroamericano de Investigación y Technología
ICAR — Indian Council of Agricultural Research
ICARDA — International Center for Agricultural Research in the Dry Areas
ICIPE — International Centre for Insect Physiology and Ecology
ICRAF — International Council for Research in Agroforestry
ICRISAT — International Crops Research Institute for the Semi-Arid Tropics
ICSU — International Council of Scientific Unions
IDRC — International Development Research Centre
  AFNS (Agriculture, Food and Nutrition Sciences Division)
  CD (Communications Division)
  HS (Health Sciences Division)
  IS (Information Sciences Division)
  SS (Social Sciences Division)
  ASRO (Asia Regional Office)
  EARO (East Africa Regional Office)
  LARO (Latin America Regional Office)
  MERO (Middle East and North Africa Regional Office)
  WARO (West Africa Regional Office)
IFDC — International Fertilizer Development Centre
IFPRI — International Food Policy Research Institute
IFRI — Inland Fisheries Research Institute
IITA — International Institute of Tropical Agriculture
ILCA — International Livestock Centre for Africa
INCAP — Instituto de Nutrición de Centro América y Panamá
INRF — Institut national de recherches forestières
INTEC — Institute for Technological Research
IRRI — International Rice Research Institute
IUFOST — International Union of Food Science and Technology

IUNS — International Union of Nutritional Sciences

IVITA — Instituto Veterinario de Investigaciones Tropicales

LDC — Less Developed Country: Latin America and the Caribbean area, Africa (other than South Africa), Asia (including Israel but excluding China, Democratic People's Republic of Korea, Mongolia, Vietnam, and Japan). UN Secretariat document E/AC54/L81

LLDC — Least Developed Country: Countries with a per capita GDP of U.S.$100 or less in 1968, manufacturing as a share of GDP is 10% or less, a literacy rate of 20% or less — UN Resolution 27681 of 18 November 1971

MARDI — Malaysian Agricultural Research and Development Institute

MSA — Most Seriously Affected (country): Formally defined by the United Nation's Emergency Organization (UNEO) in 1974 to include countries suffering severe adverse effects from increased oil prices

NGA — National Grains Authority

ONAREST — Office national de la recherche scientifique et technique

ONERSOL — Office national de l'énergie solaire

PCARR — Philippine Council for Agriculture and Resources Research

PRL — Prairie Regional Laboratory

RIIC — Rural Industries Innovation Centre

SAIS — Sociétés agricoles d'intérêt social

SAT — Semi-Arid Tropics

SEAFDEC — Southeast Asian Fisheries Development Centre

SEARCA — Southeast Asian Regional Centre for Graduate Study and Research in Agriculture

SISIR — Singapore Institute of Standards and Industrial Research

TAC — Technical Advisory Committee

TADD — Tangential Abrasive Dehulling Device

UNCSTD — United Nations Conference on Science and Technology for Development

UNDP — United Nations Development Programme

UNESCO — United Nations Educational, Scientific and Cultural Organization

UNU — United Nations University

UPEB — Unión de Países Exportadores de Banano

UPLB — University of the Philippines at Los Baños

USAID — United States Agency for International Development

WARDA — West Africa Rice Development Association

WBG — World Bank Group

WINBAN — Windward Islands Banana Growers' Association

Chapter 1

History, Philosophy, and Style

History

The Agriculture, Food and Nutrition Sciences (AFNS) Division of IDRC began in October 1970. Over the decade its program has been devoted to the encouragement and support of applied research for the benefit of rural people who constitute the vast majority of Africa, the Middle East, Asia, and Latin America and the Caribbean. At its first meeting, the IDRC Board of Governors agreed that AFNS should give first priority to the people of the semi-arid tropics (SAT) among whom, by any recognized economic or social criteria, the poorest and least privileged are to be found. Very soon after AFNS declared the SAT as its first priority, savage droughts focused the world's attention upon the chronic state of climatic and agronomic uncertainty and the tragic results of frequent yet unpredictable drought that afflict the Sahel, the SAT zone that borders the Sahara.

Though the term "semi-arid tropics" cannot be precisely defined, the SAT regions are characterized by poor soils; low and unreliable levels of rainfall; poor crop yields; and, in consequence, chronic malnutrition among the poorest people. Until the early 1970s, the SAT were regions of seriously neglected people, lands, and food crops.

The AFNS program seeks to stimulate applied research for the benefit of neglected rural people and to increase the productivity of lands and water, food crops, terrestrial and aquatic animals, and trees and other vegetation. The manner in which the program has sought to redress some of these earlier neglects forms the main theme of this publication.

Applied Research

Louis Pasteur wrote: "There are no applied sciences . . . there are only applications of science . . . ." Pace Pasteur, AFNS is dedicated to the support of applied research — research for human benefit. Whenever necessary, help is given to define whom the research seeks to benefit and how the benefit is to be delivered. The program, which has ranged over a broad spectrum of scientific complexity, technological competence, and experience, gives preference to projects carried out in close cooperation with the rural people they purpose to benefit.

Consonant with Pasteur's dictum, and contrary to some contemporary wisdom, sound scientific principles and methodologies are universally applicable and transferable; many technologies are not. Because they are influenced by and interact with the physical, social, and economic environments in which they exist, biological technologies are notably difficult to transfer from one place to another. Every developing country, therefore, needs its own research service that has the competence to modify and adapt new or improved technologies to its prevailing environment. In the AFNS context "research" can be defined as: "A logical and systematic progression from the known into the unknown." The more than 400 projects supported by AFNS include examples of simple adaptive research and of applied research of considerable diversity, complemented in some instances by fundamental research; the whole involving many levels of competence and experience in scientific techniques, methods, and management.

Philosophy

"Partners in Development," the report of the Pearson Commission on International Development, which provided inspiration for much of IDRC's philosophy, recommended greater support for research in developing countries and "that industrialized countries assist in the establishment of international, regional, and national centres for scientific and technological research in developing countries . . . ." The Pearson Commission recommended, specifically, centres that concentrate upon food supply and tropical agriculture.

The Division has contributed scientifically, administratively, and financially to the creation of several international agricultural research centres (IARCs). It also supports specific research programs in IARCs linked with networks of projects supported by the Centre in developing countries.

Some scientists subscribe to the theory of the better mousetrap; that scientific excellence and ingenuity will generate their own demand and of themselves bring forth social benefit. Because this is rarely the case, the Division includes a small Agricultural Economics Group (AEG) that, together with the other program groups, helps recipients to identify who will benefit from the research and to ensure that adequate consideration is given to relevant social and economic factors.

A Systematic Approach

It is contemporary to advocate multidisciplinary research despite the fact that many, perhaps most, scientists are educated in specialized disciplines and relatively few in the management and systematic integration of technical, economic, and social sciences to a common purpose. Many research institutions, particularly in the least scientifically developed nations, are neither structured nor organized to pursue research that requires the balanced input of a diversity of disciplines. Nevertheless, however modest the project's scope, the AFNS staff encourage and help define a systems approach that comprehends those whom the research is intended to benefit and the social, economic, and physical environment of the intended beneficiaries.

A systematic approach in project planning, implementation, and adaptation of the results serves to short-circuit the traditional research sequence that begins with research in a laboratory or experimental farm followed by demonstration and "extension," leading eventually to adoption by rural artisans. A systems philosophy requires that the research begin with a broad understanding of the relevant rural communities and that much of the research be undertaken cooperatively with recipients.

Among the least scientifically developed countries, relatively simple projects predominate. Among countries where institutional and human capability permits, one finds more complex projects that involve multiple cropping, fish polyculture, and farming systems in which animals and/or tree species are integrated with crop production and postproduction systems. The integration of post-production with production research is bearing fruit in several countries where, in addition to crop yield and production potential, attention is given to edible quality, utility, stability, marketing, and distribution of food products.

Style and Scope

The IDRC style of operation and its support for indigenous effort, untrammeled by the exigencies of tied aid, appear to be attractive to governments and research institutions in many developing countries. The AFNS Division receives more requests than can be supported with the financial and human resources at its disposal. Though several agencies have examined IDRC's style, relatively few operate with the Centre's flexibility and degree of freedom.

Tables in Appendix 1 present a summarized statistical record of the AFNS program over its first 10 years and the manner in which the program has grown by budget and number of projects. In addition to those recorded in the tables, the Division has managed 36 special projects financed to the extent of $9 million by the Canadian International Development Agency (CIDA), together with more than $7 million IDRC has administered as executing agency for the Consultative Group on International Agricultural Research (CGIAR) and other donor groups.

The CGIAR, of which IDRC was one of the founding members, is an informal consortium of donor agencies and representatives of developing countries and is sponsored by the World Bank, the United Nations Development Programme (UNDP), and the Food and Agriculture Organization of the United Nations (FAO). The CGIAR supports a variety of IARCs, each dedicated to increasing food production in developing countries. Each Centre is staffed by experienced scientists drawn from a broad range of relevant disciplines. The IARCs develop improved crop cultivars, maintain germ plasm (breeding stock) banks, evolve agricultural research methodologies, and provide training facilities, all of which are available to agricultural scientists in developing countries. (A list of IARCs and their responsibilities is given in Appendix 2.)

The IARCs play an essential role in several AFNS program networks. IDRC has contributed financially to specific programs within selected IARCs including cropping systems at the International Rice Research Institute (IRRI), legume improvement at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Center for Agricultural Research in the Dry Areas (ICARDA), and cassava research at

Cropping systems research at IRRI.

the Centro Internacional de Agricultura Tropical (CIAT) and the International Institute of Tropical Agriculture (IITA). Simultaneously, AFNS supports cropping systems projects, legume research, and root crop improvement research in several countries, and each group of related national projects is integrated into cooperative networks that draw upon the relevant IARC for planting materials, research methodologies, scientific advice, and training.

The Division cooperated with the Ford Foundation in creating ICRISAT, the first of the new IARCs to be sponsored by the CGIAR; it financed and provided leadership for the team that defined the scope of ICRISAT's program in the SAT of Africa. The CGIAR invited IDRC to act as Executing Agency, first for the creation of the International Livestock Centre for Africa (ILCA) with headquarters in Addis Ababa, Ethiopia, and later in the establishment of ICARDA, which, in spite of regional political adversities, has elaborated an impressive research program in crops and farming systems of importance to the Mediterranean, the Middle East, and North Africa.

At the request of the Chairman of the Technical Advisory Committee (TAC), the group of scientists that advises the CGIAR on its priorities and IARC programs, the Division supported missions that studied, reported, and recommended priorities for postharvest research in Asia and Africa, aquaculture research in Asia, and a strategy for research in water management.

More recently, IDRC supported a study that led to the creation of the International Council for Research in Agroforestry (ICRAF), with headquarters in Nairobi, Kenya, dedicated to improved land use through the integration of tree species into farming systems. On behalf of a consortium of donors that, at present, functions outside the CGIAR family, IDRC has acted as Executing Agency during the formative years of ICRAF. Also outside the boundaries of the CGIAR, but on behalf of several of its members, the Centre acts as Executing Agency for a network of research and training projects in Southeast Asian countries, each related to one or more aspects of postharvest rice systems.

The Division is one of the founding members of the Group for Assistance on the Storage of Grains in Africa (GASGA), which has worked cooperatively to improve postharvest conditions for cereal and legumes and has formulated a comprehensive statement of priorities for postharvest research in developing countries. The Division also provides the Chairman to the Interunion Commission on the Application of Science to Agriculture, Forestry and Aquaculture (CASAFA) created following the United Nations Conference on Science and Technology for Development (UNCSTD) by the International Council of Scientific Unions (ICSU).

Networks

In those areas of the Division's program for which no relevant IARC exists, including fisheries, forestry, postproduction systems, and in large part animal sciences, other forms of technical support for project networks have been devised. One takes the form of network technical advisers, individual or small teams of experienced scientists and technologists who, like circuit riders, regularly visit projects united in the network by a common interest or a related technological theme. Network advisers provide technical advice, assist in the accumulation and exchange of germ plasm among projects, and arrange periodic workshops where scientists from different countries share their results and exchange experience in matters of common interest.

It is a Divisional priority to establish and maintain communication among different projects that share common interests or related goals. Few research institutions in developing countries possess human and financial resources sufficient to sustain all the research needed in agriculture, forestry, fisheries, postproduction systems, and the basic sciences upon which all applied research depends. Countries that share similar agroclimatic, economic, and social conditions often best serve their own and each other's needs by cooperation and regular intercommunication. The postharvest rice research network and its team of technical advisers is described in detail in the Asia section of Chapter 2. The Division supports more than 20 research projects in social forestry, i.e., forestry by and for the benefit of local communities, in countries that surround the Sahara and other semi-arid regions of Africa. At the outset, forestry research directors from several SAT countries mapped out a comprehensive and integrated program of research more diverse and demanding of resources than any individual country could provide but to which each country now contributes a significant input. To stimulate progress and cooperation, the Division provides two African forestry research advisers who combine many years of experience in forestry research and development in Africa and the Middle East with fluency in Arabic, English, and French. These two advisers regularly visit each of the projects in the network and occasionally bring the project leaders together for a collective review of progress.

Fundamental Studies

Virtually all applied research, whatever its scope or scale, is eventually constrained by obstacles and difficulties that call for studies of a more fundamental nature. Approximately 10% of the AFNS program projects took the form of grants mostly to Canadian institutions for fundamental research to complement applied research in other countries. Under the newly created Canadian Cooperative Programs Unit with its promise of increased funds from the Government of Canada's pledge to UNCSTD, it is hoped that cooperation between Canadian research institutions and those of the developing world can be substantially expanded and diversified.

During the decade fundamental research supported by AFNS has resulted in the generation, through plant tissue culture, of disease-free cassava from infected plants; the chemical means by which parasitic weeds that depredate tropical cereals and legumes can be induced to germinate and, in the absence of a host, to die before the cereal or legume is planted; the isolation and identification of the naturally occurring polyphenolic tannin that both increases the resistance of sorghum to attack by birds, moulds, and possibly insects, and at the same time significantly reduces the nutritional quality of the grain; microorganisms that under tropical conditions increase by fermentation the protein content of cassava and other starchy substances; the identification and microanalyses of the hormones that regulate the tolerance of sorghum to continual or periodic drought stress; and a greater understanding of the etiology and pathology of trypanosomiasis, the tsetse-borne disease that afflicts large African cattle populations.

Almost all of these fundamental studies have involved graduate or postdoctoral scientists from developing countries. Thus, they serve to alleviate specific difficulties; to increase the capability of scientists of the developing world; and to establish cooperation and, one hopes, mutual sympathy between scientists in Canada and other nations.

The Information Sciences (IS) and the Communications Divisions (CD) of IDRC in cooperation with AFNS provide a variety of support services including films and slide presentations; computer print-outs, summaries and abstracts; and state-of-the-art reviews, some published by the Centre, some by commercial publishing houses (a list of all AFNS publications is found in Appendix 3). The Division also sponsors working groups to identify specific research needs, to lay the basis for new research networks, and to review the state of knowledge in subjects of rural importance. For example, early in 1980, together with the United Nations University, two international scientific unions, and several other agencies, IDRC sponsored a working group that met at the United Nations Educational, Scientific and Cultural Organization (UNESCO) in Paris, France, to review what is known of the nutritional status of the rural people of the African Sahel (see *Nutritional status of the rural population of the Sahel: report of a working group, Paris, France, 28-29 April 1980*. IDRC. Ottawa, 1981. IDRC-160e, 92p. Also available in French IDRC-160f).

Administration and Organization

Administratively, the Division's program is organized in a conventional manner according to groups of related disciplines. Each disciplinary group has developed its organization and program pattern individually according to the needs perceived by the program's associate director and his colleagues. For example, the Crops and Cropping Systems group is spread across the continents, however, the Postproduction Systems group is located as a unit at the University of Alberta.

Crops and Cropping Systems The Crops and Cropping Systems group has administered more than 44% of the 400 projects approved and slightly more than 50% of the total AFNS program budget appropriated during the decade. The average cost of a crop science project has been close to $250 000; the average duration 35 months. Over the decade projects were supported in 46 different countries, 27% in Africa, 25% in Asia, 21% in Latin America, 14% in the Near East, and the balance mainly in Canada. Considering that the poorest rural people of the developing countries derive at least 60%, and in some instances close to 90%, of their food energy and other essential nutrients from edible plants, it is not inappropriate that crops and cropping systems have absorbed the largest share of the Division's budget.

The program has concentrated upon relatively neglected food crops including the principal cereals, legumes, and oilseeds of the SAT; cassava and other root crops that provide the main source of subsistence for more than 300 million people; oilseeds, which could reduce the need to import edible vegetable oils; and bananas and plantains, neither having received attention commensurate with their importance as local food crops. To increase the returns to land and labour on smallholder farms, research on cropping systems has been promoted first in Asia and more recently on other continents. It is envisaged that in the future there will be a greater concentration upon farming systems research, taking advantage of the methodologies evolved in Asia and adapted more recently in Latin America. The cropping systems methodology is based upon a bottom-up rather than a top-down philosophy. Each research project begins with a comprehensive study of the farmers, their traditions, resources, constraints, opportunities for greater productivity, and the risks attendant upon whatever technological change is foreseen. The methodology requires that much of the research be undertaken in farmers' fields where the tolerance of new cultivars and cropping systems to the prevailing environment can be compared with those well established. Fig. 1 illustrates the concept of the cropping systems research methodology and Fig. 2 shows the interrelationship of the variables that constitute the "family farm," the basic unit of analysis.

Animal Sciences The Animal Sciences program disbursed roughly 14% of the 10-year budget in support of 49 projects at an average cost of $230 000 and an average duration of 35 months. Projects have been established in 21 countries, 53% in Latin America, 14% in Africa, 12% in the Middle East, 10% in Asia, and the balance in Canada.

Because, in terms of biological energy conversion and land use, it appears more efficient for humans to consume plants directly rather than through intermediate animal products, many commentators do not speak favourably of animal production research. Such disfavour is reasonable when cereal, legume, oilseed, or edible root crops that are suitable for direct consumption by human beings are fed to animals. Nonetheless, farm animals can convert many forms of vegetation, agricultural by-products, and rural and industrial wastes into milk, eggs, meat, and other edible products.

The program, therefore, gives priority to animal production systems that embody improved pastures on marginal lands unsuited to food crops and to the utilization of agricultural, industrial, and domestic by-products unsuitable for direct human consumption. Research on native and well-adapted animal breeds that survive and thrive more successfully than exotic animals is of special interest in the program.

Fisheries Forty-two fisheries projects were approved at an average cost of approximately $220 000 and an average duration of 35 months. Fisheries projects were supported in 20 countries, 38% in Asia, 30% in Latin America, 14% in Africa, 10% in the Middle East, and the balance in Canada. Fisheries research has fallen into two broad categories: aquaculture and mariculture — the cultivation of aquatic plants and animals in fresh, brackish, and maritime coastal waters; and the improvement of artisanal fisheries.

Most projects concentrate upon fish as food for poor rural communities although a few recognize the importance of fish as a cash commodity. Aquaculture and mariculture projects have included breeding; disease control; cage culture; and other management systems for fresh, brackish, and saltwater species. In the future, more investment may be directed to aquatic plants and to artisanal coastal and lake fisheries, including low-cost energy-efficient technologies for small-scale fisheries.

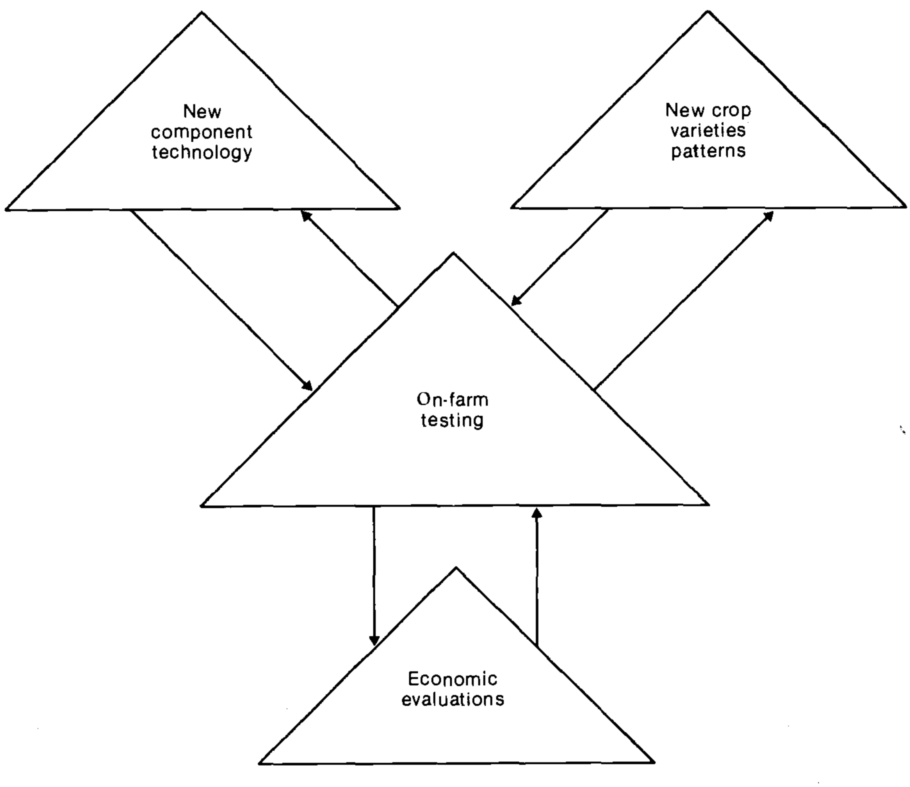


Fig. 1. Cropping systems research methodology.

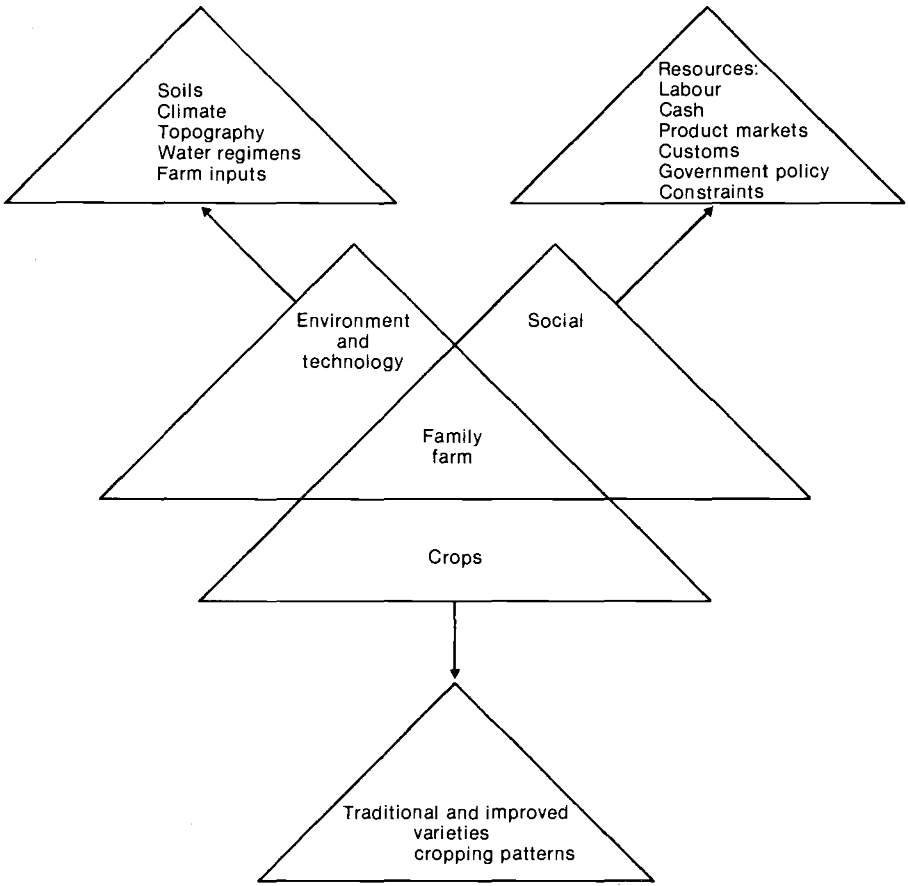


Fig. 2. Multiple cropping systems.

Forestry Forty-two forestry projects were approved at an average cost of $225 000 and an average duration of 38 months. Close to 57% of the projects were in Africa, 17% in Latin America, 17% in the Middle East, and 7% in Asia. Forest products provide the only source of fuel for more than one-third of the world's population. In rural West Africa the purchase of fuelwood absorbs more than 35% of the income and women spend many hours walking long distances to collect firewood to heat their homes and cook their food. Therefore, priority has been given to social forestry research, such as the establishment of village woodlots and tree crops to provide fuel and construction materials for homes and farm structures. Fast-growing, drought-tolerant, wood-producing species are cultivated that, through their deep root nutrient pumping systems, provide fodder for farm animals and/or fertilizer in the form of leaf litter for other crops. Close to the Sahara, projects seek to develop tree shelter belts to protect food crops and arable land against desiccating winds and drifting sand.

Postproduction Systems The Postproduction Systems program has sustained 91 projects at an average cost of slightly under $100 000 and an average duration of 31 months. Almost 41% of the postproduction projects were in Asia, 31% in Africa, 9% in the Middle East, 9% in Latin America, and the balance in Canada. The Postproduction Systems program has concentrated upon harvesting; drying; storage; processing; distribution; and consumption of cereal grains, food legumes, and root crops. More recent projects are dedicated to the preservation and processing of fish, oilseeds, tropical fruits, and vegetables. Overall objectives of these projects include the orderly integration of production and postproduction systems; the stimulation among plant scientists of a concern for edible quality and utility as well as agronomic superiority; and an awareness among food scientists of the influence of genetic and agronomic history upon properties that control nutritional quality, stability in storage, and other important postharvest attributes.

Because postproduction systems embrace all essential activities from harvesting to the end product, i.e., whatever form is eaten by the consumer, the Postproduction Systems group has sought to generate, among developing countries and the international community of donors, an awareness of the importance of a total systems approach to postproduction technologies. (A total postproduction grain system is illustrated in Fig. 3.)

Agricultural Economics Group The Agricultural Economics Group (AEG) provides a service complementary to the other five program groups in project identification, definition, implementation, and evaluation. The AEG makes sure that adequate attention is given to microeconomic and social factors and to the consequences and benefits to be realized from the applied research supported. The AEG helps to design research methods that take account of the needs, attitudes, and constraints of those producers, processors, distributors, and consumers that each project is intended to benefit.

AFNS Staff Though AFNS does not direct research, the program described was in large part made possible through the efforts of the Division's experienced scientific staff, from each of whom three essential qualities are required: a high degree of relevant professional research competence, direct experience of research in developing countries, and personal dedication to serving the needs of the rural poor. Of the 15 scientists involved in the six programs mentioned above and the Operations Group that is responsible for technical administrative support, more than half have served the Centre for more than 8 years. Collectively, the AFNS staff represents roughly 250 person-years of experience working with developing countries and international development programs. The older members of the AFNS family came after having gained experience with other scientific assistance agencies; the great majority of the younger members gave earlier service in developing countries with such agencies as the Canadian University Service Overseas (CUSO) and the Peace Corps.

Over the past 5 years the staff has remained relatively constant in number. In 1975 there were 20 professionally qualified persons; at present there are 22. During the fiscal year 1975-76 the Division was responsible for 117 active projects and new projects were coming in at a rate of about 40 per year. In the present fiscal year, 1980-81, there are more than 210 active projects and approximately 65 new projects will probably be approved in the next year. The numerical ratio of projects to scientific staff is roughly double

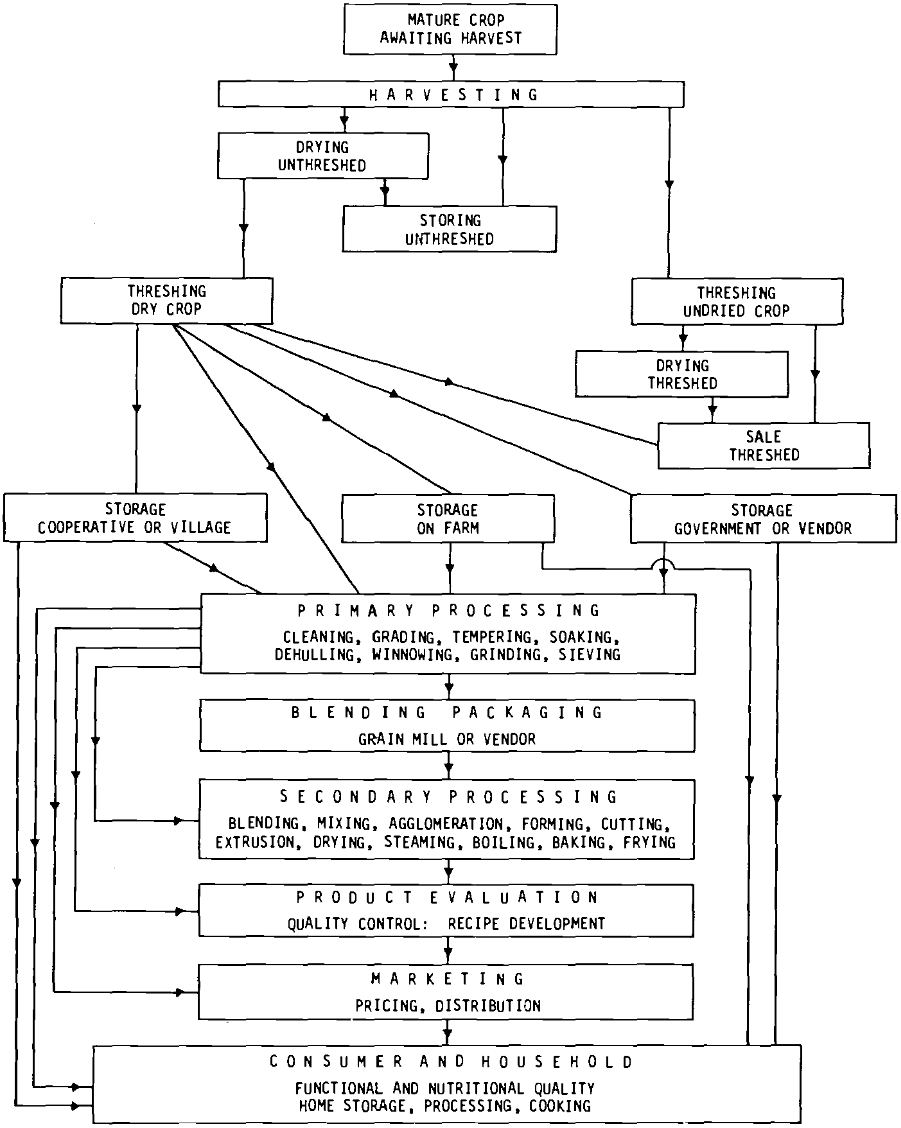


Fig. 3. A total postproduction grain system.

what it was 5 years ago. In the fiscal year 1975-76 the average cost per project was approximately $236 000; the 1979-80 project cost averaged $214 000. Because of inflation and the de facto devaluation of the Canadian dollar, the Division's purchasing power was little greater in 1980 than in 1975.

A desk in Ottawa is not an ideal place from which to judge agricultural research needs in other countries. Therefore, from the beginning, most of the AFNS program staff were based in developing countries or in Canadian universities strong in relevant disciplines. The associate directors of fisheries and animal sciences work from the University of British Columbia, the Postproduction Systems group is at the University of Alberta and, until recently, the associate director of forestry was based at Laval University. The Crops and Cropping Systems group is spread over several developing countries of Asia, the Middle East, and Latin America. The first two associate directors of Animal Sciences were located in Colombia; one Fisheries officer is in Singapore; and other program staff are to be found in Senegal, Kenya, and Singapore.

This pattern of dispersion and decentralization serves to maintain a lively awareness of the current opportunities and difficulties in the developing countries, together with a greater concentration upon scientific research and rural development than upon urbanized bureaucracy.

In many projects the scientists work in relative isolation and without regular IDRC contact and support they would have little opportunity to meet, communicate with, or learn from other research workers with similar interests and activities. Consequently, much of AFNS staff time is taken up in visiting projects, not simply to ensure satisfactory technical progress but, more important, to give advice and encouragement and to provide access to relevant sources of information. It is a matter of considerable concern that the increased ratio of projects to AFNS staff has resulted in less frequent personal contacts than occurred during the first 5 years.

In the fulfillment of its role and responsibilities, the Division's scientific staff is in travel for an average of 128 days, some for more than 170 days every year. The stipulated working year of the headquarters staff is 220 days. The contribution to the Division by the spouses and families who contend successfully, and more or less cheerfully, with long and frequent separations deserves special recognition.

Response for the Future

The contemporary hue and cry about fossil fuels among the rich of both developed and developing countries is obscuring what is of far greater seriousness to the vast majority of the world's people: the decline in per capita production and continued escalation in the cost of essential foods. The FAO, the World Bank Group (WBG), and the International Food Policy Research Institute (IFPRI) all present pessimistic forecasts of food availability during the next 2 decades. Table 1 shows the change in per capita food production by continents between the 1960s and 1970s. Only in Asia, where

Table 1. Change in per capita food production between the 1960s and 1970s (%).

	1961-70	1970-78
Africa	0	-1.3
Asia and Far East	0.2	0.5
Latin America	0.7	0.6
Near East	0.5	0.4
All developing countries	0.4	0.2
Poorest developing countries (less than $200 per capita)	0.1	-0.1
Developed countries	2.4	2.2

Source: FAO statistics

the higher yielding cultivars of rice and wheat have been widely adopted, is a modest increase evident. Recent surveys indicate that while total food production in Africa increases at about 0.5% per year, population increases by 3% and food demand by 5%.

Hopefully IDRC's support of applied research will help bring some early relief to this sorry situation and kindle hope that in the future the less developed nations will enjoy a more equitable share of the world's resources.

The following chapter describes projects carried out by scientists, technologists, and rural people in more than 60 developing countries and supporting research undertaken in Canada. In a few instances the results have been spectacular; in most, the progress justifies the confidence placed in those by whom they were designed and executed. The whole illustrates the potential benefits to poor rural people from a relatively modest investment in applied research.

Chapter 2

Africa

For administrative convenience, and to some extent for ethnological and agroclimatic reasons, IDRC activities in Africa are classified according to the countries served by its three regional offices: East Africa Regional Office (EARO), Nairobi; West Africa Regional Office (WARO), Dakar; and Middle East Regional Office (MERO), Cairo. The Maghreb countries of Morocco, Tunisia, and Algeria are included with Egypt, Sudan, and those developing countries and their neighbours that surround the eastern end of the Mediterranean.

Including the North African countries, the African continent may be regarded as a plateau with a land area of close to 3.0×10^7 km^2, which represents 25% of the world's land mass, 40% of which is steppe or desert and 33% savanna. The elevated plateau, at an altitude between 500 and 1500 m, represents two-thirds of the total continent, while the remainder consists mainly of three large depressions: the Sahara in the north, the Kalahari basin in the south, and the Congo River basin in the centre.

Phytogeographically, Africa is composed of three zones: the northern subtropical zone bordering on the Mediterranean in the north and merging into the Sahara to the south; the equatorial zone, which falls largely within the tropics; and, the south African zone. In all three zones rainfall varies widely from arid or semi-arid to the heavy precipitation of the humid tropics. If one excludes the major oil exporters of the north and the industrialized south, the rural population represents between 80 and 90% of the total of more than 400 million people. At the same time, the urban growth rate of more than 5% is among the highest in the world. More than 60% of the total cultivated area of tropical Africa is devoted to subsistence farming though Africa produces one-third of the world's coffee and three-quarters of its cocoa. Agriculture accounts for 36% of Africa's gross national product and 60% of its export revenue. Sixty percent of the land and 80% of the labour force is given to subsistence production.

With few exceptions, Africans, particularly those of the arid and semi-arid tropical regions, are among the poorest and least technologically developed of the world's underprivileged. Of its 74 countries, 27 are classed as Most Seriously Affected (MSA), 20 as Least Developed Countries (LLDCs), and 27 as Less Developed Countries (LDCs) (see the list of Acronyms and Abbreviations for a definition of these classifications).

In spite of the dominance of subsistence agriculture, population growth exceeds the increase in food crop production and it is anticipated that by 1985 food grain deficiencies throughout the poorest countries will be close to 1.5×10^7 t. Because of the inferior legacy in science and technology inherited by many African countries from their former colonial masters, it is generally the most difficult continent on which to pursue IDRC's chosen policy of support for existing indigenous scientific effort. Nevertheless, given the heavy dependence upon subsistence agriculture, it is in Africa that one encounters the greatest need to combat rural poverty through agricultural research and development. Consequently, in spite of the recognized difficulties, close to 30% of the 436 projects approved for AFNS support have been undertaken in African countries south of the Sahara. Almost 15% of the total budget of the decade has been invested in West Africa, about 8% on 21 projects in the Sahelian countries of Senegal, Mali, Upper Volta, and Niger.

The Division gave its first priority to the semi-arid tropics and some of its earliest projects included grain milling and utilization; sorghum breeding and grain preservation; sorghum intercropping; and sorghum, finger millet, and pigeon pea improvement, all in African SAT countries. Before the droughts of the early 1970s drew the attention of the world to the Sahel, the Division had recognized the plight of the people of the SAT countries of Africa where soil deterioration was aggravated by overgrazing and/or overcultivation, the vegetative cover being destroyed, the soil exposed to wind and rain erosion, a process that in many areas appeared almost irreversible. A great deal of research was then and is still required to encourage and train African scientists to develop more conservative and orderly farming systems based upon accepted, well-adapted cereal and legume grains and other food crops.

Also recognized was the heavy dependence upon wood as the only source of fuel and the need to combine trees with other components of the rural economies to protect soil and crops from searing winds and blowing sand, as materials for building and fencing, as forage for animals, and as fuel for cooking and heating homes. It was discovered that many African women devote almost 10 h every day to fetching water and fuelwood and to pounding grain. As a result, in addition to agronomic research on food crops of the SAT, the Division has supported more than 20 social forestry projects and close to 20 postproduction projects, most related to postharvest storage and processing of subsistence cereals and legumes. IDRC's Health Sciences (HS) Division gives its attention to problems of rural water supply and sanitation. Table 2 presents the total appropriations and number of projects in African countries.

Crops Research

More than 25% of the projects and appropriations for crops research have been invested in 17 African countries. From the beginning priority was given to sorghum; pearl millet; and later to the drought tolerant legumes grown by subsistence farmers in East, West, and North Africa and the Middle East. The associate director was a member of the mission that laid the basis for the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and he led the team that first defined ICRISAT's African cooperative program.

Sorghum

The Ethiopian sorghum improvement project, which began in 1972, is

Table 2. Total appropriations and number of projects in African countries.

Country	Crops and Cropping Systems		Fisheries		Animal Sciences		Forestry		Postproduction Systems	
	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects
Botswana									205 (100%)	2 (100%)
Burundi	251.8 (100%)	1 (100%)								
Cameroon	546 (71%)	2 (66%)					220.5 (29%)	1 (34%)		
Congo Brazzaville	105 (100%)	1 (100%)								
Ethiopia	2227 (90%)	7 (78%)			150 (6%)	1 (11%)			108.3 (4%)	1 (11%)
Ghana			527.1 (45%)	1 (14%)			347.3 (30%)	2 (29%)	284.5 (25%)	4 (57%)
Kenya	804.7 (17%)	5 (28%)	197.1 (4%)	1 (6%)	1440 (31%)	4 (22%)	2140 (46%)	6 (33%)	72.4 (2%)	2 (11%)
Malawi							203 (100%)	1 (100%)		
Mali	700 (49%)	2 (25%)					504.6 (35%)	3 (37.5%)	216.4 (16%)	3 (37.5%)
Mozambique	271.3 (100%)	1 (100%)								
Niger	153 (28%)	1 (25%)					306.2 (57%)	2 (50%)	80.7 (15%)	1 (25%)
Nigeria	565.2 (29%)	3 (25%)			283.2 (14%)	2 (17%)	821.9 (41%)	4 (33%)	323.3 (16%)	3 (25%)
Rwanda	197 (42%)	1 (50%)	276.1 (58%)	1 (50%)						

Senegal	2558.6 (67%)	5 (46%)					709 (19%)	3 (27%)	542.1 (14%)	3 (27%)
Sierra Leone	126 (19%)	1 (16%)	321.8 (48%)	2 (34%)					228.2 (33%)	3 (50%)
Somalia	276.9 (100%)	1 (100%)								
Swaziland	143.4 (95%)	1 (50%)							7 (5%)	1 (50%)
Tanzania	123.7 (73%)	5 (56%)					238.2 (14%)	2 (22%)	212 (13%)	2 (22%)
Togo	53.4 (22%)	1 (50%)	190.1 (78%)	1 (50%)						
Upper Volta	734.4 (80%)	3 (60%)							187.3 (20%)	2 (40%)
Uganda	882.4 (100%)	5 (100%)								
Zambia									101 (100%)	1 (100%)

among the best illustrations of what IDRC's founders had in mind when they emphasized the need to support indigenous effort. Sorghum is truly indigenous to Ethiopia and is grown over at least 10^6 ha by subsistence farmers at altitudes ranging from sea level to more than 2500 m. Ethiopia is the home of many wild and cultivated sorghum types that contribute to its own breeding and selection program and are distributed to sorghum breeders throughout the world.

The first phase of the project began modestly at the Alemaya College of Agriculture of Addis Ababa University. Subsequently, in spite of many political and other adversities, the project blossomed to become the coordinated Ethiopian National Sorghum Improvement Program. The research started by screening existing sorghum germ plasm collections and by crossing superior types best suited to the Ethiopian highlands. Later the activities were expanded to include types suited to lowland and/or highland conditions, an objective that called for large-scale screening of indigenous materials and germ plasm from other sorghum-breeding programs; extensive agronomic and on-farm trials; and studies of pre- and postharvest production, together with research on cooking quality.

More recently, the project has sought sorghum types resistant to the parasitic weed *Striga*, which causes serious depredation of the crop. The production program is now integrated with sorghum milling and utilization research, referred to later under the postproduction systems activities. Altogether, more than 5000 entries of indigenous sorghum types have been classified into a collection that demonstrates a wide range of genetic diversity. Of potential nutritional importance, not yet exploited, was the discovery of an Ethiopian sorghum with a genetically controlled high lysine content. Unfortunately, this high lysine type displays inferior grain quality and plant breeders have not been able to combine the high lysine trait with the desirable characters of a plump grain.

When the research began, average on-farm yields of sorghum were less than 1 t/ha. The project has identified cultivars now released to farmers that yield 3-4 t/ha and some recently developed hybrids yield 7-8 t/ha under rainfed lowland conditions. Varieties of breeders' seed with a yield potential of up to 8 t/ha under rainfed highland conditions are being multiplied by the Ethiopian Seed Corporation.

Perhaps more significant, in terms of its development implications and the technical achievements of the project, has been the establishment of the semiautonomous Ethiopian National Sorghum Improvement Program. In addition to its research, development, and demonstration activities, the Program maintains strong international contacts with ICRISAT, and other national sorghum breeding programs with which it exchanges germ plasm, and with the Ethiopian Nutrition Institute to ensure that satisfactory nutritional qualities are combined with desirable agronomic characters.

Equally gratifying, but for different reasons, has been the progress made in two semi-arid crop improvement projects in Uganda: one at Makerere University, the other in what was formerly an East African Community research station at Serere. In spite of internal upheaval and the departure of most expatriate advisers and bilateral donors, IDRC continued to support the young Ugandan research workers. The Centre's confidence in these brave and dedicated young people was amply justified. Though surrounded by strife and turmoil, not only did they continue to make satisfactory technical progress but they managed and were able to account for the resources supplied by IDRC during the long period when conditions made it impossible for IDRC staff to visit the project. Because of the perhaps unique relationship that has been established between AFNS and agricultural scientists in Uganda, the Ugandan government invited IDRC to provide a mission to define immediate and future agricultural research priorities.

The project at Serere began with the breeding and selection of sorghum cultivars resistant to attack by birds, leaf diseases, parasitic weeds, and the sorghum shootfly. Later, the research team devoted its attention to the improvement of finger millet (*Eleusine coracana*), a food grain that probably originated in the Uganda region and where it is still widely grown at altitudes between 1000 and 2000 m. Because traditional practices yield between 600 and 1800 kg/ha, the emphasis at Serere has been on selection and agronomic management for higher, more stable yields; white grains, resistance to prevalent diseases, and the identification of male sterile lines to permit hybridization. The project has provided breeding material to several other African countries.

The Makerere University project has been complementary in that it has concentrated on the physiological control of desirable attributes in sorghum and finger millet, together with research to improve traditional intercropping practices that combine sorghum, finger millet, and pigeon peas. Much of the research, which included cropping systems trials on the University's farm and on smallholdings managed by Ugandan farmers, was carried out by graduate students in pursuit of higher degrees. Since 1972, both Ugandan projects have been conducted entirely under the direction of Ugandan scientists.

A sorghum improvement project started in Senegal in 1972 is interesting in several aspects. At the beginning there was no West African adequately trained to direct the project; in fact, most of the project leaders at the Centre national de recherches agronomiques (CNRA) were French nationals. At the request of Senegal, IDRC provided a Haitian plant breeder as scientific adviser to CNRA's sorghum improvement program and made provision through the life of the project for 14 francophone West Africans to study for higher degrees in various agricultural scientific disciplines, taking their course training at Laval University and their thesis research at CNRA.

Results from the project include sorghum genotypes of high-yielding capacity and good grain quality, which mature in less than 100 days thus permitting the crop to mature and to be harvested before the end of the rainy season. After the harvest the land can be replowed while it is still moist. The next crop is seeded immediately after the first rains so that it will benefit from the flush of soil nitrogen liberated by the rain. Harvesting before the end of the rainy season delivers a crop high in moisture and therefore rapid maturity has been combined with some resistance to fungal infection by the breeders.

For other parts of the country, sorghum types that mature within 120 days with a yield potential between 6 and 8 t/ha have been developed and

Gathering sorghum for experimental analysis at CNRA, Senegal.

tested in six research substations and distributed to more than 120 smallholders for on-farm trials. The project, now under the direction of Senegalese scientists trained during the first phase, is integrated with a postharvest research project referred to later.

The higher-yielding sorghum types are now undergoing on-farm trials with peasant farmers in Southern Senegal in which productivity from improved agronomic practices is compared with traditional systems.

Recently started is a sorghum improvement project in Somalia, a country with an average annual income per capita of less than $250, where more than 80% of the population depends upon agriculture, and where only 13% of the land is cultivable. Approximately half of the cultivated land is under sorghum; average sorghum yields being little more than 0.33 t/ha. The chronic inadequacy of native food supply has been seriously exacerbated by the large influx of migrants from Ethiopia. The Somalian Agricultural Research Institute has sought IDRC's help to introduce small farm cultivation systems that will produce significantly larger yields of sorghum. It is believed that much of the experience gained in the Ethiopian sorghum project will be beneficial to the Somalian endeavour.

Parasitic Weeds The parasitic witchweeds of the genus *Striga* wreak widespread damage to sorghum, millet, maize, and other crops in Africa causing yield losses greater than 50% on severely infested lands. Each *Striga* plant disperses millions of small seeds that remain dormant in the soil until stimulated to germinate by a root exudate from the sorghum or other host plant. After germination the *Striga* attaches to the sorghum plant and grows parasitically, thus debilitating the host and decreasing the vegetative matter it produces. Under an IDRC contract, Tanzanian and Iranian scientists at the

University of Sussex (Canada maintains a phytosanitary interdiction against the import of *Striga*) have synthesized compounds that simulate the root exudate and cause *Striga* to germinate under laboratory conditions. The potency of these strigol analogues is remarkable, *Striga* seed germination being induced at concentrations of one part in 10^{12}.

In Upper Volta, in cooperation with ICRISAT, scientists are treating *Striga* infested soils with the synthetic germination stimulant that causes the *Striga* to grow and, in the absence of a host, to die before the sorghum is planted. It should be emphasized that though the synthesized germination stimulants work satisfactorily under some conditions there is much to be learned about their interaction with different soils and environments. In addition to control by induced germination, the agronomists and weed scientists at Kamboinse are studying other herbicides, screening sorghum and millet for low root exudation and resistance to *Striga*, and implementing agronomic practices that eliminate or minimize parasitic loss. Trials of all factors are in progress at several environmentally different locations. The research has already highlighted the immense complexity of *Striga* resistance and susceptibility, marked differences being evident at narrowly different latitudes. Above 13°N pearl millet is highly susceptible, but sorghum is relatively little attacked. Between 12 and 13°N both sorghum and millet appear susceptible. At close to 12°N sorghum is most susceptible; from 10 to 12°N both sorghum and millet are attacked but by different *Striga* strains.

Another important pest of sorghum is the sorghum shootfly (*Atherigona soccata*). As most sorghum cultivators in the developing world are subsistence farmers who cannot afford to control these pests by the use of chemicals and sprays, the best way to reduce loss is by breeding pest-resistant cultivars. This work has been undertaken as part of ICRISAT's program and, in cooperation with this effort, the Division is supporting basic research at the International Centre for Insect Physiology and Ecology (ICIPE) where scientists are investigating the behaviour of the insect and the environmental factors that influence its population dynamics. Resistance to the shootfly is made manifest in several ways. Some sorghum types generate antibiosis and attempts have been made to isolate and identify the chemical substance responsible. Other types display a capacity for regeneration following attack, a phenomenon that, analogous to drought survival, may be hormonally controlled.

The Agricutural Research Institute of Rwanda is seeking to establish improved production practices for sorghum, triticale, and sunflower at several locations representative of its widely diverse agroecological environment. Agronomic trials will determine to which conditions these crops are best suited.

Triticale

Building on the success at the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) and the University of Manitoba, efforts to establish triticale as a viable crop have been supported in Ethiopia and Kenya. In both countries the triticale hybrid demonstrated agronomic characters suited to adverse conditions including poor, sandy, and acidic soils and resistance to stripe and stem rust. Because of superior disease resistance during an adverse growing year, in several areas of Kenya triticale yields were almost double those of established wheat varieties. Unfortunately, though laboratory milling and processing trials and small-scale consumer acceptance studies indicate that triticale can substitute for established grains in several traditional and adopted foods, its unfamiliarity to rural consumers and smallholder farmers militates against its being rapidly adopted as a food grain. The work on triticale utilization at Egerton College in Njoro, Kenya, has focused on recipe development. A few consumer acceptance studies on triticale *mandazi* (doughnuts) were conducted on the campus using a simplified one-question response sheet. Over 100 respondents reported the 100% triticale *mandazi* were as good as or the same as the familiar wheat *mandazi*. This and the recipe development studies indicate that dehulled triticale flour can be incorporated into familiar home recipes.

Rice

Although rice is of greater overall economic importance to the high rainfall areas of Asia, it is much in demand in many African countries where annual rice imports cost close to $150 million. Largely in response to the efforts of the West Africa Rice Development Association (WARDA), which IDRC has supported for several years, annual rice production in West Africa has increased from 1.8×10^6 to more than 2.5×10^6 t over the past decade. Areas of West Africa that favour rice production include those of high rainfall and some soils of the SAT that can be irrigated from lakes or rivers. Fourteen West African nations cooperate to sustain and direct WARDA's activities in pursuit of its objective to make West Africa self-sufficient in rice.

A project directed by WARDA to improve rice production and rice cropping systems on small West African farms is located at Fanaye on the Senegal River. Over many centuries the river has washed down and deposited at Fanaye, soils from the whole length of its course. Consequently, the Fanaye station embodies a range of soil types representative of almost the entire Senegal Valley from vertisols containing 70% clay, to 20% clay alluvial "fonde" soils.

During the first phase IDRC supported development of land and water management facilities at the experimental site while CIDA provided funds for essential capital and accommodation facilities. Rice cultivars have since been identified that mature early and yield more than 7 t/ha, that are tolerant to low temperatures, and resistant to prevalent pests and diseases. Progress has been made in determining optimum soil, fertilizer, and water management systems for the various soil and rice types.

Work is now in progress to provide cultivars and agronomic practices suited to each of the three possible cropping seasons: the hot rainy season when rice is sown between June and August and harvested between October and December, the cold dry season with sowing in November and harvest between March and May, and the hot dry season when the crop is sown in February and harvested in June or July.

As improvements arise at the main station, multilocation trials are carried out at substations in Senegal, Mauritania, and Mali. Agroeconomic studies of existing farming practices provide baseline data against which to judge the benefits of establishing improved rice cultivars and more productive rice cropping systems on small farms.

Cowpeas

In cooperation with the International Institute of Tropical Agriculture (IITA) the Centre is supporting a network of cowpea improvement projects in several West African countries. In Upper Volta, cowpea breeding and selection is identifying types resistant to the prevalent insect predators including aphids, thrips, pod suckers, and bruchids. Because cowpeas, in common with other food legumes, carry their insect predators from the field to the store, the breeding project is integrated at the same site with the cowpea storage project described later. The team in Kamboinse is studying both photoperiod sensitive and insensitive types. Most local types are photosensitive and traditionally are sown with sorghum or millet immediately after the first rains. By crossing photosensitive with insensitive types the segregating populations produce various plant types that flower at different times and mature at different rates. Selection among these will permit adaptation to different cropping patterns. Agronomic studies are in progress to provide reliable relay intercropping systems for high rainfall and mixed intercropping systems for the more northerly low rainfall areas. Average rainfall in Upper Volta ranges in the south from more than 1300 mm to less than 400 mm in the north. Cowpeas and appropriate agronomic systems are needed for all regions. The cattle raisers of West Africa are also interested in cowpea as a forage crop. One line generated 38 t/ha of green vegetative matter.

Therefore, the research is being carried out at three different stations each representing a precipitation pattern. As described later, soil fertility studies will explore the benefits of processed indigenous rock phosphate on the main phosphorous deficient soils. It is believed that the nitrogen-fixing capacity of the cowpea combined with rock phosphate will help remedy the two main soil deficiencies. Soil nitrogen and phosphorous contents are being determined after different periods of cultivation. The Upper Volta project is the subject of a film "Pods of Protein" produced by IDRC's Communications Division and now extensively used for training purposes.

A second Voltaïque legume project at the University in Ougadougou examines the resistance of cowpeas to attack by bruchid beetles. The project provides training for Voltaïque graduate students who are severally investigating the biology and ecology of bruchids, plant-insect relations, and the relative efficiency of traditional and advanced methods of plant protection and pest elimination. Cowpea improvement projects with similar objectives are being supported in Niger, Mali, and Sierra Leone where, in addition to a training program for young graduate scientists, cowpea cultivars are studied in pure stand and intercropped with cereals or other food crops.

A project conducted cooperatively between IITA and the Agro-Hydro Meteorological Agency in Niger, is seeking to identify and quantify cowpea characteristics that confer tolerance to drought and to investigate the ecological factors relevant to the availability and optimum management of water in the semi-arid, cowpea-producing areas.

Harvesting cowpea experiments in Upper Volta.

At Sotuba in Mali an interesting collection of cowpea types is being assembled from across Mali from IITA and neighbouring countries. Breeding and selection seek to combine high yields with the large white grains most acceptable to local consumers. Intercropping and relay cropping systems are being studied using cowpea types that mature at different rates and are planted at various periods following sowing of maize and other cereals. In addition to the influence of agronomic variations upon productivity and residual soil fertility, a home economist is paying close attention to those essential physical characters that influence cooking quality and acceptability.

Pigeon Pea

In East Africa pigeon pea is among the most drought tolerant of all cultivated food crops and when drought is extreme in those semi-arid zones, which represent 80% of Kenya's land surface, pigeon pea is often the only crop that yields a harvest. Plant scientists at the University of Nairobi are making a detailed study of established and exotic pigeon pea types. The project combines conventional breeding and agronomic studies with more basic physiological research into grain yield potential, transpirational rates, and root growth patterns among genotypes. Results demonstrate significant genotypic differences in resistance to leaf spot, pod borers, thrips, and other pests and diseases. Research station studies and on-farm examinations were carried out at various locations and at altitudes up to 2000 m above sea level. Though the research may take time to reach fruition and to bring noticeable benefit to local farmers, improved types are being demonstrated to farmers and overall progress, under entirely African management, reveals a high quality of competence. The built-in training program will furnish a cadre of scientists to expand food legume and cropping systems research in the future.

Oilseeds Improvement

Recently at the Morogoro campus of the University of Dar es Salaam and at the Universidad Eduardo Mondlane in Maputo, Mozambique, related projects were started to increase the small-farm production of groundnuts for local consumption. In the Tanzanian project soybeans and bambarra groundnuts are included. The objectives are to increase and stabilize yields and to select types that have a high edible oil and protein content combined with tolerance to pests, diseases, and other prevalent hazards.

Of recent advent is an oilseeds improvement project in Ethiopia where at four main and seven subsidiary testing sites, representative of a wide range of agroclimatic conditions, five oilseed crops — niger seed, flax, rapeseed, mustard, and sunflower — will be subjected to breeding, selection, and agronomic trials. Ethiopian scientists hope to increase yields of seed; to increase oil content; and to breed and select cultivars adaptable to various climatic zones and seasonal differences, particularly in the Ethiopian highlands, and that are resistant to the diseases to which oilseeds are subject.

A network research adviser will be appointed to ensure the distribution of superior germ plasm and continuous exchange of research results and experience among all of the oilseed projects supported by IDRC in Africa, the Middle East, and South Asia. The adviser will provide a valuable and essential service, because there is no international agricultural research centre responsible for most of the important oilseed crops.

Intercropping

By tradition African subsistence farmers grow more than one crop each year, hence cropping systems research is in progress in several countries. At Morogoro in Tanzania, the results of intercropping studies that included improved sorghum cultivars, drew the enthusiastic attention of both the President and the Prime Minister. Equally, if not more important was the training component that provided a cadre of scientists in the young Faculty of Agriculture who were able to work together in applied research and demonstration projects for the benefit of Tanzania's rural economy.

A researcher examining sesame pods in an oilseeds improvement project in Tanzania.

To build further upon this capability, a more ambitious farming systems project is being started, in which the University will study existing farming practices among smallholders in two zones: (1) a mountainous region ranging from 500 to 3000 m above sea level and (2) a lowland area. Following a diagnostic survey of traditional farming systems, improved crop cultivars and systems believed more economic of land and labour will be gradually introduced in cooperation with the farmers. In zone (1) the crops will include vegetables and root crops, in zone (2) sorghum, maize, *Phaseolus* beans, pigeon pea, soy, sunflower, and sesame. Particular attention will be given to water management recognizing the unpredictable and often agronomically inadequate bimodal rainfall pattern.

At the University of Nairobi, agronomists and graduate and high-school students studied and recorded the influence of various crop rotations on the pattern of growth and yields of maize. At the Ministry of Agriculture's research station in Burundi, local and exotic lines of maize and some food legumes are being studied in cooperation with local farmers.

At the Université de Bénin in Togo, various cultivars of several food crops including maize, cassava, cowpeas, and tomatoes, are being studied in different rotational and intercropping patterns. The effects on soil fertility of crop residues, animal manure, and processed rock phosphate with and without supplementary irrigation are also included.

Intercropping studies at the University of Swaziland include maize, sorghum, cowpeas, lima beans, *Phaseolus* beans, mung beans, groundnuts, sweet potato, pumpkins, and cotton. Multiple relay crop rotations and the management of crop residue are also being examined. The project staff has established good working relations with both farmers and the Ministry of Agriculture.

At the Office national de la recherche scientifique et technique (ONAREST) in Cameroon, agronomic research is under way to improve the productivity and disease and pest resistance of plantain and to improve the local marketing system of this important but neglected relative of the banana. Evidence of the sizable potential local market is afforded by the good price that the project is receiving for planting materials of plantain that may be interplanted with groundnuts and other crops.

Cassava and Other Root Crops

In cooperation with IITA, the Division has supported a number of projects on cassava and other root crops in Africa including yams, coco yams, and sweet potatoes. Scientists at the Institute of Agriculture and Forestry Research in Cameroon have crossed cassava materials from IITA with local varieties and are studying the pattern of disease in these new cultivars when intercropped with maize, cowpeas, sweet potatoes, and coco yams. Breeding and selection programs are also under way with yams and sweet potatoes.

In Zanzibar, scientists of the Ministry of Agriculture and Lands have screened local cassava materials and those from IITA for resistance to cassava mite, mosaic, and leaf spot, and promising lines have been multiplied and distributed to farmers. Work is in progress to introduce biological control of the cassava mite in cooperation with the Commonwealth Institute of Biological Control (CIBC). A similar project has recently been initiated in Congo Brazzaville.

Because of inadequate phytosanitary control, cassava imported to several African countries from Latin America has been accompanied by a serious pest, the cassava mealybug (*Phenacoccus manihoti*). The pest causes extensive defoliation, withering, and often total destruction. In its indigenous Latin American environment, the mealybug population is controlled by natural parasites and predators but, because none of these appear to have accompanied the pest during its intercontinental migration, the mealybug proliferates and causes extensive damage to cassava in Africa. To introduce to Africa effective methods of biological control the biology and ecology of the mealybug are being studied together with the identification, controlled breeding, and distribution among cassava plantations in Africa of identified natural predators that control the mealybug's proliferation in Latin America. Laboratory populations of known predators are being maintained by the CIBC and distributed for field trials among collaborators in Nigeria, Congo Brazzaville, and other affected African territories.

Crop Production

The Research Division on Rural Production Systems of the Malian Institute of Rural Economy is engaged in an intriguing project in the south of the country. Though the project region is in one of the higher rainfall zones (~ 1300 mm/yr) it nevertheless contains many extremely poor people with farm families working small areas of relatively poor soil. Though the majority are very poor, the levels of agricultural technology, crop productivity, and family income vary significantly, and the project has divided its efforts over three categories of village. In the first, which is the most prosperous and longest established, approximately 80% of farms have animal-powered farm equipment; in the second category only 50% have farm equipment; and in the third group, 90% or more of the farms rely entirely on manual cultivation. Many of the farmers, particularly the more prosperous, grow cotton as a cash crop; all grow a variety of cereal grains including sorghum; pearl millet; maize; rainfed rice; some legumes (mostly cowpeas); groundnuts; and a small quantity of vegetables, spices, and condiment herbs.

The purpose of the project is to increase crop production and it started with a detailed typology study that has classified the inhabitants and farm families according to their income; consumption; area of land cultivated for various purposes; their activities throughout the year; and the nature and quantity of their resources including farm equipment, animals, and their opportunities for and constraints to greater productivity and a larger income. The more progressive farmers have already demonstrated their willingness to accept change for improvement by adopting more efficient systems of cotton production, yields of which now range between 1.3 and 2 t/ha. In contrast, among the poorest villages, yields of cereal grains are of the order of 500 kg/ha.

At present, after hand ginning, most of the cottonseed is fed to the animals whose manure is used to fertilize the fields. With the growing demand of the Malian oil mills for cottonseed, it will be necessary to provide alternative feed for the animals, and included in the project are studies of improved forage crops and the use of other agricultural by-products. Consequently, the future research will concentrate on improved systems of food crop and animal production; cereal processing and utilization; and, it is hoped eventually, the introduction of valuable tree crops. It is anticipated that the experience gained in simple mechanization of shea butter pressing, sorghum, millet, and cowpea processing and utilization mentioned later will bring benefit to the Malian community with whom the research project is cooperating.

Though low and uncertain rainfall poses the greatest threat to increased crop production in Africa, soil infertility constitutes a major hazard of uncertainty. Many soils of the SAT are deficient in phosphorus; facilities for the manufacture of chemical phosphate fertilizers are everywhere inadequate and in many countries nonexistent. Throughout the region there exist many rock phosphate deposits in which the phosphorus is present in a chemically bound, relatively insoluble form, unavailable to growing plants. As is described under the project supported in cooperation with the International Fertilizer Development Centre (IFDC) in the United States and CIAT in Latin America, by relatively simple mechanical and chemical procedures solubility and availability of phosphorus in various types of rock phosphate can be increased thus making rock phosphates potentially useful as fertilizers on local phosphorus-deficient soils. In cooperation with the Government of Mali, IFDC will carry out soil fertility trials on phoshorus-deficient soils of the Sahel using local rock phosphates processed by methods found effective in Latin America.

Postproduction Systems Research

Postproduction research has been more intimately integrated with crop production in Africa than on any other continent. The first postproduction project, though slow in gestation and the fulfillment of its purpose, served as a guide for many subsequent activities. The Nigerian Ministry of Agriculture had long recognized the need for small-scale rural grain mills each capable of processing several different locally grown cereals and legumes. Many rural women in the West African SAT spend 4 or more hours a day hand pounding grains, first to remove the outer seedcoats, then to reduce the remaining endosperm to a coarse or fine flour. It is neither technically nor economically feasible to ship grains grown in Northern Nigeria to the port flour mills on the south coast: first, because of the unsustainable cost of transporting the grain south and the milled products back north again; and second, cereal and legume grains widely different in size and shape cannot be processed in break and reduction mills designed for accurately size-graded imported wheat. The Nigerian government recognized the need for small mills, simple in design, and each capable of processing sorghum, millet, maize, and cowpeas in quantities sufficient for a medium-sized rural town at locations close to the sites of agricultural production and finished product demand. The manner in which IDRC responded and the details of the project's accomplishments are to be found in an IDRC publication (IDRC-152e) and film both entitled *An End to Pounding.*

The project has been described by several casual observers as a transfer of technology. But this is precisely what it was not. From certain basic principles, studied cooperatively between the Prairie Regional Laboratory (PRL) in Canada and technologists in Northern Nigeria, a new technology was developed and implemented in Nigeria to satisfy a defined local demand and suited to local conditions.

The project began with a market research study among more than 1000 households in the northern town of Maiduguri to determine the quantities and kinds of milled products demanded and the purposes for which they would be used. Based upon the results of the consumer demand study, carried out by rural extension agents and home economics students, the milled products desired and the capacity and basic design of the mill required were determined. It was decided to combine an abrasive system of seedcoat removal with a plate or hammer mill in which to reduce the debranned endosperm to flours of acceptable particle size. In the first experimental mill established in Maiduguri, no combination of existing manufactured equipment was found that could produce satisfactory debranning at an economically efficient extraction rate and with the relatively high ratio of fine flour to coarse semolina that was demanded. After many trials and modifications, a satisfactory mill was installed consisting of a precleaner to remove stones and other foreign matter, an abrasive dehuller consisting of circular carborundum stones mounted at 1.5–3 cm intervals on a horizontal shaft rotating inside a rubber-lined metal case, a modified hammer mill to reduce the decorticated (debranned) endosperm to finer particles, and a sifter to separate the ground endosperm into fractions of different particle sizes. The whole system is driven by two diesel engines and complemented by a weighing, bagging, and sealing unit.

Through operational research studies the output of the mill has been steadily increased and in present operation it achieves a better than 80% extraction rate (weight of ground endosperm flour as percent of original grain weight) compared with the less than 65% recovery rate achieved by traditional hand pounding. With sorghum production estimated at 800 000 t annually in the northeast state of Nigeria, if only half the sorghum grain is milled by the Maiduguri technology, the higher extraction rate would provide an increase of 60 000 t/yr of usable sorghum grain. In addition, the bran removed in the abrasive decorticator is recovered, bagged, and used as animal feed. Traditionally, the hand decorticated grain is air winnowed when most of the bran and attached endosperm fragments are blown away.

From its own resources, and with technical advice from Canada, the Government of Nigeria is constructing mills of the Maiduguri design across the north of the country. In addition to converting locally grown sorghum, maize, and cowpeas into flour that is commercially profitable and acceptable to rural consumers, the mills will liberate many women from the tedium of hand pounding for more productive enterprises such as the tending of kitchen gardens and the raising of poultry.

Following the success of Maiduguri, a system of sorghum milling based on the Maiduguri principle of abrasive decortication before grinding has been devised by the Rural Industries Innovation Centre (RIIC) in Botswana. Here again, principles rather than technology were transferred, the technology being developed in Botswana to suit the prevailing conditions.

The abrasive dehuller in Nigeria was designed for the continuous processing of relatively large quantities of grain. At RIIC the original decorticator was modified to permit small amounts of grain to be processed, either continuously or in response to rural demand, in batch quantities. The batch mills process grains brought by rural producers and consumers who wish to be assured that only their own grain is milled and returned to them. By incorporating a novel emptying device, in the form of a reinforced hinged door at the bottom of the dehuller casing, batch quantities as small as 10 kg can be dehulled without stopping the mechanism.

Sorghum dehulling with the dehuller developed by the PRL in Saskatchewan and the RIIC in Botswana.

RIIC, in cooperation with PRL is now studying the replacement of carborundum discs by much lighter discs of resinoid in which aluminum oxide is dispersed in a plastic matrix. The resinoid, less than a quarter the density of carborundum, may be rotated safely at more than 6000 rpm (1000 rpm is the safe maximum for carborundum) and because the resinoid discs are much thinner, more than double the abrasive surface area becomes available within the same volume chamber. The cost of resinoid is lower than carborundum and because of its lighter weight, power consumption per unit weight of grain processed is also reduced. Research is continuing to gain maximum return from this promising innovation.

The experience gained in Nigeria and Botswana is being used in grain-milling systems supported in Senegal where millet is being processed, in Ethiopia and Sudan where different patterns of sorghum milling integrated with sorghum-production projects are in progress, and in Ghana where abrasive removal of the seedcoats from cowpeas precedes their conversion to a variety of traditional foods. Support for a sorghum-milling project by the Small Industries Development Organization in Dar es Salaam has started recently in Tanzania. Home economists in Nigeria have studied consumer demand and acceptance of mill-processed cowpeas.

Two interconnected projects in Senegal, one in the rural community and the other at the Institut de technologie alimentaire in Dakar, seek respectively to establish integrated postproduction systems of storage and milling of pearl millet, and to increase the utilization of sorghum and millet flour alone and in composites with other cereal grains in baked bread and other foods.

A three-season survey among 800 Senegalese rural women identified several needs that included better access to water and milled grain (of a 16-h working day, the women spend up to 10-h in grinding grain and fetching water and wood). As a result, dehullers and new village wells are being gradually introduced. The survey revealed a marked preference for pearl millet over other cereals in *couscous*, the traditional food that is eaten every day in 75% of the homes sampled.

Trials with a Maiduguri-type (PRL) dehuller gave successful results with locally grown pearl millet, maize, and sorghum. The superiority over a European cone dehuller lay in the ability of the PRL machine to process grains of different size and shape. The PRL unit satisfactorily dehulled mixtures of grains, which is a distinct advantage to Senegalese smallholders many of whom mix different threshed grains in farm stores. Progress is reported, using the dehuller, in producing millet flour included in Senegalese bread at 15% of the flour and in "riz de mais," a substitute for rice made from maize.

Food and nutrition scientists in Upper Volta have begun work on a survey of foods made from sorghum, cowpeas, and millet, and on the determination of standard physical and chemical characteristics of these grains so that the acceptibility of new cultivars may be compared with established well-accepted types. In cooperation with PRL, using the TADD microdecorticator described later, the susceptibility of different local sorghum types to abrasive decortication is being assessed. Simple physical tests will be related to indices of quality as expressed by local consumers. (The overall scope of the postproduction systems program is described in the IDRC publication *Food Systems* (IDRC-146e). The milling projects are reviewed in *An End to Pounding* (IDRC-152e) and several other publications listed in Appendix 3.)

On-Farm Processing

In Ghana, it was discovered that of the 175 man-days required to produce and market 1 ha of rice, more than 70 man-days were absorbed in harvesting, threshing, and other on-farm processing. Ghanaian scientists at the University of Science and Technology in Kumasi have, therefore, developed and are field testing pedal-operated, single-drive rice threshers. Field tests are in progress at 17 different locations in cooperation with various church missions and other assistance agencies. Initially, there was a skeptical response from farmers but, as machine design and efficiency have improved, acceptance has increased, and it has been demonstrated that in an 8-h period two men with a pedal thresher can thresh four times the amount of harvested grain that can be processed in the same amount of time using the traditional method of beating with sticks. Of complementary advantage is a lower incidence of shattering of the rice panicles by the mechanized system. The means, possibly through cooperatives, by which the pedal threshers can be most economically distributed and used is now under study.

The Division du machinisme agricole in Mali is developing and field testing newly designed, low cost, manually operated millet threshers by adaptation of the principles used in existing tractor-driven threshers. Three different models have been designed and prototypes are being constructed prior to on-farm testing at Mopti, to the south of Tombouctou. Local blacksmiths will be trained in their construction and maintenance, and by demonstrations village communities will be encouraged to test and adopt the machines, each of a capacity of about 50 kg/h. The government will provide the necessary credit facilities to enable local communities to purchase whichever design proves most suitable.

Storage Technology

Grain storage projects are under way in Ghana where comparisons are made of maize stored in silos of different materials ranging from ferrocement to laterite blocks and lined jute bags; in Swaziland where university scientists have compared the scale and cause of losses and the efficiency and economics of different maize storage systems on farms in four regions; and in Upper Volta and Sierra Leone on cowpeas stored on farms where current losses equal 40% of the cowpeas harvested, a level of wastage that discourages greater food legume production.

At Kamboinse, integrated with the Upper Volta cowpea improvement project, a comprehensive study of traditional and more efficient systems of cowpea storage is providing valuable results. The life cycles, patterns of transfer from field to store, and the size and nature of insect infestations at different locations and seasons and under various storage conditions are all being examined. The traditional storage methods in the northern, central, and southern regions typified by low, medium, and high rainfall patterns, respectively, are recorded. Improved means of storage are being tested alongside the traditional in each zone.

Two local plants, *Hyptis spicigera* and *Cassia nigricans*, display insecticidal properties and when dried and layered among the dried cowpea pods in the storage cribs, serve to reduce infestation by bruchids and other insect pests. As elsewhere in West Africa, wood ash and sand used to fill the interstices among the stored cowpeas reduce infestation levels by reducing the oxygen available and by scoring the protective waxy chitin on the adult insects' abdomens.

The cowpea storage (Sierra Leone) project has completed an initial survey to determine the place of cowpeas in the rural community and the types of storage technology in existence, and some initial work has been done on the use of old oil drums as storage bins.

At the Rice Research Station in Rokupr, Sierra Leonians are assessing losses from various causes in harvested rice stored on farms. The underlying principles of improved systems of storing high-moisture rice in Asia will be adapted to the development of improved storage systems in West Africa.

In Botswana, the economically efficient methods of milling sorghum, described earlier, have encouraged farmers to grow more sorghum and thus reverse the trend toward greater consumption of milled maize flour imported from South Africa. More efficient postproduction systems of storage and distribution of cowpeas in West Africa, and other legumes elsewhere on the continent, promise comparable stimulation to native legume cultivators.

Traditional methods of storage of cowpeas in Upper Volta have been surveyed. Of particular interest is the practice of placing leaves of certain local plants (*Hyptis* species and others) and ashes of certain trees to poison, or at least to repel, insect pests such as bruchid beetles.

From an observant study, a scientist in West Africa determined the zenith angle of the sun and the direction of the prevailing winds for all times of the year. From the results, it was possible to design and construct a natural cross-flow, solar-heated grain dryer that could be tilted and oriented with the harvested grain that had been stacked in a manner to gain maximum drying rates from the sun and wind.

A comparison of grain storage bins of traditional and exotic design showed that, up to approximately 1 t capacity, the traditional woven basket designs were as efficient as the more expensive imported models provided that certain requirements were observed. The bins were most efficient when the height and diameter were roughly equal and when the wall insulation was reinforced with mud and protected from the sun by a large overhanging woven lid. These precautions reduced differential moisture gradients within the grain and thereby prevented mould growth. Storage life was also increased by drying the threshed grain before filling the bin, filling the bins early in the cool morning, packing the grains tightly within the bin to reduce air spaces, filling the air spaces with sand or wood ash, and raising the bins on blocks to prevent ingress by rodents.

For quantities of grain larger than 1 t, Senegalese scientists devised a "silo magasin," a series of walled compartments each of which is filled with grain and closed by a locking top cover. The silo magasin is easy to construct from local mud, wattle, or clay brick. Small silo-cellules were designed to enable farmers to treat a 3-week supply of grain with the pesticide bromophus, which remains active for roughly 3 weeks.

High moisture content is a major cause of postharvest loss among all harvested crops. Therefore, projects to improve technologies of dehydration and drying are in progress in several African countries. Solar-powered crop dryers for use among rural communities are being designed and tested by the University of Sierra Leone, and in Niger l'Office national de l'énergie solaire (ONERSOL) has designed and is constructing two multipurpose models of different capacities for the dehydration of locally grown onions. Each model consists of a solar collector and a drying chamber built of various alternative materials including locally made brick, woven sorghum stalks, other agricultural by-products, and plastic sheeting.

Of the 80 000 t of onions grown annually in Niger under irrigation, less than 30% are eaten by the producers, more than 60 000 t being sun-dried for export. Direct sun-drying is difficult to control, unsanitary, and generates a product of uneven quality. The objective is to develop indirect solar dehydration systems to provide an end product of higher and more uniform quality to stimulate local and export demand with a greater financial return to rural producers and processors. The Government of Niger and the Arab Development Bank have committed sizable investments to the further development and exploitation of the process.

In Sierra Leone work is under way to optimize various designs for crop dryers based on criteria established by interviews with farmers to determine which crops must be dried, when and how much, and the present levels of waste and loss.

More efficient methods of dehydration and their effect upon the nutritional quality of a wide range of vegetables, indigenous to Kenya, are under investigation at the University of Nairobi, and recently the National Council of Scientific Research in Zambia began a project to adapt the principles of the solar rice dryer developed at the Asian Institute of Technology to the dehydration of locally produced leafy vegetables.

Another recently instituted project in Mali is attempting to reduce the extensive loss in processing of fish harvested from the very productive waters of the Niger Delta in Mali. The cooperating institutions are Opération Pêche of the Ministry of Rural Development, which specializes in all aspects of fish production, processing, storage, and marketing; and the Laboratoire de l'énergie solaire, which has considerable expertise in solar energy. Together, the staff of these institutions is attempting to develop a low-cost, effective, indirect solar drying system suitable for use by the fishermen of Mali at Mopti and capable of producing fish that is sufficiently dry to resist bacterial, fungal, and insect attack. A prototype solar dryer has been built consisting of a raised wire frame base and a detachable convection chimney, the whole covered by a plastic tent to prevent contamination by dust and insects. The dryer is readily dismantled and reassembled and is, therefore, portable.

In an interesting project in Mali, the Ministry of Rural Development is quantitatively investigating, and seeking to improve traditional methods of extracting and processing shea butter, which is one of the few naturally occurring edible fats of plant origin that is solid at normal temperatures. Shea butter is obtained from a tree (*Butryospermum parkii*), known locally as Karite, that grows wild in the African semi-arid tropics. The fat has many local culinary uses in addition to being a valuable export for food and cosmetic use in other countries. Based on principles and processes developed elsewhere, it is believed that more efficient systems adaptable to the rural shea butter industry will be developed by the Malian scientists.

Traditionally, the shea nuts are roasted in beehive ovens and ground to a dark brown paste by hand pounding in a large pestle and mortar, and then the fat, liberated by disruption of the oleaginous cells, is separated by flotation in water. The isolated fat closely resembles edible tallow in appearance and consistency. The purpose of the research is to standardize and mechanize the process of extraction using animal power to replace women's labour.

Forestry Research

In 1970, the year IDRC began its work, an FAO officer calculated that in the Maghreb countries of North Africa, approximately 100 000 ha were turned into desert by deforestation and overgrazing. More recently, the UN Conference on Desertification produced startling statistics on the rate at which once productive land is being eroded by destruction of the vegetative cover. Though approximately half of tropical Africa is classified as forest, roughly 98% consists of various types of bush cover, and barely 2% is dense forest. The area covered by forest plantations is infinitesimal.

It is estimated that of the 3.0×10^8 m^3 of African wood used annually, at least 90% is consumed as firewood and charcoal, 9% being used for construction purposes. The shortage of firewood is reaching desperate dimensions, particularly among those rural people that rely on tree species that grow outside the forest. For this reason, IDRC's forestry program gave

Harvesting branches from a forage tree (Acacia holosericea) *in Senegal.*

first priority to social forestry projects with the purpose of increasing the supply of fuel and structural materials, together with fodder for their animals, to the more than 150 million rural Africans who live in the semi-arid tropics.

Social Forestry

A project to establish village woodlots in Niger illustrates some of the opportunities and difficulties of the more than 20 social forestry projects supported in East, West, and North Africa and the Middle East.

The project's objective is to establish approximately 150 ha of woodlots around 70 villages near to Zinder, a town in southeastern Niger. The woodlots, to be managed by the rural inhabitants, will produce firewood and building materials. A nursery has been established in each cooperating arrondissement, and tree survivals in village plantations approach 90% of those planted over more than 150 ha. Several well-adapted, fast-growing species of neem (*Azadirachta indica*), *Eucalyptus*, *Albizzia*, and *Acacia* have been identified. A wide range of other potentially suitable species is being studied together with improved methods of propagation in the village nurseries, each of which is under the control of a villager chosen by the community. The village nurseries produce up to 3000 plants per year. Improved methods of transplanting from nursery to woodlot are being developed to gain maximum advantage from the short rainy season.

A sociological study among participating villages indicated a keen awareness by the rural people of the value of village woodlots with a marked preference for ownership by individuals or families over ownership and control by the government or the community at large. This preference for individual over collective ownership and responsibility is consistent with findings from other rural development projects in other countries. The greatest hazards to woodlot survival are goats and other browsing animals, therefore, during the early phase each plantation was protected by a barbed wire fence. This has proven to be too expensive and work is in progress to develop live fences of woody plants that resist the browsers. Forest research workers from the Ministry of Rural Development in cooperation with the villagers are studying improved taungya silvicultural systems in which food crops, such as groundnuts and cowpeas, are grown in the spaces between the growing trees. Suitable tree species appropriately spaced provide fertilizer in the form of tree litter for food crops, which can be cultivated until the tree canopy grows sufficiently to exclude sunlight.

The project has excited interest among a number of other agencies including the European Development Fund, the Church World Service, and the International Development Association, which have financed similar ventures but on a much larger scale than IDRC's budget can sustain.

Other social forestry projects include the establishment of plantations of *Acacia senegal*, a tree that, in a manner similar to the Canadian maple, exudes from lesions in its trunk the polysaccharide gum arabic that is used in many foods and pharmaceutical and other chemical products. Traditionally, the crude gum is collected by stripping bark from trees that grow wild in the West African savanna. Seminomads collect the gum in this manner as they drive their herds from one watering place to another. The project, carried out by the Senegalese Ministry of Rural Development, seeks to establish gum arabic plantations close to nomadic settlements and to select from native and exotic *Acacia* species those that survive and grow rapidly and produce high yields of gum. Silvicultural trials include methods of vegetative multiplication for high-yielding trees, spacing trials, and the suitability of the leaves as animal forage. The project has been combined with an earlier rural reforestation project in the Senegal savanna in which suitable tree species, including *Acacia senegal*, are used to recover land laid bare around water holes and other regions of the savanna because of overgrazing of migrating animals. More than 250 ha of *Acacia* plantations have been established and tests have been carried out to study the effect of mycorrhyzal fungi on tree growth. In spite of serious damage to the nurseries and young trees by rodents following the droughts of the mid-1970s the project is making good progress.

Rural Afforestation

In Mali, close to the Niger River, a study is being made of the silvicultural and economic viability of irrigated tree plantations to supply wood to those rural populations of the Sudanese and Sahelian zones that live relatively close to main waterways. In spite of many difficulties, not the least being the relative remoteness of the research site from many essential facilities and amenities, remarkable progress has been made during the first 4 years. More than 50 tree species have been planted and compared under two systems of irrigation both in single species plots and in combinations as windbreaks. Irrigation was provided by submersion in "planches" (bunded plots) and in "billons" (furrows to which the water is supplied at different controlled flow rates). The latter proved more satisfactory but are more costly to establish because the ridging and furrowing requires mechanized equipment.

More than 22 ha of trees has been planted. The more successful include species of *Eucalyptus, Gmelina, Dalbergia, Acacia,* and *Leucaena.* Of particular interest is the rapid natural regeneration of the *Leucaena glauca,* a species capable of providing forage for animals and soil fertilizer in the form of tree litter. Because the site embodies three different soil types and variable water table levels at different times, the influence of many interacting factors upon survival and growth rate are being examined. It is believed that the results will be of extensive benefit to people of the region by providing wood for fuel, forage for animals, and barriers for crop and soil protection. More than 11 000 plants of *Eucalyptus camaldulensis, Azadirachta indica,* and *Dalbergia sisso* have been distributed among neighbouring village communities.

In East Africa, rural afforestation projects to meet the objectives cited above are in progress in cooperation with smallholder farmers and village people. In Kenya the purpose is to establish woodlots close to farming communities on land ill-suited to food crops. In Tanzania, the project site is close to Dodoma, the new capital, where, in one of East Africa's most arid zones, efforts are being made to protect plantations with live fences of thorny plants. Fuelwood plantations are also being developed by the Forestry Research Institute in Malawi where, in addition to rural household needs, close to 1.8×10^7 m^3 of wood were used annually for curing tobacco, smoking fish, and kilning bricks.

Agrisilviculture

North and south of the Sahara several countries seek to promote agrisilviculture in which tree crops are integrated with smallholder farming systems. In the light of experience gained in the development of a multiple cropping research methodology, it may be some years before methodologies appropriate to agroforestry research are formulated and adequately tested. To accelerate the process, IDRC acts as executing agency on behalf of a number of donors in the establishment of the International Council for Research in Agroforestry (ICRAF), which, from headquarters in Nairobi, is guided by an international Board of Trustees, drawn equally from developed and developing countries.

The Federal Department of Forestry Research in Nigeria, through species trials, is selecting combinations of trees that provide appropriate shelter for growing crops and is studying the effects of these shelterbelts on crop yields, soil and water conservation, and the ecological environment.

In Ghana, Cameroon, and Nigeria, modest progress has been made in research to replace bush fallow with more productive systems of land management. Traditionally, itinerant cultivators first clear the forest by chopping down the trees and burning the scrub bush before exhausting the soil nutrients by raising underfertilized crops for several years. They then move on to repeat the process elsewhere. Bush fallow is the name given to the natural regeneration of native bush plants on the exhausted land vacated by the shifting cultivators. Attention is being given to replacing bush fallow by leguminous tree species interplanted with food crops that grow until the tree canopy excludes the essential sunlight.

The need to use forest products more efficiently and economically is evident throughout Africa. The Forest Products Research Institute in Ghana started an interesting attempt to convert wood fibres into particle board and building bricks by binding the wood wool with mineral cements.

To reduce importation of structural timbers from other countries, wood technologists in Mali are examining the properties of *Pterocarpus* and other native timbers to determine their suitability for cutting, drying, and various structural purposes. Forest products specialists at Laval University have been particularly helpful in advising the Malians on methods of standardization and wood-processing technologies.

The Forestry Department at the University of Dar es Salaam is studying the design and materials of construction of various charcoal-burning stoves to achieve greater fuel economy in stoves that in structure and function are acceptable to Tanzanian rural communities.

Network Advisers

Forestry science and technology has many obstacles to overcome in Africa, not the least being a serious shortage of suitably trained scientists. All projects, therefore, include a significant training element ranging from advanced graduate studies to on-the-job technical demonstrations. Central to this training element, and indeed to the sustenance of the entire social forestry network, is the research advisory service provided by two African forestry scientists stationed at EARO in Nairobi. Their combined trilingual facility, together with many years of experience in African and Middle Eastern forestry research and development, enables the two advisers to encourage and integrate the efforts among the social forestry projects already described. Theirs is not the role of project manager or director to any of the 20 projects in the program. Rather it is to provide advice on the design and implementation of appropriate methodologies; to facilitate the exchange of information, results, and other relevant experience among the projects in the network; and, where necessary, to supply germ plasm and other material resources.

The provision of network advisers is essential to groups of projects in countries where research institutions are relatively weak and are staffed largely by young scientists whose lack of experience calls for frequent encouragement and sympathetic and competent advice. This form of scientific service is wholly consonant and not in conflict with the Centre's policy of support for indigenous effort. The advisers offer counsel not coercion; encouragement not enforcement. Though complementary, the advisers do not duplicate the responsibilities of the Division's permanent staff who monitor and evaluate progress in the projects the Centre finances.

Animal Research

A little more than 5% of the total 10-year AFNS budget has financed basic research of complex problems relative to some aspect of rural development. These have usually been carried out by a Canadian research institution, in cooperation with a project in a developing country.

Protozoal Diseases

Trypanosomiasis, known in humans as sleeping sickness, is one of a number of diseases caused by pathogenic protozoa. The protozoa that cause trypanosomiasis are transmitted by the tsetse fly, a blood-sucking insect that collects the trypanosomes probably from wild game animals, which are pathogen carriers that have evolved a high degree of immunity to the disease. The trypanosomes are conveyed by the tsetse fly to infect domestic animals upon which the insect lands for another blood meal. The protozoa proliferate and undergo metamorphosal changes in the animal and the insect vector, both of which are essential to the organism's life cycle. Elimination of the tsetse fly and of trypanosomiasis would open up land sufficient to support an additional 125 million head of cattle in East Africa.

Theileriosis, East Coast fever, a tick-borne disease, kills an estimated 500 000 head of cattle every year in East Africa. These two protozoal diseases constitute the greatest single obstacle to a healthy livestock industry over at least 10^7 km^2 of Africa.

Twin projects between the University of Guelph and the Veterinary Research Institute of Kenya seek to gain a clearer understanding of the etiology of trypanosomiasis and theileriosis through a basic study of the immunopathology of these two protozoal infections.

A study that involved Canadian and African scientists, supported by graduate students in Kenya and in Guelph, began with an analysis of the anemias caused in animals by *Trypanosoma congolense* and *T. vivax*, and the delayed hypersensitivity associated with *Theileria parva*, the protozoan that causes East Coast fever. It was found that the two infecting trypanosomes act in a markedly different manner and that *T. congolense* forms aggregates in the small peripheral blood vessels, particularly in the brain and heart. The

Researchers in Kenya examining a tick in the ear of a cow. The ticks transmit theileriosis, a disease that causes extensive loss of cattle.

team studied the possibility of dispersing these aggregates, because chemotherapeutic agents cannot reach and destroy trypanosomes located at the centre of a clump. The mode of action of the pathogens and the resultant physiological response in the animals is highly complex and a single method of control, either through immunization or drug therapy, seems unlikely of realization in the near future. The research demonstrated that the pathogenic trypanosomes predispose cattle to other infectious diseases such as rinderpest and contagious bovine pleuro-pneumonia.

A second project, financed by CIDA but managed by IDRC, is examining the mechanism of transmission of trypanosomiasis, theileriosis, and a variety of other African animal diseases. One purpose of this project is to determine to what extent infectious pathogens exist in, and are transmitted from, indigenous species of wild game, which over the centuries have evolved immunity to them.

In Kenya, in cooperation with the University of Guelph, a great deal has been learned about the disease transmission between domestic and wild game animals. The project was designed to identify naturally occurring parasites and pathogens and the transmissibility of the pathogens between wild and domesticated species. The project included a sizable training program for Kenyan veterinarians. Small captive herds of several wild game animals were established and blood samples were collected from these animals and from animals in the wild that were temporarily immobilized by hypnotic darts. Though immunity to several diseases has been shown in wild game, which may act as infective carriers, not all infections of domesticated species originate in wild game.

Diseases specifically studied include trypanosomiasis in zebra, oryx, giraffe, and wildebeest; East Coast fever in eland and topi; foot-and-mouth disease in buffalo; malignant catarrhal fever in wildebeest and several species of gazelles; mycotic dermatitis in rhinoceros; and avian tuberculosis in flamingoes.

Several Kenyans have been trained in veterinary science and the results promise, for the first time, to demonstrate systems in which wild and domesticated ruminants can satisfactorily coexist and that wide scale slaughter of the wild species is not a prerequisite for the maintenance of successful domestic cattle raising.

Animal Feeds

Other projects in Africa have studied agricultural by-products in animal feeds. At the University of Ife in Nigeria feeding trials on poultry, swine, sheep, and goats have been carried out with cassava meal supplemented with protein from the leaves of cassava and other plants and with palm oil cake.

The University of Nairobi is analyzing and evaluating the by-products commonly used on small farms to feed poultry and is exploring the possibilities for using them combined with available inexpensive nutrient supplements to produce more efficient feeds. In the laboratory, local birds are fed typical small-farm diets and compared with birds fed nutritionally superior combinations of locally available materials. The feed found most economical will be tested among smallholders who raise poultry as a component of mixed farming systems.

Fisheries Research

Because of the paucity of trained fisheries biologists in Africa, relatively few projects have been supported. One of the more technically successful undertakings is the oyster culture project in Sierra Leone where fisheries scientists have succeeded in cultivating native oysters in estuarine waters to a much larger size than occurs in the wild. The motile spat of the wild species attaches mainly to the roots of mangroves that grow along tidal estuaries. Because of overcrowding, natural wild oysters are small and, if close to human settlements, the waters may be polluted and the oysters consequently infected.

The project staff has established systems of rack and raft culture out in the clearer deeper waters of the estuaries where the food supply is more abundant; therefore, the oysters grow faster and to a much larger size. Studies have been made of growth under continued submergence, the effect of changes in water salinity, the factors that influence the ratio of meat to shell, and the biology of the principal fouling organisms and predators. Postharvest studies including economics of processing, packaging, and marketing and distribution will determine the economic viability of these more productive systems of oyster culture.

Tilapia is a freshwater fish widely accepted in many African countries. Its potential for cultivation in natural lakes and rivers has never been realized mainly because of the inadequate facilities for fisheries research mentioned above. By applying recent advances in the biological control of reproduction together with modern systems of aquaculture management, including cage culture, the annual production of tilapia could be greatly increased.

At the University of Nairobi work is in progress on cage culture of four species of *Tilapia* in the running water of canals and in the relatively static water of rice paddies. Work is also in progress on the artificial stimulation of maturation and breeding in tilapia using extracted pituitary hormones, the significance of which is described in greater detail in relation to fisheries projects in Asia.

Selection and cultivation of local fish species is in progress at Lake Mihindi in Rwanda, and research on the breeding of stocks of juvenile fish for cultivation in fixed or floating net pens in Togo Lake and Lomé Lagoon is being pursued by the Division des productions halieutiques in Togo.

An artisanal fisheries project in Ghana brought forth several significant technical advances in boat and net design, in inshore fishing techniques, in the technology of drying by smoking and salting, and in the economics of marketing. The fishermen and their families who inhabit the entire coastline of Ghana and many other African countries depend almost entirely upon fishing for their livelihood; the men being the harvesters while the women and children are responsible for preservation by smoking and drying and for

Oyster culture in Sierra Leone where systems of rack and raft culture have been established.

selling the processed fish in the local markets. For a variety of reasons including several changes of government and scientists responsible for the work, the project appears to have had less impact upon the lives and systems of the coastal fishermen and their families than was hoped for and indeed possible. If and when stable administration and an adequate research and development team can be maintained the Division will reactivate its support. The application of the research results could bring significant benefit to the many thousands of poor rural inshore fishermen and their families.

Middle East and North Africa

Among international agencies and political geographers different continental designations are assigned to the various groups of countries that make up this region. It is, therefore, necessary to define which countries IDRC includes under the designation North Africa and the Middle East. The countries in which projects have been or are being supported are Algeria, Egypt, Jordan, Lebanon, Syria, Sudan, Tunisia, and Turkey.

The region embraces a range of topographic, edaphic, and climatic conditions so complex and varied that several volumes could be written to describe them. The region is of particular agricultural significance, being the original home of wheat, barley, and several other important cereals and food legumes. Consequently, valuable additions to crop-breeding programs have been made through germ plasm expeditions in various countries of the region.

The region, with its diversity of affluence and poverty, its contrasts of exceptional intellectual and cultural attainment alongside extreme backwardness, together with its long and impressive history of scholarship and agriculture, defies any attempt at rational generalization. Because of their deeply rooted civilization and long-established universities, certain countries, particularly Egypt, are ideally suited to IDRC's style of support for indigenous research effort. In other countries poverty goes hand-in-hand with little institutional research capability; in others their wealth of natural resources places them in the category of developed countries that do not qualify for projects supported by IDRC.

The Division is at present supporting close to 40 active projects in the region: 47% in crops, 16% in forestry, 14% in postproduction systems, and 11% each in animal sciences and fisheries, the largest number being concentrated in Egypt and Sudan. Table 3 lists the total appropriations and number of projects supported in the eight countries of the region in which the Division has been active.

Forestry Research

At one time much of the region was protected by extensive tree cover, man's destruction of which led to progressive soil deterioration and desert spread. The restoration of tree species is vital to an efficient settled agriculture and the economic well-being of rural communities. Shelterbelts are essential in the reclamation of arable lands and for the protection of farm lands and growing plants. Among the most useful tree species translocated from their native Australia to Egypt, to which relatively little systematic research has been devoted, is the genus *Casuarina*, out of whose 45 known

Table 3. Total appropriations and number of projects in the Middle East and North African countries.

Country	Crops and Cropping Systems Appropriations ($ '000)	Crops and Cropping Systems No. of projects	Fisheries Appropriations ($ '000)	Fisheries No. of projects	Animal Sciences Appropriations ($ '000)	Animal Sciences No. of projects	Forestry Appropriations ($ '000)	Forestry No. of projects	Postproduction Systems Appropriations ($ '000)	Postproduction Systems No. of projects
Algeria	380.1 (100%)	2 (100%)								
Egypt	1372.2 (39%)	6 (33%)	233.6 (6.5%)	1 (6%)	802.9 (22.5%)	3 (17%)	309.7 (9%)	2 (11%)	810.5 (23%)	6 (33%)
Jordan	266.5 (61%)	1 (50%)					168.2 (39%)	1 (50%)		
Lebanon	1387.3 (91%)	3 (75%)							137.7 (9%)	1 (25%)
Syria	3250.2 (79%)	7 (78%)			848.4 (21%)	2 (22%)				
Sudan	717.4 (39%)	3 (34%)	348.7 (19%)	2 (22%)	268.4 (15%)	1 (11%)	371.2 (20%)	2 (22%)	137.7 (7%)	1 (11%)
Tunisia							417.7 (100%)	2 (100%)		
Turkey	474.6 (69%)	2 (67%)	212.5 (31%)	1 (33%)						

These Casuarina *seedlings will eventually be used as shelterbelts to recover and protect valuable arable land.*

species only three, plus one natural hybrid, are widely found in Egypt. Important results have emanated from the University of Alexandria where a detailed study was made of the many phenotypes of the locally established *Casuarina* species. Germination, growth, and survival rate studies from seeds of apparently superior types are well advanced. Techniques of vegetative propagation have led to the establishment of a clonal seed orchard, and cooperation with silviculturalists in Australia has provided new provenances for future research. Though not leguminous, *Casuarina* species can be induced to nodulate and symbiotically fix nitrogen, significant species differences in nitrogen-fixing and mycorrhizal associations having been noted.

The project's boundaries have recently been extended to include more intensive studies of germination and growth characters under a variety of soil conditions including the sandy calcareous loams of the Mediterranean littoral, the inland sandy soils of the Sinai, and the cool and hot desert conditions in the Aswan region. Physiological studies (investigations of tolerance to salinity, drought, and attack by nematodes) of important phenological characters including flowering and pollination and the useful properties of the timber for fuel, structures, and pulping are all in progress.

In the Sudan, about one-third of irrigated arable land is lost every decade by inundation with blowing sand. In a project covering several hundred hectares of the Kerma basin in northern Sudan, several tree species are being studied in shelterbelts intended to recover and protect valuable arable land. The shelterbelts consist of two, three, or four rows of trees spaced at intervals that vary between 100 and 250 m across the direction of prevailing winds. Measurements of the efficiency of these shelterbelts, together with their effect upon the microclimate and water economy and yields of crops they protect, represent the main purpose of the research.

Also in the Sudan, the potential of various species of the leguminous tree genus *Prosopis* as forage and feed for animals and for other useful purposes is being studied in four regions each representative of a different soil type. In Jordan, efforts are being made to establish fast-growing trees that germinate quickly and put down roots during the short rainy season. The seedlings are planted in wadis and on terraced hills to take advantage of the collected rain water, which elsewhere is rapidly absorbed or evaporated when the rains cease.

The protective influence of shelterbelts on agricultural crops is also being studied by the Institut national de recherches forestières (INRF) in Tunisia, which is also investigating the production, harvesting, and technological properties of alfa grass (*Stipa tenacissima*). Alfa grass is a plant that is pulped to make fine paper and is used in many household applications but, despite a century of cultivation in Tunisia and surrounding countries, it has received little attention from research workers. Although it is a grass and not a tree, because of its woody nature and end use (like bamboo referred to in a later section), alfa grass generally falls within the province of forestry rather than agronomic research.

Plowing behind a 12-year-old Casuarina *windbreak in Egypt.*

Crops Research

Crop Improvement

The food legume improvement network in the Middle East has developed into one of the most gratifying of the Division's endeavours. It began in the early 1970s when the Centre cooperated with the Ford Foundation in the Arid Lands Agricultural Development (ALAD) program that, with its headquarters in the Lebanon, operated a crop and farming systems improvement program in alliance with several countries of the Middle East. The novel approach to a regional crop improvement program, upon which the present legume network depends, had its origins in ALAD.

Following several detailed studies of agricultural research needs and priorities in the Middle Eastern region, IDRC was invited by the CGIAR to act as Executing Agency in the planning and establishment of the International Centre for Agricultural Research in the Dry Areas (ICARDA). ICARDA's research domain covers rainfed agriculture over much of the region of North Africa, the Middle East, and West Asia, a region where agricultural productivity is constrained by a lack of water; annual precipitation ranges from 600 mm to less than 200 mm. In the original plan pursued by IDRC and the CGIAR, ICARDA was to have three main stations; one each in the Lebanon, Syria, and Iran, the latter to concentrate upon problems typical of the high plateau of the region on a suitable research location close to Tabriz. Subsequent political events in the region dashed hopes of implementing the Iranian plan and constrained progress in the Lebanon.

In spite of these adversities, ICARDA has established impressive research facilities including an outstanding program of legume research from a central station close to Aleppo in Syria. ICARDA's legume program, which IDRC continues to support, is central and critical to the network of six national projects in Egypt, Algeria, Sudan, Turkey, Jordan, and Pakistan. Each of these national projects, supported by IDRC, operates independently; its objectives, priorities, and plans are determined by the national research workers. ICARDA's role in the legume network is a good example of the essential complementarity between an IARC and the national research programs it seeks to serve. ICARDA does not control the funds, dictate priorities, direct the research, or provide expatriate advisers to any of the national projects. From its integrated legume research program, ICARDA provides a broad selection of improved breeding materials; recommendations on agronomic practices; and technical advice in the form of publications, workshops, and exchange of visits; the whole sustained by an imaginative, practical training program.

The intensive training courses are fundamental to the network and the trainees, who spend several months at ICARDA, where they follow the region's principal legume crops through all stages of preparation, planting, agronomic management, and harvesting. They then select from the harvested seed those cultivars that seem best suited to their national requirements and conditions. Close to 20 trainees take part in annual 6-month intensive courses. In addition, shorter courses on specific subjects and techniques are presented. When they return to their own countries each of the trainees continues to exchange with ICARDA germ plasm material, results of trials, and other information, and cooperates in experiments that require environmental or other conditions unavailable at ICARDA's main station.

Three legumes dominate the program: lentils, faba beans, and chick-peas; research on chick-peas is being conducted in cooperation with ICRISAT. The collections consist of more than 4500 accessions of lentils, 3000 of faba beans, and 3500 of chick-peas, all of which are being increased continually by additions from cooperating countries and expeditions to select new cultivars and wild types.

Breeding and Selection

The ICARDA program is comprehensive, covering all components typical of a major breeding and selection program. The national projects collect, combine, and select plant types from seed collected locally and received from ICARDA. Some provide ICARDA with off-season nursery facilities and all the projects make their results known and thus contribute to what is already a large and continuously growing base of information and experience on food legume improvement. When the ALAD program first began, there were relatively few scientists in the region specifically trained in advanced techniques of legume research. There are now more than 120 legume research specialists spread throughout the cooperating countries.

For several years Algerian scientists have worked successfully to increase on-farm production of lentils, chick-peas, broadbeans (*Vicia faba*), and field peas. They have had notable success in identifying types that mature early, and those with a shape conducive to mechanical harvesting.

An intensive legume improvement project is making progress at several research sites and is being conducted in cooperation with farmers throughout Egypt. In addition to providing improved planting materials and agronomic systems of management, the Egyptian project provides facilities for a disease nursery and includes studies on the control of the parasitic weed *Orobanche* that, like *Striga*, is also induced to germinate when the seeds are treated with synthetic strigol analogues.

Economic studies in several governorates show that improved cultivars and cultivation practices for lentils and faba beans increase profit to the farmers. Breeding and selection have identified a faba bean cultivar with 50% higher protein content than has ever been found before, several lentil cultivars highly resistant to downy mildew and fusarium wilt, and an exotic introduction that matures 20 days earlier than any known local variety.

This broadly based legume improvement program, carried out at research stations and in farmers' fields representative of all the major agro-climatic production zones of Egypt, is under the direction of the Field Crops Research Institute. Specific attention is given to yield stability, protein content, and resistance to prevalent diseases including chocolate spot and rust in faba beans and root rot and wilt in both faba beans and lentils. Mentioned later, and complementary to this and other legume improvement programs, is the study of quality and utility at the University of Alexandria.

Crossbreeding cowpeas in a greenhouse.

Food legumes are a main ingredient of both the breakfast and evening meal for more than 5 million of Sudan's rural poor. As the price of animal foods escalates, food legumes assume an ever-increasing importance in the diets of Sudanese and other Middle Eastern people. At four stations breeding, selection, and agronomic research is designed to improve Sudanese production of faba beans, lentils, and haricot beans; faba beans are second only to sorghum in the area cultivated.

Research on lentils and chick-peas in Turkey will prove beneficial to farmers in neighbouring countries such as Iraq, Iran, Lebanon, and Syria where similar agroclimatic conditions prevail. Though archaeological evidence shows that chick-peas were grown in Turkey more than 5000 years ago, until recently relatively little investment was dedicated to improving the low-yielding local varieties that display insufficient tolerance to low temperatures and prevalent diseases. Collections in Turkey are serving to expand both the national and regional germ plasm base.

Scientists trained in legume research at the Faculty of Agriculture in Amman are exploring improved cultural practices for different ecological conditions in Jordan and surrounding countries; improving cereal-legume-cereal rotations; and testing and adapting a locally developed harvesting machine for lentils and chick-peas, which are the legume crops of primary interest.

The legume improvement programs in Pakistan and Bangladesh, referred to under the Asian region, also derive benefit from ICARDA and the Middle Eastern network, which is a program that approaches an ideal for AFNS involvement, embodying financial support for a specific program within an IARC to which are linked several complementary national research, demonstration, and training projects.

Other food crop improvement projects have included triticale improvement in Algeria and Lebanon, the former now being entirely financed by the Algerian government, and a recently approved barley improvement project carried out by the Central Anatolia Agricultural Research Institute in Turkey. Also of recent origin is an Egyptian project designed to ameliorate on-farm production of the oilseeds sesame, sunflower, rapeseed, and groundnuts; soon to be complemented by research into the technologies of extraction of the constituent edible oils and use of the protein-rich residual meal.

The Agricultural Research Corporation of the Sudan recently started a project to improve the agronomic, nutritional, and technological characters of groundnuts and sesame, established oilseed crops, and soybeans, which through breeding, selection, and agronomic research will add to existing patterns of oilseed production. A particular objective is to delay the time at which the sesame seed pods open and scatter their seeds (the "open sesame" phenomenon) and to simplify the harvesting process, which is largely manual.

Soil scientists at the University of Alexandria seek to increase the efficiency of phosphorus uptake by cereals and legumes from local rock phosphate and other fertilizers in crops planted on calcareous soils highly prevalent throughout the arid zones of the region. By chemical and microbiological means it is hoped to liberate some of the 80–90% of phosphorus immobilized by natural chemical reaction in the calcareous soils. The beneficial effect of small amounts of sodium pyrophosphate on retarding calcium phosphate precipitation in pure systems and in calcareous soils has been demonstrated.

Traditional rainfed cropping systems in Syria and neighbouring countries employ intermittent fallowing in fields used for wheat and other cereal production. In cooperation with ICARDA, progress is reported from the Syrian Ministry of Agriculture and Agrarian Reform in novel cropping systems that include various legume combinations in rotation with the traditional cereal crops. Syrian scientists have examined moisture distribution patterns and nutrient status within the soil profile as affected by the crop, i.e., the rotation and degree of tillage, and have screened and selected from a large volume of cereal, food legume, and oilseed germ plasm obtained from ICARDA and other international sources.

Desert Reclamation

Among the most challenging of all projects in the program is the project in Egypt where scientists from several universities and government departments are searching for means to establish smallholder farming systems on desert land, a project which if successful could benefit many countries of the arid tropics. If Egypt, once the breadbasket of the Mediterranean region, is to approach self-sufficiency in food supply, large areas of desert must be rehabilitated and productively subjected to cultivation. The project plans to use *Casuarina* and other tree species as protective barriers to soil that has been made fertile through the establishment of hardy pasture grasses and forage legumes raised with minimum irrigation and that, when plowed back and later submitted to controlled grazing of sheep, will establish a topsoil suitable for eventual production of food and forage crops. The project will draw upon the results of the *Casuarina*, forage crop, and fertilizer efficiency projects referred to earlier in this section. The proposed techniques of soil restoration are considered practical and economic and will not resort to the use of expensive chemical substances advocated elsewhere in the region to increase moisture retention. After a topsoil has been established, cropping systems of various cereal and legume combinations, in rotation with controlled grazing of cultivated pastures, will be studied.

The project is under way at two sites, one close to Sadat City where the agricultural research will take place alongside complementary rural development projects that seek to make maximum use of the available resources. A desert research laboratory with accommodation for visiting scientists is being built entirely with bricks fashioned from local clay.

Animal Research

Throughout history, sheep, goats, and camels have provided food and clothing to the people of the Middle Eastern region, where nomadic pastoralism has coexisted with animals in settled production systems. As elsewhere, the Division's priorities have been to improve the cultivation of pastures of well-adapted grasses and forage legumes and to supplement grazing and harvested forage with the by-products from agriculture, rural households, and industries that are unsuitable for direct human consumption.

The Animal Production Research Institute in Egypt is testing the adaptability and nutritional quality of various fodder crop introductions including elephant grass (*Pennisetum purpureum*), various clovers, and other pasture legumes over a variety of soils and ecological conditions. Elephant grass and several of the cultivated medicago legume species show a potential for superior dry-matter production under the conditions prevailing. From six cuttings, elephant grass produced up to 70 t/ha of green forage during the 6 summer months. When fed on elephant grass alone, Egyptian buffalo cows produced as much as 7 kg of milk per day, Friesians produced 9 kg/day, and local beef cattle gained 500 g/day in body weight.

Complementary to the pasture improvement project is a University of Alexandria study to improve the digestibility and feed value of a wide range of agricultural by-products through physical, chemical, and microbiological processing. Alkali treatment increases the digestibility of such lignocellulosic materials as woody stalks from trees, sugarcane bagasse, and the stems and straw from oilseed and cereal crops. Caustic sodia (sodium hydroxide), the alkali most often recommended, is clearly unsuitable for use among poor rural communities in developing countries. Caustic soda is expensive; it is manufactured in relatively few countries, and its highly corrosive nature presents a dangerous hazard, particularly to young children. Consequently, the Egyptians are exploring the effectiveness of alkaline solutions derived from the ashes of burned wood and other solid fuels that are found among most village communities. Also being studied are several novel approaches to ensilaging of agricultural materials including straw mixed with urea and covered with citrus pulp to absorb the generated ammonia. Finely chopped straw and ground date stones also show encouraging promise as animal feedstuffs.

Studies by the University of Alexandria in Egypt are being made to improve the digestibility and feed value of a wide range of agricultural by-products.

Related projects are being supported in the Sudan, a country that generates large quantities of molasses, bagasse, and other unused by-products, and in Syria where alkaline-treated cereal straw and other processed by-products will be fed to sheep, goats, and beef and dairy cattle. These and other related projects in the region may well benefit from the research on lignocellulolytic fungi in Thailand reported under the Asian region.

Fisheries Research

Four projects, one on mariculture and three on inland aquaculture, are being supported in the Middle Eastern region. Since recorded time, the black lip pearl oyster has been harvested from the shallow waters of Dongonab Bay situated on Sudan's Red Sea coast. The iridescent mother of pearl coating that lines the oyster's shell has provided the basic raw material for a large craft industry for many years. The estimated demand by local craftsmen and foreign manufacturers for buttons and artworks is for at least 1000 t of shells per year. Suddenly, in 1969, the oysters inexplicably died in large numbers. Whatever the cause of the morbidity, its speed was credited to the high oyster population density. Fisheries scientists of the Agricultural

Research Corporation in Khartoum are developing systems of oyster cultivation to eliminate the overcrowding typical of the natural habitat and thereby prevent a recurrence of high mortality. By systems of raft or tray culture described elsewhere in this publication, higher and more sanitary levels of production can be achieved.

Sudan, the largest country in Africa, includes within its territory close to 4×10^6 ha of fresh water. Apart from the harvest of wild indigenous species, this massive body of water is largely unexploited as a source of edible fish. The government is now dedicated to increasing per capita consumption from 2 to 10 kg, a target that calls for extensive fish farming in the foreseeable future.

The Fisheries and Hydrobiological Research Section of the Agricultural Research Corporation is charged with the responsibility for aquaculture research and has established a station at El Shegara close to Khartoum. The purpose is to establish systems of polyculture in which the well-established *Tilapia nilotica* and Nile perch (*Labeo niloticus*) are cultivated together with various exotic species of carp.

Stocks of the five species of interest have been maintained, seed of the indigenous species being collected from the Nile. Attempts to induce spawning by hormone injection of exotic grass carp have been encouraging and studies are being made on the rate of growth of fish fed compounded feeds from local agricultural by-products. The rate of growth and composition of plankton under various fertilizer regimens is also under examination.

Fish from the Nile has been a staple ingredient of the Egyptian diet for thousands of years. Construction of the Aswan High Dam has noticeably reduced the fish population of the Nile Delta and the harvest from Lake Nasser (approximately 23 000 t/yr) is far short of what is needed. In addition to embodying 300 000 ha of shallow lakes, Egypt has irrigation canals estimated to exceed 2000 km in total length. In all of these, cage aquaculture appears to be a highly feasible means of increasing edible fish production. The Institute of Oceanography and Fisheries is pursuing the realization of cage, fish pen, and enclosure culture in several inland lakes.

Beginning in 1978, floating cages of metal frames and fine netting supported by metal drums were stocked at different population densities with common carp. The results show significant differences in weight gain at different stocking densities and also indicate that in some cases mortality may result from the ingress to the lakes of agricultural pesticides.

Comparative studies with two species of *Tilapia* showed superior weight gains in *T. nilotica* over *T. galilea*, the former increasing from 83 to 354 g during a 3-month period.

It is of particular importance to ensure adequate survival among the juvenile fish. Early results indicate that the feeding and management systems being tested result in a high survival rate among fingerlings of mullet (*Mugil capito*) and common carp.

Pen culture research in Lake Burullos began with limnological studies, data on water composition and condition being collected at 26 stations.

Chemical composition, phytoplankton, and zooplankton contents were recorded and three enclosures, each of 2 ha in surface area, are being stocked with two species of mullet (*M. cephalus* and *M. capito*) and the gilt head bream (*Chrysophyrus auratus*).

A more complex and difficult project in the Turkish Keban reservoir on the Euphrates River, calls for biological, physical, and other limnological studies. The purpose is to develop methods of stocking, management, conservation, and harvesting of fish species in this man-made lake. If and when established, fish harvested from the lake could serve as a valuable source of food, employment, and income for the nearby rural population. Good road communication facilitates the expeditious delivery of fish, surplus to local needs, to the urban markets in Ankara.

Postproduction Systems Research

Although lentils, chick-peas, and faba beans have been of major importance in rural diets for centuries, relatively little study has been devoted to those properties that influence the nutritional and cooking qualities and the acceptability of legumes. Nor has much attention been given to improving postharvest technologies of storage and processing. At the University of Alexandria, an effort is being made to relate phenotypic characters, agronomic environments, and conditions of cultivation and storage of the principal legumes to the biological and chemical properties that influence cooking, nutritional, and other essential qualities. The project is integrated with the Egyptian legume improvement project, legume samples being provided to the University from the breeding and selection program in addition to the many samples collected from 50 farms and storage trials in Upper Egypt and the Nile Delta. The effects of different storage conditions on cooking quality following modifications to the traditional methods of roasting faba beans are also included.

Taking advantage of the results of the sorghum milling projects in Nigeria, Botswana, Ethiopia and elsewhere, the Food Research Centre at Khartoum is evaluating five different machines to determine which appears best suited to the decortication of sorghum in Sudanese rural villages. The machine proven most satisfactory in laboratory trials will be installed in one or more rural sorghum mills.

Between the 22nd and 33rd latitudes that form the northern and southern boundaries of Egypt, a country that enjoys an annual average of 3600 h of sunshine, solar intensity varies between 700 and 900 kcal/m^2/h. Consequently, the drying of food crops by direct sunlight is a long-practiced tradition. The hygienic and technical unsuitability of direct sun drying has already been referred to. At the Solar Energy Laboratory of the National Research Council in Cairo, several prototype solar collectors and convection dryers have been designed and constructed and their technical and economic efficiency is now being studied in the dehydration of fish and several vegetable crops at several locations in Egypt.

Data collected from the various locations include intensity of solar radiation; seasonal average wind speed; rainfall; ambient air temperature and relative humidity together with data relevant to production, harvesting times, and conditions; and condition and chemical composition of various products of agriculture and fisheries potentially suitable for solar drying. Based on what might be termed optimum demand criteria, a dryer was designed, consisting of a solar air heater, to heat 800 m^3 of air per hour driven by a centrifugal fan. The heated air removes moisture from the product being dried, which is spread on stainless steel wire trays fixed to the walls of the drying chamber.

During demand studies a familiar contradiction was encountered. Government agencies preferred large-capacity dryers designed to serve a large community. On the other hand, farmers asked for small-capacity dryers that could be owned and operated by a single farm family. The design described above is expected to satisfy the government's requirement. For the individual farmer, the Solar Energy Laboratory has designed a prototype family-size dryer that operates on a convection principle and will be subjected to field trials at several locations and on a number of commodities. Cooperative linkages have been created between the Egyptian project and other projects supported by IDRC including onion drying in Niger and fish dehydration in Indonesia, Mali, the Philippines, and Thailand. Field trials are being conducted by a group of interested agencies including the Aswan Governorate at Lake Nasser, a village created for the rehabilitation of disabled war veterans, Sharkia University, and at Kafrlelalao in the Giza Governorate where vegetable dehydration and the feasibility of drying berseem clover as a preserved forage will be essayed.

Despite their large and rapidly growing populations, Egypt and other Middle Eastern countries experience seasonal shortages of farm labour. Appropriate mechanization is, therefore, essential to gain maximum productivity, efficient harvesting, storage, and distribution of the principal food crops. Early in 1978 the Behera Corporation, a parastatal company based in Alexandria, began the development of an integrated small-farm mechanization system. A single multipurpose 12 hp (9 kW) diesel motor provides power to various farm machines including a thresher, seed drills, planters, sprayers, irrigation pumps, and a half-tonne utility vehicle. After selection of the drive motor, a rice thresher, developed in the Philippines, was extensively modified and simplified for the threshing of Egyptian wheat, barley, and sorghum, a process requiring the effective separation of the grain from finely chopped straw (*tibn*) used in animal feedstuffs in Egypt. The many changes included reducing the clearance between fixed and moving knives, redesigning of sieves, the division of the fan housing into two sections each with a separate air inlet to provide the higher air speed needed to separate the finely chopped straw, and other modifications to reduce the cost of manufacture. In addition to acceptance among the Egyptian farming community, the Behera design won an international competition and more than 580 of the threshers will be manufactured by the Behera Corporation with World Bank financing.

Field testing has been undertaken in Upper Egypt where sorghum, food legumes, and wheat are grown, and in the Middle Delta where the Behera system is being applied to maize, wheat, cotton, and rice. In each case modifications have been made to suit local needs. Work is continuing on an axial-flow irrigation pump and a sprayer to be used in conjunction

The Behera thresher undergoing field trials on a government farm near Tanta, Egypt.

with the traction unit also being field tested for the planting of wheat, barley, cotton, maize, and berseem clover.

Credit to rural communities to purchase the Behera system is provided through Egyptian farmers' cooperatives. The Behera thresher and other component machines may soon be supplied to other IDRC-supported projects in the Sudan, Ethiopia, Botswana, and Tanzania, the Behera technologists acting as advisers to these other countries. In almost every respect the Behera project has proved to be a most rewarding and gratifying investment demonstrating the value of applied research carried out in direct cooperation with rural users rather than in a remote laboratory.

Asia

Asia is the largest of all the world's continents, embracing a total area of 4.582×10^7 km^2 equivalent to 30% of the earth's total land mass. The estimated total population of Asia in 1970 was about 970 million and it is forecast to increase to 1.5 billion, which will represent 60% of the world's population by 1985. Asia displays the greatest variation in topography, soil, and climatic conditions of all the world's continents, including the highest peak, Mt. Everest at 8800 m, and the world's deepest continental trough, Lake Baikal, which is 1600 m deep and whose bottom is 1300 m below sea level. Precipitation varies from less than 10 cm/yr in the deserts of West and Central Asia, to more than 1200 cm in the equatorial belt.

Though Asia includes regions of extreme cold, it is across the tropical regions of West, South, and Southeast Asia that IDRC's program is spread. Pursuant to the recent signing of an agreement with the People's Republic of China, the range of agroclimatic conditions may expand in the future.

The rural inhabitants of Asia are among the poorest in the world; 22 Asian countries being classified as Less Developed Countries (LDCs), 7 as Least Developed Countries (LLDCs), and 10 as Most Severely Affected (MSA).

Excluding Japan, the average annual per capita income for all Asia in 1977 was approximately U.S. $240, the average by country ranging from about U.S. $110 in Burma to more than U.S. $850 in South Korea. Approximately 80% of all Asians live in rural areas, and between 70 and 80% depend entirely upon the land for their livelihood. Consequently, it is upon agriculture that most of Asia's economy depends, smallholder farming being the principal occupation. Cereal grains, principally rice (60% of the world's rice is grown in Asia), legumes, and root crops provide most of the essential nutrients. In spite of remarkable increases in rice and wheat yields in recent years, Asia suffers an overall cereal deficit, forecast to reach 4.6×10^7 t/yr by 1985. Consequently, a greater political commitment to and investment in agricultural research and development is needed throughout Asia for many years in the future.

Several countries demonstrate the benefits that accrue from a dedicated commitment to agriculture. In India, for example, agricultural research and development appears as the leading edge of economic development. The remarkable benefits derived from research to improve wheat and rice illustrate what might result if equivalent research investments were devoted to food legumes, oilseeds, roots, and tubers.

Cereals and food legume seeds are best consumed in a ratio of two parts by weight of cereal to one of legumes, in which proportion their proteins are nutritionally complementary. Having received relatively little attention from research workers, legume yields are low and consequently farmers have reduced their plantings of legumes and oilseeds, and throughout South and Southeast Asia the present ratio of cereal grain to legume production is approximately 9 : 1.

As on other continents, the greatest investment in the Division's program in Asia has been on crops research, including a network of cropping systems projects, with several projects devoted to such neglected crops as the minor millets, oilseeds, root crops, and several legumes. Most valuable, for cropping systems research throughout the world, is the research methodology developed at IRRI and continually refined, modified, and adapted to the needs and resources of individual countries.

Some of the most spectacular results have arisen from aquaculture and mariculture research, and the experience gained is now being adapted in other continents. A network in which IDRC has cooperated with several other donor agencies has stimulated a novel approach to postharvest systems research. Support for forestry research has been less extensive with relatively few projects in Asia, though the number will increase when several bamboo and rattan improvement projects begin. The smallest number of projects has been in animal sciences, however, with the appointment of a new associate director for animals, who has resided in Asia for several years, support for animals research is likely to expand. Table 4 presents the cumulative number of projects and total appropriations in 11 countries of Asia.

Fisheries Research

Fish Farming

Fish farming of fresh, brackish, and saltwater species has been practiced in Asia since recorded history. Until recently, however, improvements in fish culture systems derived more from empiricism than systematic scientific study. Although other agencies are now taking an interest, the AFNS Division from its early years gave more encouragement to aquaculture research than most other development agencies.

Fish farming offers attractive returns particularly in inland lakes, village ponds and rivers, and in estuaries and other calm coastal waters. Because they use relatively few calories to maintain body temperature, fish, in general, are more efficient converters of feed to flesh than are terrestrial animals. Many aquatic plants that fish feed on use sunlight with greater photosynthetic efficiency than their land-borne relatives. Fish farming is clearly safer than ocean fishing and, when scientifically controlled, the yields are more predictable. Fish farming can be profitably integrated with other rural agricultural and artisanal production systems; species are selected according to their ability to subsist upon a wide range of agricultural wastes and by-products, including some unsuitable for domestic land animals.

Most traditional fish farming in Asia begins with the harvesting of juvenile species from shallow waters and spawning grounds. Because this

Table 4. Total appropriations and number of projects in Asian countries.

	Crops and Cropping Systems		Fisheries		Animal Sciences		Forestry		Postproduction Systems	
Country	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects
Bangladesh	903.5 (65%)	3 (50%)					183.7 (13%)	1 (17%)	310.9 (22%)	2 (33%)
India	4109.6 (78%)	13 (76%)	373.1 (7%)	1 (6%)					755.3 (15%)	3 (18%)
Indonesia	426 (27%)	2 (18%)	457.1 (29%)	2 (18%)	98.4 (6%)	1 (9%)	29.1 (2%)	1 (9%)	561.1 (36%)	5 (46%)
Korea									276.9 (100%)	3 (100%)
Malaysia	363.1 (28%)	1 (12.5%)	746.5 (57%)	5 (62.5%)	99 (8%)	1 (12.5%)			96.3 (7%)	1 (12.5%)
Pakistan	376.1 (100%)	1 (100%)								
Papua New Guinea	140.2 (100%)	1 (100%)								
Philippines	6338 (67%)	13 (46%)	1354 (14%)	4 (14%)			288 (3%)	1 (4%)	1471.6 (16%)	10 (36%)
Singapore			599.5 (82%)	3 (60%)					133 (18%)	2 (40%)
Sri Lanka	1412.6 (93%)	7 (88%)	109.7 (7%)	1 (12%)						
Thailand	1552.3 (57%)	4 (21%)			401.4 (15%)	3 (16%)			789.4 (28%)	12 (63%)

ancient method of netting fish "seed" is inadequate, uncertain, and relatively wasteful of an essential resource, it was to the problem of "breeding in captivity" that the Division first provided assistance in Asian fisheries research.

The reluctance of the gravid females of some fish species to spawn in captivity was well known. It had been demonstrated, first in Brazil, that egg laying could be induced by injecting the gravid females with crude pituitary extracts or other sources of gonadotropin sex hormones. To satisfy the need for fish pituitary gonadotropin throughout Asia, the Centre, through a contract with the British Columbia Research Foundation and in cooperation with a large salmon canning operation on the Canadian west coast, obtained large quantities of Pacific salmon pituitaries from which the hormones were extracted using a method developed by the Fisheries Research Board of Canada. This material gave a start to induced breeding in several Asian projects where, subsequently, pituitary extracts from species indigenous to Asia were found to be at least as and often more effective than the salmon hormones.

In Malaysia, aquaculture offers a relatively cheap and available source of protein from inland waters that occur naturally and also result from large dams, barrages, and tin mine excavations. Aquaculture produced about 42 000 t in 1980 and over 50 000 t are forecast by 1985. To achieve this increased production, at least 10 million additional fry of Chinese carp, local carp, and other accepted species will be required. Malaysia imports a minimum of 25 million Chinese carp fry every year. In the project conducted at Malacca by the Malaysian Agricultural Research and Development Institute (MARDI) both Chinese and local species of carp have been spawned in captivity. Silver carp and bighead carp can be spawned with 80 to 90% success, and, though proportionally poorer than the other two, grass carp have also been induced to spawn. Hatchling and fingerling survival has been improved, mainly through the cultivation of a supply of live food consisting mainly of *Daphnia* and rotifers. Other well-accepted local fish species have also been spawned. Recent progress has been impressive though spawning techniques require further refinement and standardization over the range of seasonal, climatic, and environmental conditions that prevail.

The University of Sains Malaysia is studying other sources of gonadotropin including the pituitaries of tuna caught on the west coast of the Peninsula. Of particular value is the finding that pituitaries of common carp will induce spawning in most of the species of interest to Malaysian fish farmers. Whether sufficient amounts of common carp pituitaries can be collected and extracted to satisfy the demands of future induced breeding systems has yet to be determined. More research is needed on factors that affect brood stock, the survival of hatched fingerlings, and the rate and growth of development of juvenile and adult cultivated species. More information is urgently needed on the nutritional requirements of cultivated species at all stages of growth and development and under all environmental conditions to which they may be subjected. In the nutritional laboratory at Malacca, results indicate that hatchlings require live food for at least 10-14 days after yolk sac absorption and that while compounded and synthetic diets support reasonable growth and survival in some species, in others, including bighead and silver carp varieties, abnormalities result from synthetic feeds and are possibly a result of micronutrient deficiency. Recent results indicate, however, that live food can be produced in almost continuous culture by organic and inorganic fertilization of the waters.

Though each of the aquaculture and mariculture projects supported by IDRC has added to the sum of relevant knowledge, there is a clear need for an international aquaculture research centre endowed with human and physical scientific resources comparable to those of an international agricultural research centre. The embryo of such a centre is to be found in the Aquaculture Department of the Southeast Asian Fisheries Development Centre (SEAFDEC) whose several research stations have been sustained largely by the Government of the Philippines, in a lesser degree by the Government of Japan, and more recently by IDRC. The priorities for aquaculture research that could be pursued and/or coordinated by SEAFDEC are included in the recommendations of an Asian Aquaculture Study Mission financed by IDRC.

Milkfish

While continuing to encourage more widespread donor support for a comprehensive international agricultural research effort, AFNS has concentrated its research support in the Philippines on the milkfish (*Chanos chanos*) a project rewarded with notable success.

Though apparently most abundant in the waters of Southeast Asia, milkfish are found in the Red Sea, along the east coast of Africa, across the Indian and Pacific Oceans, and as far as the coast of Mexico. The life cycle of the milkfish is roughly the reverse of the Pacific salmon. The adult females lay their eggs in shallow coastal waters, the juveniles migrate up freshwater rivers and in due course return to the deep ocean where they grow to maturity. It is reported that milkfish culture, beginning with fry netted in coastal waters, began in Java before the 15th Century. Milkfish ponds are now found in the Philippines, Indonesia, Hawaii, Vietnam, the Rewa Delta of India, Taiwan, Fiji, and the Gilbert Islands. Collectively, the Philippines, Indonesia, and Taiwan raise more than 250 000 t of milkfish in brackish and fresh waters, valued at more than $100 million annually.

Milkfish are amenable to various culture systems. They adapt to fresh, brackish, and saltwater conditions; and are essentially herbivorous and grow well in net, pen, or cage enclosures, in the eutrophic waters of reservoirs, abandoned mining pits, brackish lagoons, natural ponds, and flooded bunds. Feeding on benthos and filamentous algae, milkfish grow to marketable size in coastal ponds of less than 1 m in depth. They are thus hardy, versatile, and adaptive. Unfortunately, the females resist laying their eggs in captivity and the supply of naturally spawned fry is totally inadequate to meet present and expected future aquacultural demand.

Though a number of earlier attempts failed, scientists in the IDRC-supported project in the Philippines were successful in inducing gravid female milkfish to spawn in captivity. Induced spawning was first accomplished in 1977 by injecting a female milkfish with a mixture of acetone-dried salmon pituitary extract and human chorionic gonadotropin. Of the incubated fertilized eggs deposited, 45 of the resulting larvae were reared to the fry stage, 25 of which survived and grew to a weight of 1 kg. Induced spawning was repeated in 1978 at SEAFDEC's Tigbauan station where milkfish eggs were artificially fertilized and hatched. Of the resulting larvae, those fed artificial feeds died within 4-5 days, whereas those fed naturally occurring aquatic foods, such as *Chlorella* and *Brachionus*, survived. A stock of wild milkfish was subsequently domesticated and reared in experimental ponds at Pandan. Survival rates of between 81 and 97% were achieved during transport from the wild to the domestic environment. Milkfish juveniles raised from wild fry in maturation pens are so domesticated they are fed by hand, having learned to associate feeding time with the striking together of two bamboo sticks.

Early sexing of milkfish was possible following the discovery that the males display an anal plus a single urogenital opening, but the females carry separate anal, urinary, and genital pores. Results from feeding experiments indicate that microbenthic algae are a good source of natural food for all stages of pond-reared milkfish. The response of adults to pelletized synthetic feeds is under examination.

Studies of polyculture (several species in the same water enclosure) showed a high growth rate when prawns and milkfish were raised in the ratio of roughly 25 : 1. Because the two are noncompetitive, the combination serves to increase each pond's carrying capacity. In the freshwater lake at Binangonan, milkfish production averaged 5 t/ha per harvest though yields were lower in turbid waters, which appeared to inhibit phytoplankton growth.

Fingerlings — the result of induced spawning of milkfish at SEAFDEC.

Socioeconomic studies showed that milkfish culture provides direct employment for about 170 000 Filipino workers; average production yields approximate 600 kg/ha/yr, and the peak season for fry collection is April-June. The studies also determined the average and range of price for fingerlings and marketable fish, levels of capital and operating investment required for different scales of production; credit availability, and average earnings from fish pond and fish net culture. The research priorities for the future include increased seed production, reduced mortality during nursery rearing of the juveniles, brood stock development to provide gravid female milkfish for the hatcheries, and improvement in culture and management techniques. Different aquatic environments require different systems of management and work is now beginning on cultivation in cages in man-made lakes and other large bodies of water.

Mariculture

Singapore's population of 2.2 million, living on 580 km^2, imports 75 000 t of fish every year. Intensive mariculture appears to be the only means whereby Singapore can reduce its dependence upon off-shore supplies. Promising results have been reported from two mariculture projects conducted by the Primary Production Department of the Government of Singapore. Each is concerned with the establishment of economically sound fish farming systems, one through the intensive culture of maritime finfish in cages and raceways and the other through the culture of mussels below floating rafts in the coastal waters of the East Johore Strait. The cages are kept afloat by plastic drums coated with antifouling paint and held in position to trapezoidal concrete anchors. Since the research began a growing number of fish farmers and palisade fish trap operators have constructed floating cages for small-scale fish cultivation.

During 1977 the grouper (*Epinephelus tauvina*) and later the golden snapper (*Lutjanus johni*) were induced to spawn in captivity and 2-year-old fish can now be spawned throughout the year depending on the stage of gonadal development. Studies on hormonal induction of sex inversion have also been completed showing that 2-year-old groupers can be transformed into functional males with methyltestosterone treatment. Males produced in this way are thus available for reproduction much earlier in the life cycle.

Other commercially important species have now been bred artificially following a close study of their breeding cycles. Results from induced breeding of the commercially attractive rabbit fish showed that spawning activities adhere closely to the lunar cycle. Research will continue to ensure an adequate supply of fish seed at all times of the year. An important problem that remains is the development of a hatchery and nursery system for large-scale fish fry production. This requires the perfection of a seawater pumping and filtration system to ensure that the hatchery water is free from undesirable contaminants.

Nutritional studies seek to provide feed for adult fish compounded from available by-products of fisheries and agroindustries. Because of the demand for the species cultivated, which appear to grow well in floating cages, the potential economic return to small-scale coastal fishermen

Floating cages where the natural spawning of milkfish in captivity has been achieved.

appears attractive and is much less hazardous than going to sea in small boats. Preliminary studies indicate a potential production rate of 40 kg/m^2, which over the available area may be extrapolated to approximately 400 t/ha with a value of close to S$4 million (Singapore dollars) per annum.

Mussels are among the most efficient converters of phytoplankton to animal flesh and, being one of the hardiest of marine organisms, they are highly amenable to extensive mass mariculture. In the past mussels have been cultured mainly in European countries, however, the rich resource of plankton and high temperatures of tropical waters offer a much greater but as yet unexploited potential for mussel culture. At present mussel culture in Asian countries represents less than 5% of total world production. The coastal Kampong people in Singapore collect naturally occurring mussels from the poles of their kelong fishing traps. Because of overcrowding, production is low and in some instances sanitation is unsatisfactory. The nutritional quality of mussel protein is comparable to that of other animal proteins, and mussels generally carry a higher percentage of meat to shell than most other shellfish. In fact, mussels are among the most prolific producers of edible protein in the animal world. Under favourable conditions, the annual yield of protein per hectare of surface water for mussels far exceeds the protein produced by 1 ha of soybeans.

In common with other bivalves, the juvenile mussel spat is motile for only a brief period after hatching, and in the wild it attaches to any suitable submarine surface where it grows by filtering its food from the surrounding waters. Filter-feeding serves to concentrate not only essential nutrients but also pathogenic organisms from contaminated water. Consequently, mussel, oyster, and other bivalve culture requires an unpolluted environment with tidal flows that ensure continuous food supply. As with many aquatic species, the higher the water temperature, the more rapid the rate of growth. Consequently, mussels and oysters in tropical waters grow considerably faster than those in the northern latitudes.

In Singapore studies have been conducted on various methods of culture including raft, long line, pole, and bouchot methods of which the raft and long line seem most promising. Scientists at the Primary Production Department have devised a highly productive mussel culture system in which long submerged ropes are attached to floating rafts. Because of the heavy weight of mussels when all are grown to maturity, very strong woven polyethylene ropes were necessary. It was found, however, that polyethylene alone was too smooth to permit the mussel spat to attach. Consequently, rough strands of coconut coir were attached to the rope and were sufficiently spaced to ensure that the mussels did not overcrowd. The polyethylene-coconut coir rope serves for both spat-catching and grow out without subsequent thinning and, therefore, reduces the cost of labour in addition to yielding 52 kg of live mussel per 4-m length of rope per 6 months of culture.

From biological studies on factors that affect growth and spat fall, the scientists have identified areas most suitable for spat collection and grow out. The most suitable areas show high phytoplankton concentrations and slow currents.

Rafts are basically wooden pontoons supported by 200-litre plastic drums. The polyethylene-coconut coir rope is 14 mm in diameter with 30-cm coir pieces attached to the centre of each metre. The ropes are suspended at 4 ropes/m^2; spat settles densely on the open ends of the coconut fibres, which thus uniformly disperses the settlement over the entire rope.

In the open coastal waters around Changi 0.25 t of mussels are cultivated below each square metre of raft in a 6-month period, which by extrapolation is roughly equivalent to 90 t of protein per hectare of surface water. In comparison, a satisfactory crop of soybeans will produce about 0.9 t/ha/yr of protein.

The project promises a highly productive system of mussel culture and emphasis is now being given to postharvest treatment including shelf life studies on fresh mussels and solar-dried mussel meat.

In Sabah an initial survey located the best coastal areas for tropical oyster cultivation and two species of *Crassostrea* and one of *Iredales* have been identified as abundant and suitable for cultivation. The techniques of spat collection and systems of raft culture are now sufficiently advanced to be demonstrated to coastal village people. The relatively high demand for oysters promises a satisfactory return on the capital and labour investment.

Freshwater culture is far from being adequately exploited and there are many species indigenous to Asian inland waters that could be cultivated if their essential biology were better understood. In Sarawak, the State Ministry of Agriculture and Community Development is studying the stocks of

Mussel culture in Singapore.

native freshwater fish species, the ecological environment and how it is changing, and the decline in fish stocks resulting from more efficient fishing with monofilament gill nets and from morbidity caused by toxic and noxious pollutants. The ultimate purpose is greater conservation and the identification of local fish species suitable for culture in cage or other systems of freshwater management. Progress has been relatively slow, partly because the study is unique to the region and methodologies are not well established. Also, severe floods inflicted heavy losses upon brood stocks in cage culture trials. As in several other IDRC-supported projects, valuable assistance has come from CUSO, who supplied two volunteers to the project, which is expected to have important implications for inland fisheries in a number of Southeast Asian countries.

Two inland fisheries projects are supported in Indonesia. The first seeks to control important natural parasitic infestations and diseases and the second to develop cultivation techniques for well-accepted local freshwater species. Ectoparasites of the genus *Lernea* cause serious depredation of free-swimming and cultured species in the inland waters of Sumatra and other parts of Southeast Asia.

Studies are in progress on the epidemiology, the life cycle, and natural and man-created ecological factors that favour *Lernea* and related ectoparasites. Progress has been made in the control of *Lernea* through more efficient filtration at the hatcheries. Debilitation caused by toxicity from increased concentration of agricultural pesticides in the natural waters appears to increase the fishes' susceptibility to parasites. A valuable manual on fish parasitology was prepared by a consultant to the project.

At the Universiti Pertanian Malaysia, a recently started project is also studying the life cycle and means of control of *Lernea* and related copepods, minute Crustaceae that live parasitically upon many fish species.

The Inland Fisheries Research Institute (IFRI) in Bogor is studying the biology, life history, ecology, and pattern of reproduction of several native species with a view to selecting those amenable to induced spawning and cage culture. Present knowledge makes possible the cultivation of only a small fraction of the more than 1000 known species of edible freshwater fish. Research to control parasites including *Trichodina* among cultured and wild freshwater fish in the Philippines is being studied at the Central Luzon State University.

In Sri Lanka, the Ministry of Fisheries is studying the applicability of cage culture systems to the ancient "tanks" described in the section on cropping systems. Per capita fish consumption has recently declined in Sri Lanka in response to rising costs of ocean species. There is an unexplored potential for fish culture in the more than 10 000 tanks (irrigation reservoirs) that exist. Stocking of the tanks with free-swimming species is not satisfactory as the adults are difficult to harvest. Culture of suitable species within submerged cages or other discrete enclosures offers a viable alternative.

Twelve experimental cages have been constructed at each of three project sites. The use of fine mesh nets in constructing the cages, permits early stocking with young small fry. A compounded feed formulated by the Institute of Fish Technology is being tested with Chinese carp and additional cages are being built to expand the number of experiments. Economic studies will examine the costs and returns from cage culture, together with transportation, distribution, and marketing costs.

It is foreseen that cage culture will in due course be managed by and bring economic and nutritional benefit to the same communities that are implementing the more productive cropping systems described under the Asian crops program.

Polyculture

The success of the research on polyculture by the Central Inland Fisheries Research Institute (CIFRI) in Barrackpore, India, has been reported in a number of IDRC publications. With World Bank support, the Government of India now seems destined to establish facilities for seed production and seed banks in various parts of the country to proliferate the production systems developed at CIFRI and successfully tested with IDRC support in the states of West Bengal and Orissa.

Briefly, the polyculture system consists of stocking village ponds with five or six different fish species that consume different components of the available food resource. A polyculture combination extensively studied consisted of three native and three exotic species of carp, each of a different feeding habit. Before stocking with the mixture of young fry in predetermined proportions, each pond is first cleared of all existing competitors and potential predators by dosing the water with a local oilseed cake containing a toxic biodegradable alkaloid Mowrin that, after it has destroyed the competitive organisms, breaks down to harmless substances. The ponds are then stocked and regularly fertilized with organic manure and inorganic phosphates to stimulate growth of aquatic plants. Cut vegetation and the trimmings and waste products from vegetable gardens and markets are floated in baskets along with rice bran and other agroindustrial by-products. The herbivorous species of grass carp soon learn to feed from the floating commissary. Before introduction of polyculture systems, village ponds yielded perhaps 0.5 t of fish per hectare per year. By adding polyculture, yields in excess of 6 t/ha have been reported.

In addition to its adoption by village communities, polyculture has appealed to various institutions including the Indian Institute of Management, several orphanages, and a number of schools, some of which now include aquaculture in their curricula of biological sciences. In a manner analogous to the cropping systems research, the Indian polyculture research has provided a valuable research methodology, together with techniques and culture management systems that, with IDRC support, can be adapted by other developing countries.

Although each of the projects described involves the studying of different aspects of aquaculture and mariculture, there are many common features and the Division's purpose, through its program staff in Singapore, is to ensure cooperation among the various participants. As indicated, noteworthy progress has been made in induced spawning, though much remains to be learned about the reproductive physiology of brood stock and the effect of all relevant factors upon larval and juvenile survival, nutritional requirements, rate of growth, and resistance to parasites and diseases. The Division will continue to encourage greater investment in aquaculture and mariculture among the nations of South and Southeast Asia and by other donor agencies.

Crops Research

Multiple Cropping

Multiple cropping may be defined as growing more than one crop in the same year on the same piece of land and includes intercropping or mixed cropping, in which two or more crops are grown simultaneously; relay cropping, wherein a second crop is planted before the first is harvested; or sequential cropping, when additional crops are planted before and/or after the normal cropping season. Because rice is the principal food crop of Asia, most of the cropping systems have been built around small rice farm production economies. The network of projects supported in Asia has been linked with the International Rice Research Institute (IRRI), which, in cooperation with several Asian countries, developed the basic methodology and put to the test the various systems proposed for alternative climatological, soil, and socioeconomic conditions.

Multiple cropping systems research began at IRRI in the late 1960s and was of modest proportions until 1971 at which time IDRC gave support to an agronomist and an agricultural economist. IDRC support for the IRRI program has continued through the decade though the research team and its activities are now much larger than IDRC can finance alone.

From the beginning IRRI worked to formulate a cropping systems research methodology including concern for both technical and socioeconomic factors and to develop alternative cropping systems for areas with broadly similar agroclimatic environments. Of equal value is the cropping systems training program that the IRRI scientists developed in cooperation with the University of the Philippines at Los Baños (UPLB). IDRC also contributed to the first of a series of regular workshops at which cropping systems research workers throughout Asia shared their experiences and compared results.

Training at IRRI and UPLB ranged from short specialized courses to postgraduate training. One of the most imaginative training activities involved young graduate scientists from several Asian countries in disciplines ranging from plant breeding and agronomy to rural sociology. They all worked in the same *barrios* on aspects of multiple cropping relevant to their respective disciplines and eventually presented what might be described as a set of interlocking graduate theses.

Early in the program IDRC financed a study in which two scientists characterized, mapped, and assessed the actual and potential productivity of the soils on which rice is grown throughout Asia. The study included both superior and "problem" soils such as those high in acid sulphates, salinity, alkalinity, and iron; and those deficient in zinc, phosphorus, and other essential nutrients. Together with the data from a climatological survey, IRRI and national scientists were able to classify the region and select sites typical of larger agroclimatological areas on which to evaluate alternative cropping patterns of potentially wide adaptability. Though cropping systems tend to be "site specific" and greatly influenced by the physical, social, and economic environments in which they exist, important general principles have evolved that are of broad application.

In addition to the IRRI program, IDRC has supported specific cropping systems projects at selected sites in the Philippines, Indonesia, Thailand, Bangladesh, and Sri Lanka, with much of the research being conducted in farmers' fields. Each project began with as comprehensive a study as resources permitted of the existing farming systems; the patterns of crop production; and such important economic factors as labour demand and availability, costs and financial returns, and credit and marketing facilities. From this baseline data it is possible to determine the effects and limiting constraints that result from subsequent changes in the cropping systems. (The basic components of cropping systems research are shown in Figs. 1 and 2.)

IDRC support for IRRI and the five national programs has greatly stimulated on-farm cropping systems research in the Asian region. At more than 70 locations young research workers are developing improved production technologies in cooperation with smallholder farmers, most of whom work on less than 2 ha of land.

In Indonesia, the Philippines, and Sri Lanka, improved cropping patterns involving new crop varieties and management practices have been widely adopted by farmers and are the basis of large-scale national production programs. In Indonesia, dryland rice-growing areas susceptible to erosion are now planted in a combination of intercropped and sequentially planted crops that include rice, cassava, maize, cowpea, and ricebean, the land never being left bare during the growing season.

Sri Lanka's studies of the historic tank-based rice production systems, with its complex of dryland and wetland fields, has led to a stable two-crop production system for the wetlands; improved systems are now applied in more than 40 "minor tanks" in the dry zone of Sri Lanka.

In the Philippines, double cropping of rice was introduced in rainfed wetland areas that previously produced one crop per year. Expansion of these production systems in rainfed areas of the central and southern Philippine Islands is financed by the World Bank. Short season food

Improved crops and cropping patterns have been developed in Sri Lanka for use with the ancient tank-irrigation systems.

legumes grown after rice have been successfully introduced at many locations. Cowpeas grown after rice substantially benefited the following rice crop by enriching the lighter-textured soil areas in Sri Lanka. In the Philippines, improved insect control increased farm level mung bean yields from 250 to 750 kg/ha. The net returns from the postmonsoon upland mung bean crop exceeded returns from rice. The Bureau of Agricultural Extension, in a province-wide program in Central Luzon, is introducing these improvements to farmers beyond the original research site.

Most countries participating in the Asian Cropping Systems Network are encouraging production programs to establish new cropping patterns over wider areas by providing credit and technical advisory services.

In addition to collecting a vast amount of economic data, the IRRI program gave rise to technical advantages too numerous to mention. In cooperation with the University of the Philippines, plant types were bred that in form and growth habit fitted specific cropping patterns better than standard varieties. Weeds were reduced by shading with leafy legumes. Insect depredation was reduced by row intercropping, insects often being unable or unwilling to cross the barrier intervening between the rows of their favourite crop for attack. Groundnuts brought with them a carnivorous spider that attacked and reduced the populations of several crop pests.

To obtain year-round socioeconomic information, standardized data sheets were completed by Philippine school children who, during the summer, literally followed their farmer parents all day to record the time spent and investments made on every relevant activity.

In a cropping systems project carried out by UPLB, work began in 1972 in six villages close to Los Baños and was expanded to 18 more villages in January 1974. These expansion villages were located in provinces that were less populated and less accessible than the one involved in the initial work. Research was continued in each *barrio*, supervised by a UPLB technician, for 4-5 years. In addition to providing technical advice the technicians were responsible for assisting with credit and marketing facilities and for helping farmers to obtain loans from neighbourhood banks. A revolving credit fund provided by IDRC was used as collateral by farmers who had insufficient fixed assets to obtain normal bank loans. Marketing of produce and purchase of fertilizer, chemicals, and improved seeds, were undertaken through village cooperative associations. A home technology food preservation and nutrition program was also included in the UPLB project.

By 1976, results from the project inspired the Philippines government to expand the program over a larger area covering all of one province in Central Luzon. In 1977 it expanded further over a still larger area in Central Luzon and to a number of *barrios* in other regions of the country. The success influenced the government to restructure its agricultural services, integrating extension more closely with research and development, Also, rather than being responsible for a specific crop, each extension technician continually advises a specific group of farmers in all aspects of their cropping systems and farm management.

In several of the villages near Los Baños farm income increased particularly where the crop grown after rice was watermelons, cucumbers, or eggplant. The technology spread spontaneously to neighbouring villages that were not covered by project technicians. The revolving credit fund helped to familiarize smallholders with rural banks and the banks to accept smallholders as reliable credit customers, an experience relatively novel on both sides.

In Indonesia, the Central Research Institute for Agriculture (CRIA) selected two cropping systems research sites. The first location, Lampung, is representative of an area extensively used for transmigrant settlements from the overpopulated islands of Java, Madura, and Bali. Traditionally, rice is grown alone or intercropped with maize and cassava. An improved cropping pattern of rice-maize-beans gave greater total yield and a higher net return than the rice alone. Alternatively, by planting an early maturing rice it was possible to grow two rice crops followed by an upland crop. Fertilizer requirements for each pattern were determined.

The second site, at Indramayu, represents the high rainfall, alluvial soil conditions of the coastline where partial irrigation is available. An agro-climatic survey determined the time of year when irrigation water would be available and optimum cropping systems were prescribed for 10-month, 7-month, and 5-month irrigation regimens. A World Bank project to improve irrigation and drainage facilities in the Indramayu region is being developed.

Cropping systems research in Bangladesh is carried out by the Bangladesh Rice Research Institute (BRRI), based in Joydebpur, at four research sites within a 150 km^2 area. The research focuses on rainfed upland rice cropping, lowland rice cropping with tubewell irrigation, and deep water rice. Following a survey of established land use patterns wheat, jute, millet, white potato, sweet potato, mustard, groundnut, soybean, maize, cowpeas, and sorghum were tested as additional crops after the rice harvest.

At the Bhogra village site, typical of rainfed double-rice cropping patterns high-yielding varieties increased rice production by 72%. Minimum tillage experiments reduced the turnaround time between rice crops from 14 days to approximately 1 day. Mustard, vegetables, mung bean, or soybean were grown without irrigation in place of a second rice crop.

At Salna village, tubewell irrigation permits three crops of rice to be grown in a traditional pattern. Growing only two higher-yielding rice crops a year appeared more profitable than the traditional triple-rice cropping pattern, which demands more labour for land preparation and planting. On lighter soils wheat could be profitably grown after the second rice crop.

At the Jarunbari village site, deeply flooded valleys support a single rice crop. Improved soil fertility and pest management increased rice yields by 32%. Deep water rice could be grown after the traditional winter rice by relay planting of an early maturing winter rice variety. At Laskarchala village, with tubewell irrigation, wheat has been added to the highland rice in a multiple cropping pattern.

Three new sites were added later in the flooded valley areas for deep-water rice production. In these areas, wheat, millets, watermelon, oilseeds, and pulses will follow the rice crop as the water level recedes.

In a cropping systems project jointly conducted by the Ministry of Agriculture and Cooperatives and Kasetsart University in Thailand, the University screened a wide range of upland rice varieties and conducted varietal trials on sesame, pigeon pea, chick-pea, and safflower. Four sites represented three rainfed lowland conditions and one partially irrigated area.

At the first rainfed site a two-crop system yielded 2.7 t/ha of rice and 1.1 t/ha of groundnuts compared with traditional farmer rice yields of 900 kg/ha. At the second rainfed site, mung beans yielded approximately 500 kg/ha, and the subsequent rice crop yielded 2.3 t/ha. At the third rainfed site, cropping patterns tested included four field crops before rice and five after rice. Mung bean before and after rice yielded about 650 kg/ha. At the fourth site, under partial irrigation, groundnuts and maize were grown after the rice harvest giving a greater than traditional total crop yield.

The cropping systems project in Sri Lanka illustrates how, in a relatively unique agroclimatic environment, the methodology developed within the Asian cropping systems network can be successfully adapted and applied. In the project, which started in 1975, water for irrigated or partially irrigated lowland rice in the dry zone comes from small low head reservoirs, "tanks" constructed 2000 years ago and still used by local farmers. Paddy rice dominates the dry and intermediate regions, a monoculture that is relatively inefficient in terms of land and labour. The purpose of the project is to develop cropping systems that use the rainwater collected in the tanks more efficiently.

The research is carried out within two village communities: Walagambahuwa, in the dry zone; and Katupota in the intermediate zone. The first is typical of more than 3000 similar dry zone tank village settlements with a bimodal rainfall pattern, the *Maha* rainy season lasting from October to February, the *Yala* from March to May. Three land-use patterns were identified in the dry zone including settlements with houses and small gardens, the Chena upland where shifting cultivation is practiced, and the Welyaya paddy tracts in the low-lying lands. The Katupota is in the intermediate rainfed zone where it was postulated that two fast-maturing rice types could be grown sequentially in place of the traditional one long-maturing crop. The project began with a typical baseline study of existing practices and related economics.

In the dry zone, with tank irrigation, by early land preparation and seeding, a rainfed rice crop yielded between 2 and 2.5 t/ha. In one instance pregerminated seed sown on mud soil yielded 3.5 t/ha. Subsequently, 124 different production patterns were tested, including various combinations of different rice lines, land classes, methods of planting, seed density, and fertilizer rates. The best rice cultivar for light soils, when pregerminated and seeded by broadcasting, produced over 4 t/ha, and the best for heavier soils, similarly sown, yielded about 5.5 t/ha.

Following harvest of the paddy rice, upland crops of cowpea, black gram, soybean, and mung bean yielded about 700 kg/ha during the *Yala* season. Agroeconomic studies showed an increase of more than 200% in production through improved agronomic practices and water management.

Contrary to expectation, the increased cropping intensity was not adversely constrained by labour availability even during peak periods when the upland crops are planted and the first rice crop is ready for harvest. All trials were carried out with farmers, and early results indicate the more intensive patterns provide a 125% net increase in income.

It was also shown that rice lands below tanks, often left fallow, are productive without tank irrigation, following early land preparation and seeding. The water conserved in the tanks can be used later to irrigate a second, and in some seasons a third, crop.

The project site at Walagambahuwa has continued to harvest two rice crops each year, and the methodology was extended to 10 tanks in Kurunegala district during the 1979 *Maha* season. All farmers obtained a good first rice crop, many for the first time in several years. Several farmers also harvested a second rice crop. In 1980, the improved technology was adopted on land irrigated by 40 tanks. Several tank villages observed the benefits and adopted the technology on their own initiative. The results have motivated the Sri Lankan government to repair approximately 2000 small tanks and to adapt the more productive systems around them.

At the Katupota site, early land preparation and dry seeding of rapid-maturing rice cultivars gave yields in excess of 2 t/ha. Food legumes and other upland crops show promise for further production increases during the *Yala* season. Most encouraging is the voluntary adoption of the improved systems by farmers in other villages who have observed the benefits at the research sites. It is hoped that World Bank financing will soon expand the new technology into 10 additional, tank-irrigated areas.

Harvesting rainfed rice after the Maha season in Walagambahua, Sri Lanka.

Oilseeds

Oil-bearing seeds have been sadly neglected by plant breeders, agronomists, and those who plan agricultural policy throughout the developing world. The Indian Council of Agricultural Research (ICAR) is studying many of the major oilseed crops of India including the important *Brassica* species, rapeseed and mustard, in addition to those with a nutritionally attractive oil such as sesame, safflower, and niger seed. The oilseed improvement program is being carried out mainly in Indian universities. G.B. Pant University in Pantnagar seeks to increase yields, oil content, and overall quality of local and exotic rapeseed cultivars. Scientists at the Haryana Agricultural University are breeding high-yielding types of mustard, suitable for low rainfall conditions and that mature within 70-80 days, including mustard cultivars that can be intercropped with wheat. Projects are also being supported at Tamil Nadu University to improve sesame and at the Indore College of Agriculture in Madhya Pradesh to improve safflower.

It is common throughout Asia for legumes and oilseeds to be consigned to marginal lands. Consequently, many of the accepted cultivars have been selected more on the basis of their ability to tolerate adverse soil and other environmental conditions rather than for maximum yield under favourable conditions. The Indian Agricultural Research Institute (IARI) is exploring cropping systems in which legumes and oilseeds are combined with cereals on good farm land.

Scientists at G.B. Pant University set out to explore areas that were not congenial for other cereal grains and food crops but that might prove suitable for rainfed triticale cultivation. The areas were at high elevations, in the foothills, on the hillsides, and in the valleys of the Himalayas. Agronomic trials showed encouraging results at altitudes between 2000 and 3000 m above sea level where triticale showed tolerance to low night temperatures and out-yielded wheat and other cereal grains.

Millets

Millet is the name given to many cereals of different genera whose seeds are relatively small. The most widely grown is *Pennisetum typhoides* commonly known as "pearl millet" or in India as "bajra." Though less widely grown, because of their tolerance of harsh and adverse environmental conditions the minor millets provide subsistence for many of India's poorest people. A minor-millet improvement program coordinated by ICAR is in progress at five research centres each dealing with a different species: kodo millet (*Paspalum scrobiculatum*), foxtail millet (*Setaria italica*), little millet (*Panicum miliare*), common millet (*Panicum miliaceum*), and barnyard millet (*Echinochloa frumentacea*).

Each project concentrates upon breeding and selection for higher yield, disease and insect resistance, and improved methods of cultivation. Collection, crossing, and selection of minor millet germ plasm from many locations in Africa and Asia have demonstrated that yields can be doubled in farmers' fields. The results illustrate the relatively rapid progress that is possible when competent research scientists devote their attention to previously neglected crops.

Recently, the Bangladesh Agricultural Research Institute (BARI) started a complementary millet research program. In this case, the minor millets appear as supplementary crops in rice-based cropping systems. Foxtail millet and proso or common millet, which mature quickly and use water efficiently, fit well into winter cropping patterns. More productive systems, including higher-yielding cultivars, are expected to expand the minor millets throughout the rice-producing regions of Bangladesh. They may also be grown on the temporary islands that appear as the flood waters subside during the winter. Barnyard millet tolerates flooded conditions and finger millet (*Eleusine coracana*) can be grown as a premonsoon crop. Many of the minor millets display superior stability in postharvest storage and, therefore, serve as a valuable reserve food source when the major crops fail.

Cooperation in research and training has been established among the four Bangladesh regional research stations and the relevant minor millet research stations in India where four Bangladesh scientists will undertake graduate research, each on a different minor millet.

Food Legumes

Nutritionally and agronomically complementary to the Bangladesh minor millet project is a food legume improvement project, also under the direction of BARI. The higher-yielding cultivars of wheat and rice are more attractive to farmers than food legumes, which science has neglected. Consequently, total legume production in Bangladesh has declined in recent years. The project, undertaken at two universities and several government research stations, includes six food legumes. During the first 3 years, following screening of a large number of entries, superior lines of chick-pea, black gram (*Vigna mungo*), pigeon pea and grass pea (*Lathyrus sativus*), and lentil and mung bean have been identified, out of which about a dozen cultivars are to be subjected to wide-scale testing in cooperation with local farmers. By the winter season of 1979, more than 2800 legume lines were under trial at six locations; in the summer of 1980 over 500 lines were being grown at seven locations. As in the minor millets project, several Bangladesh graduate students are in training at Indian food legume research centres.

Research on dryland crops is also in progress in Sri Lanka, Pakistan, Bangladesh, and northeastern Thailand. The Department of Agriculture in Sri Lanka, in cooperation with farmers, is seeking to increase production of sorghum, mung bean, cowpea, black gram, groundnut, and okra. This project is consistent with the Sri Lankan government's policy of restricting importation of food crops and giving greater incentive to crops for human consumption rather than as commodities for export.

Scientists at the Pakistan Agricultural Research Council are improving chick-pea, mung beans, mash beans (*Vigna mungo*), and lentils by breeding and selecting for higher and more stable yields, combined with superior resistance to *Aschochyta* blight, *Fusarium* wilt in chick-pea, yellow mosaic virus in mung bean, and rust infection in lentils. At present, Pakistan produces less than half of the legumes needed by its growing population where, as in Bangladesh and other Asian countries, legumes have been replaced by the higher-yielding cereal cultivars. A legume improvement project with similar objectives began recently in Bangladesh.

In northeast Thailand, Khon Kaen University, in cooperation with smallholders, seeks to improve production systems for sorghum, soybeans, and groundnuts. Scientists at this relatively young university are making notable progress in a research project designed to increase food grain production for local consumption and to increase smallholders' income.

Root Crops

Root crops provide the main source of calories for more than 300 million people in developing countries. In addition to managing funds provided by CIDA in support of an international cassava research program, IDRC has allocated close to $5 million in support of root crops research in more than a dozen developing countries. In Asia, support has been given to a regional research, advisory, and training program implemented by CIAT in cooperation with the Southeast Asian Regional Centre for Graduate Study and Research in Agriculture (SEARCA); and to national root crop programs mostly devoted to cassava in India, Indonesia, Malaysia, the Philippines, and Sri Lanka. Several of these, in addition to two projects in Thailand, have included preservation, processing, and other postharvest aspects. Though cassava is indigenous to Latin America, it is among Asian countries that one finds the largest annual production both for food and as a cash crop. In Indonesia, which produces 1.1×10^7 t of cassava roots annually and exports in excess of 200 000 t of dried cassava for animal feed, cassava is the third most important crop after rice and maize, grown mainly by smallholders and consumed mostly as cooked fresh roots.

At the Universitas Brawijaya in Malang, in addition to a conventional breeding and agronomic study, a potentially significant production technique, developed in East Java, has been investigated. The Mukibat system, named for its inventor, consists of grafting the tree cassava (*Manihot glaziovii*), a perennial with a large leafy canopy that does not produce tuberous roots, onto normal root-producing cassava (*M. esculenta*). Because of the photosynthetically more efficient leaf canopy, the combination produces roots three to four times the weight of normal average roots. The Mukibat and its successor, the Setraw in which a single tree-type canopy is grafted to a tripod of three tuber-producing cassava stems, deserve more intensive study by plant physiologists. At Brawijaya it was shown to be unnecessary to dig large planting holes for the Mukibat. Mukibat cassava continues to fix dry matter for up to 18 months compared to between 12 and 14 months for normal cassava. Also, at any time during growth, dry matter content appears to be higher in Mukibat than normal cassava. Much remains to be learned and many difficulties are yet unresolved. Therefore, much more research on interspecific grafts is worthy of encouragement.

The project studied the response of normal cassava to essential nutrients and the beneficial effect on tuber size of weed control. In cooperation with the local farming community, 10 members of this very young faculty and close to 20 students were involved, several using the results in graduate theses.

Of much broader dimension is the cassava improvement project at the Central Tuber Crops Research Institute (CTCRI) in south India, where the boiled then dried cassava root provides a major food source for several million people, particularly during years of poor rice harvests. The project includes breeding and selection from which two hybrids yielded close to 40 t of roots per hectare in farmers' fields. Agronomic surveys and improvements have provided a "minikit" of agronomic practices to more than 200 farmers. Studies were made of disease resistance, particularly to mosaic disease that causes serious depredation; rapid propagation; and postharvest studies on both whole and processed roots. Of particular interest is the production of silk from a local moth fed on cassava. Training at the farm level and of more than 700 extension demonstrators is particularly noteworthy. It is probable that the project, to include other root crops and other food crops grown with cassava, will soon be extended into other Indian states.

The Malaysian Agricultural Research and Development Institute (MARDI), has successfully pursued a program of breeding, selection, and evaluation of existing cassava types in comparison with imported germ plasm both directly and crossed to local cultivars. Cassava types have been selected that adapt well to peat soil where few other crops can be economically grown.

In Sri Lanka, the Department of Agriculture is improving cassava and sweet potato cultivation through higher-yielding cultivars and improved cultural practices. Selection is being made for early maturing types, low in cyanide and high in starch content. The research at several stations has produced interesting results, including higher returns to land by intercropping food legumes with cassava; cultivation of seedlings from hitherto unexploited local cassava types; grafting of "wild" cassava onto known cultivars, the preliminary results from which indicate massive yield increases in addition to the identification of some well adapted to shade to be grown under coconut palms; cassava progenies raised from local true seed, naturally cross-pollinated, which exhibit a spectacular diversity and combination of several desirable characters; and sweet potato yields in excess of 20 t/ha from preliminary trials.

In a project administered by the Philippine Council for Agriculture and Resources Research (PCARR), the Visayas State College of Agriculture, in cooperation with five other universities and colleges, is pursuing the improvement of several root crops. The Visayas region is the largest producer and consumer of root crops in a country where 1.2×10^6 t, worth $70 million, are grown, 85% being used directly as human food. Complementary research is in progress at Los Baños, Cagayan, Palawan, and Mindanao. Germ plasm collections, cultivar screening, breeding, and agronomic improvement are well under way for cassava, sweet potato, taro (*Colocasia esculenta*), tania (*Xanthosoma sagittifolium*), and yam (*Dioscorea* spp.).

Agroeconomic studies have quantified the types, quantities produced, and farm and production areas devoted in each province to root crop cultivation. Close to 20 graduate students are employed in the project and are in pursuit of higher degrees covering most aspects of the research including intercropping of root crops with food legumes. The project is laying the basis for a national root crop research, demonstration, and training program.

Postproduction Systems Research

Following the recommendations contained in a report prepared for the CGIAR in 1975, IDRC instigated the formation of the Southeast Asia Cooperative Post-harvest Research and Development Program, a program now jointly sponsored by the governments of the Netherlands and Australia, the United States Agency for International Development (USAID), and CIDA, for which group IDRC acts as executing agency. The program is directed by a Policy Advisory Board composed of senior government officials from Indonesia, Malaysia, the Philippines, Singapore, and Thailand. A Technical Research Advisory and Support Team (the technical team) consists of one member provided by each of the donors and reports to the Policy Advisory Board. The program has concentrated principally upon rice and to a lesser extent upon other cereal and legume grains. It is the purpose of the technical team to identify problems and constraints in existing postharvest systems and the means to overcome them by research, development, training, information, and demonstration.

The program also serves to strengthen the relevant research capabilities and appropriate institutional facilities throughout the region and to stimulate cooperation among different bilateral and multilateral donors, among governments of the region and their research and development institutions, and among scientists and technologists from developing and developed nations.

The technical team provides a postharvest information service by collecting and disseminating all available knowledge and reports of activities related to their primary purpose. The team, which consists of a Filipino agricultural engineer, a storage specialist, a grain-milling specialist, and an agricultural economist, is stationed close to IRRI at SEARCA headquarters where administrative and other essential facilities are provided. The technical team gives direct technical support to a variety of existing postharvest projects, some financed by IDRC, some by other donors, and some by governments of the participating countries. Through its regular contacts with those responsible for postharvest research and development, in workshops and publications, the technical team is gradually inculcating a total systems approach to postharvest improvement throughout the region. The success of the venture has attracted the interest of several other donor organizations and the program promises to expand during the foreseeable future.

In addition to the cooperative program, the Division has given technical and financial support to more than 20 postproduction projects in South and Southeast Asia. Though other food grains are included most projects have concentrated upon rice, which is the crop that suffers the most postharvest damage and loss. During the second half of the decade, several fish-processing and preservation projects were added. Throughout the tropics fish suffer greater postharvest losses than any other major food source. If aquaculture and mariculture are to achieve their potential, much more investment in research will be needed to improve fish preservation.

Each postproduction system begins at harvest time and ends when the products of the harvest have been consumed. The essential components of every postproduction grain system include the techniques of harvesting, drying, threshing, storage, primary and secondary processing, household use, and nutritional and functional quality evaluation and control. Whatever individual components are of principal concern, it is the purpose of the Postproduction Group and project advisers to guide all research workers toward a total systems approach and the study of each specific component in relation to the entire postproduction system.

Drying and Storage

In many tropical countries, the most common method of drying grain is by direct sunlight. The advent of rapid-maturing rice varieties, making possible the production of two or three crops a year, has aggravated postharvest drying difficulties because crops harvested during the rainy season are significantly higher in moisture content and cannot be satisfactorily sun-dried between the frequent rain showers. High moisture content leads to rapid microbial growth and insect infestation. Therefore, without rapid drying after harvest, much of the advantage of a second rice crop may be lost.

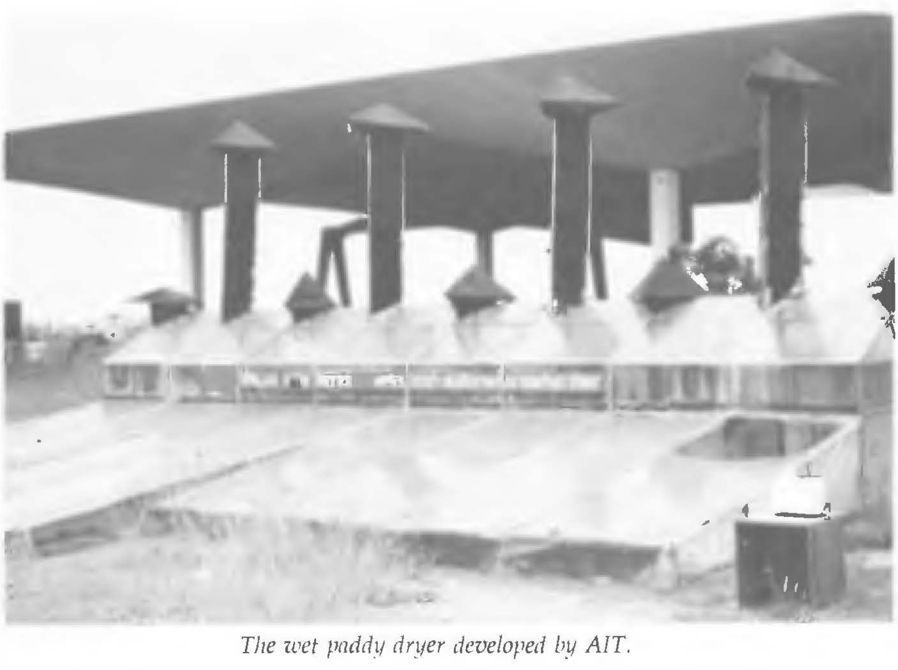
Among Asian countries, different approaches are being taken to increase rapid drying of rice immediately after harvest. In Thailand, the Agricultural Engineering Department of Kasetsart University is developing machines and devices for improved threshing, drying, storage, and on-farm milling of rice. Prototypes and advance models are provided to rural communities through loans from the Department of Cooperatives. Some 6000 mobile threshers, several flatbed dryers, grain holding and drying bins, and small-scale portable mills are undergoing field trials.

The flatbed dryers are large rectangular structures in which 2 t of paddy are spread over a mesh screen above a plenum, heated by air driven through a furnace by a fan. The rectangular box can be constructed locally, the burner and fan are both manufactured in Thailand. The furnace burns 4-7 kg of gravity-fed rice hulls per hour and, at a drying temperature of about 40°C, reduces the paddy moisture content from 25 to 14% in about 6 h. The total material cost is roughly $320. A more expensive alternative to the furnace is a kerosene burner, but in most locations rice hulls promise to be available in adequate quantities. Measurements have determined that optimum airflow through the furnace grate in the dryer is 30.5 $m^3/min/m^2$ of fire grate and that rice hulls produce about 1.16×10^4 J/g of rice hulls. The operating cost of the rice hull furnace is approximately $0.28/h; for kerosene, diesel, or gasoline the operating cost is roughly double.

The portable rice mill, with a 50 kg/h capacity, consists of two rotary stones, one above the other, each enclosed in a rubber-lined casing and each rotating with a close separation from a rubber block. Into the working surface of the upper stone, coarse emery stone is dispersed and the dried paddy is dehulled between the coarse emery stone and the rubber block. The dehulled rice falls to the lower stone, into the working surface of which is dispersed fine emery where in a similar manner the rice is polished. The rice hulls are recovered and fed to the flatbed dryer, and the rice polishings are collected and used in animal feedstuffs. By increasing the diameter of the stones and controlling the speed of rotation, heat damage to the rice has been satisfactorily reduced. The Thai engineers are now developing a larger version of the simple mill, capable of processing 1 t of paddy every 5 h.

At the Asian Institute of Technology (AIT), close to Bangkok, an alternative method of drying wet paddy has been developed. This method consists of an indirect solar heater that contains no moving parts, the wet paddy being dried by hot air convection. The drying bed consists of a shallow rectangular box, roughly 10 × 1 m and 30 cm deep. The structural members are of bamboo, the bottom of the bed is of woven bamboo, and the sides are of hardboard. Removable panels permit the farmer to load and unload the paddy. The drying box is supported 1 m above the ground, and the air heater consists of a layer of burnt rice husks spread over the ground in front of the paddy bed to absorb solar radiation. The heat absorbed during daytime insolation is gradually released in the form of air convection currents that pass up through the paddy bed even during the hours of darkness. The air-heating areas, the air spaces above and below the paddy bed, are enclosed in 0.15 mm clear plastic film supported by a simple framework of bamboo poles and wire. The total cost of material is $50 and during the wet season the dryer will reduce 1 t of wet paddy to a safe moisture content in approximately 24 h. Though much lower in capacity than the rice-hull-burning furnace, the AIT dryer is cheaper to construct and operate and is now being tested among rural communities in Thailand and in several other Asian countries and for other food-drying purposes in several postproduction projects in other countries.

The two alternative Thai systems of drying are considered complementary rather than competitive and each will find its place by adapting to different conditions and demands.



The wet paddy dryer developed by AIT.

One of the principal difficulties in processing wet paddy is to remove foreign material that sticks to the surface of high-moisture grain and is not readily removed by conventional methods of cleaning and dockage removal. MARDI, at the rice-processing station in West Malaysia, is studying alternative methods of wet cleaning, including washing with hot water in a counter flow between water and grain followed by heating and drying in a high-velocity air jet. The final moisture content is below 18% and the method is particularly well suited to rice that is to be parboiled. An alternative low-temperature method involves washing in salt solutions followed by solar-powered drying.

Problems similar to those in Thailand are experienced by the small-scale rice producers of Indonesia where postharvest grain losses have increased as the proportion of a second wet-season crop expands. The Government of Indonesia has organized farmers' cooperatives and through its National Logistics Agency (BULOG), has stimulated widespread field testing of new postproduction technologies. The farmer cooperatives and BULOG engineers have studied the performance characteristics of a number of flatbed dryers and have determined working capacities, optimum bed depths and rates of airflow, milling quality of the dried paddy, rates of fuel consumption, and overall operation costs. Most important has been the training of farmers in methods of technical and economic evaluation. Among cooperatives in Central, East, and West Java and South Sulawesi, BULOG engineers are studying the effects of improved systems of harvesting, threshing, drying, and storage on the milling characteristics and postmilling quality of rice produced on many small farms. It is encouraging that Indonesian rice farmers now receive a premium price because of the superior quality of flatbed-dried rice compared with sun-dried grain.

Satisfying progress and results of potentially wide applicability have come from two interlinked postharvest projects in the Philippines: one at the University of the Philippines at Los Baños (UPLB), the second by the National Grains Authority (NGA) in Quezon City.

Scientists at UPLB set out to determine the parameters in the Cono milling system that give maximum yield and highest quality of milled rice. The Cono system consists of one or more dehuller units, each composed of two stone discs, one stationary the other rotating, operated in conjunction with vertical cone polishers. Studies compared dehulling efficiency of the traditional stone discs with rubber roll dehullers and found the latter to be superior both in hull removal and in total recovery of unbroken kernels. Critical observations and measurements gave rise to modifications that greatly improved the efficiency of Kiskisan steel-dehuller rice mills, many of which, because of their original low recovery, were being discarded among Philippine rural communities. More efficient milling resulted from combining a rubber-roll dehuller with a Kiskisan used as a rice polisher. The modified milling system is being evaluated in several rural rice mills.

The UPLB scientists improved the stability of wet paddy awaiting drying by storage in aerated bins. Controlled aeration significantly extended the predrying storage life of threshed paddy during both dry and rainy seasons. UPLB is also studying factors that influence losses during threshing, which represent at least 7% of the harvested grains. Traditional prethreshing methods of swathing and piling have been modified to reduce threshing losses.

The NGA project staff, in cooperation with 13 farmer associations in each of the five different agroclimatic regions, is studying different systems of threshing, drying after threshing, and rural-rice milling. The NGA study also includes sorghum and other grains produced in multiple cropping systems. The NGA selected the most efficient out of eight threshers and determined how fuel consumption in two different grain dryers could be reduced by improvement in fan design and heat recycling. A dockage tester developed by NGA, which separates out contaminants in the paddy, has proved so successful that 200 units have been constructed and distributed among the rice-producing communities.

At several locations milling studies are in progress to compare the efficiency and recovery rates from mills of similar and different design. Operational research measurements have led to several recommended improvements and because the NGA is the authority that licences all milling operations in the Philippines, it occupies an excellent position from which to introduce improved milling technologies using suitably modified equipment already installed, which small rural enterprises could not afford to replace.

Some years ago, acting upon expatriate advice, a number of large silos and storage bins, designed and constructed in other countries for another purpose, were introduced into the Philippines. Because of their inherent unsuitability for the prevailing conditions, most of these stand empty. If functional, they could provide an additional 125 000 t of storage capacity. With IDRC support, the NGA is studying the modification of the structures and management systems, including possible combinations of aeration and fumigation, to see if some of these engineered white elephants can be put to profitable use. Rice stored in one of the modified large silos was satisfactory after 2 years. The research has clearly indicated the relation between the condition of the rice filled into the modified silos and the quality after storage.

Complementary to the UPLB and NGA projects is a recently approved postharvest systems project, undertaken by Isabella State University in the Cagayan Valley in northeastern Luzon. Scientists are studying how readily improved postharvest rice technologies are adopted by smallholder cooperatives.

One of the most comprehensive studies of the total postharvest rice system is being conducted by scientists at Seoul National University, located close to the southern border of the demilitarized zone that separates South from North Korea. Studies have been made of the effect of all components of the postharvest system upon different rice varieties, including longer grain Indica and glutinous Japonica varieties harvested during both dry and rainy seasons. Different threshers were compared and the most suitable were modified to give highest yields of both paddy grain and straw (widely used as cattle feed, in mats, and for packing eggs). To make it mobile, the modified thresher was mounted on a tiller trailer using two universal joints to transmit power from tiller to thresher.

On-farm paddy drying and storage was improved by in-bin drying and storage with circulating air, with and without supplementary heat, provided from a flat plate solar collector combined with a rock pile heat storage medium. Though the results have yet to be confirmed by additional in-bin storage experiments, it appears that, in spite of slightly larger moisture gradients, supplementary solar heat gives greater storage life. Korean scientists are also studying the effect on paddy quality of rewetting by rain after harvest, modifications to equipment and operational procedures to increase head rice recovery, machine capacity and milling efficiency among different dehulling and polishing systems, and the effect of all components of the system upon final rice quality.

A computer simulation model is being used to analyze the relative costs of traditional and modified rice postproduction systems and five alternative systems were compared. As the project proceeds, the model will provide a useful tool by which to assess the cost and labour implications of changing components of the postharvest system among different rice varieties at different seasons and regions of the country. To overcome a shortage of farm labour, various mechanical harvesters and binders are presently being modified to increase the efficiency of harvesting and to reduce postharvest losses.

As in all the other postproduction projects in the network, the Korean project includes detailed studies of the socioeconomic conditions that prevail and how these may be affected by the introduction of new or modified technologies and systems. Though Korea is not a member of the Association of South East Asian Nations (ASEAN) group that controls the postharvest rice program referred to above, the research team from Seoul takes part in the technical team's annual workshops.

A project accorded a high level of priority by the Government of India is studying the postharvest systems that relate to all of the principal cereal and food legume grains grown on small farms throughout India. The five cooperating institutions include three universities: Tamil Nadu Agricultural University at Coimbatore, Udhaipur University, and PKV (Krishna Agricultural University) at Akola; and the Central Research Institutes for rice at Cuttack and for agricultural engineering at Bhopal. The research workers seek to improve all the component technologies of the established postharvest rural grain systems including processing, distribution, quality, and utility. It is the stated intention of the Indian Council of Agricultural Research (ICAR) to expand the program to include oilseeds and other food crops and to add at least five more cooperating research institutions. The magnitude envisaged is an indication of the importance now assigned to postharvest problems by the Government of India.

A project of social and nutritional significance is being undertaken by faculty members and students at the College of Home Science at Andhra Pradesh Agricultural University in Hyderabad. Most of the work is undertaken among and with the cooperation of poor rural village communities in India's SAT zone. Its purpose is to improve the quantity and quality of food grains processed by traditional home methods and to devise economically and socially acceptable methods of handling, processing, and utilization. From more than 2000 households in three regions of Andhra Pradesh, data have been collected on production; consumption; storage and processing; and local preferences for specific types of sorghum, millet, chick-pea, pigeon pea, mung bean, cowpea, and faba beans. The effects of traditional dehulling and home processing on protein quality and quantity and vitamin and mineral content have been determined by analysis and biological assay. Attempts are being made to quantify what consumers describe as desirable characters and what is the effect of differing conditions of storage upon these characters and nutritional quality. The results, which will form the basis of several graduate theses, clearly indicate the need to increase production and availability and to improve the utility of those food legumes that constitute the main source of supplementary protein to a predominantly cereal diet. It is evident that food legumes are not available year round in nutritionally desirable quantities to all who need them. The project is complementary to the minor millets, oilseeds, and postharvest projects supported by IDRC in India and to other Indian food crop improvement programs.

Several aspects of the preservation and utilization of legumes grown in Asia are under investigation in the Philippines, Indonesia, Thailand, Pakistan, and Bangladesh. Food technologists at Gadjah Mada University at Yogyakarta in Indonesia are studying how to produce traditional fermented *tofu* and *tempeh*, customarily made from soybeans, which are often in short supply, from other more readily available food legumes. Of particular interest is the velvet bean, which grows well on marginal lands and costs approximately one-third the price of soybeans. An initial survey has described traditional methods of making *tempeh* in seven different Indonesian provinces, including alkaline dehulling using wood ash, and the different means by which moulds of the *Rhizopus* genus are used to inoculate and ferment the ground legume flour. The traditional methods are being modified and standardized to produce acceptable forms of *tempeh* from velvet beans by technologies technically and economically acceptable to the Indonesian rural communities. In cooperation with the agronomy department of the University, the effects of varietal differences among legumes upon the quality and composition of the final product are being studied.

At UPLB in the Philippines the comparative efficiency of four different dehulling devices applied to seven different cowpea cultivars was assessed. Significant intervarietal differences were noted; in general dark-coloured seeds being more difficult to dehull than nonpigmented types. Dehullers that relied upon abrasion were more efficient than friction-type mills. Several systems of abrasive dehulling were applied to cowpeas and mung beans and the resultant flours from raw beans, blanched beans, sprouted beans, and toasted beans were incorporated into weaning foods containing mixtures of legume flour, rice flour, sugar and milk powder, and into various traditional legume foods. The results indicated that legume flours could replace nutritionally inferior ingredients in many traditional foods without loss of acceptability. The project complements the University's legume breeding program.

In Pakistan and Bangladesh, postharvest legume projects have been started that complement and are integrated with the legume production improvement projects supported in those countries by IDRC.

In Bangladesh postharvest food legume systems are being surveyed to determine the extent and cause of postharvest loss among rural communities and to provide better systems for drying, storage, and distribution. This project is complementary to the Bangladesh Agricultural Research Institute (BARI) legume production improvement project. Several models of the solar crop dryer developed in Thailand will be tested by rural communities in the drying of legume seeds and modified as desirable. Various locally available materials including the leaves of plants believed to exert infestation control will be mixed with the legumes in on-farm storage trials. The research includes food legume grains and the viability of seed grain under a variety of postharvest conditions.

Following an IDRC-sponsored stable tropical fish products workshop in Bangkok, Thailand in 1974 (IDRC-041e), several fish processing technology projects are under way. Government scientists are studying how "trash" fish may be deboned, the flesh minced, and processed by small industries into *lukchin*, a popular local fish product. ("Trash" fish is an unfortunate misnomer for the by-catch of commercially unwanted species that inevitably accompany the landing of shrimp and other higher-priced species. The universal wastage of protein through discarding the by-catch is of appalling proportions.)

In a preproject economic feasibility study, an assessment was made of the present and future demand for minced fish and of the quantities of by-catch that could be recovered by subsequent processing.

India, which is among the top eight fishing countries in the world, processes relatively little of the fish, other than shrimp, that it lands. Consequently, virtually all the maritime species landed must be consumed quickly by coastal communities because rapid spoilage militates against inland transportation and distribution. By expanding and exploiting processes developed in the laboratory, the Central Institute of Fisheries Technology (CIFT), in cooperation with the State of Kerala's Fisheries Corporation, is seeking to industrialize fish processing and distribution on a large scale. Processes successfully developed in the laboratory are now being scaled up to include products from minced, smoked, dried, canned, and poached fish. The CIFT is working with local factories of the Kerala Fisheries Corporation to establish sound production technologies together with standards of processing and quality control. The project also includes technical and economic evaluations of different processing, packaging, storage, and transportation systems.

The Department of Food Science and Technology at Brawijaya University in Indonesia has recently started a study of fish preservation through solar and salt (osmotic) drying to provide technologies acceptable to rural fishing communities.

In the Philippines, technologists at UPLB have developed a rice-hull-fired fish dryer of approximately 2 t capacity, which is now being technically and economically evaluated by the University in cooperation with the Bureau of Fisheries and Aquatic Resources among artisanal fishing communities. A prototype dryer, composed of a single drum furnace, heat exchanger, axial blower, a plenum chamber, and several fish trays is undergoing tests on six harvested fish species at four locations in the Philippines. Following laboratory development and trials at Mercedes in Camarines

Norte, the dryer that has gone through several stages of development is being tested by fishing communities at the four sites. Agricultural by-products, tested as heating fuels, include coconut husks, shells, and rice husks. Fishermen are being trained in the use of the dryers and those who wish to purchase them will be assisted financially by the Bureau.

Operations Research

Several of the projects reviewed above embody operations research methodologies in which traditional and existing industrial methods of processing are studied to assess and enhance their efficiency in terms of throughput, consistency in quality of end product, and economy. Unfortunately, more scientific effort seems to be devoted to the invention and "transfer" of new technologies than to improving those that are already in place. No matter how superior the new technology may be, relatively few small industries can afford to scrap their existing equipment and facilities and replace them with new ones. In some instances, therefore, more benefit will be derived from operations research studies to improve the efficiency of the technologies and facilities that exist than in trying to transfer or invent new technologies. It is envisaged that the number of industrial operations research projects will increase in the AFNS program in the future. Two such projects concern cassava processing in Thailand and soy sauce and noodle manufacture in Singapore and a third in Thailand is being prepared.

For several years the Asian Institute of Technology (AIT) has studied the effect of processing variables upon the rate and efficiency of drying and upon the economics, quality, and composition of dried and pelleted cassava for animal feed. Cassava chips and pellets are produced in many small processing factories in Thailand, Malaysia, Indonesia, and the Philippines. Many of the processing technologies and systems are poorly controlled and product quality is highly variable. The operations studied in the project include harvesting, chipping, drying on various surfaces, pelleting, cooling, bagging, storage, and shipping. Standard chippers were redesigned to produce thinner, more uniform slices. Under favourable environmental conditions, black-topped surfaces reduced sun drying time by 20-25%; redesigned extrusion dies improved the hardness of pellets; and postpelleting coolers were redesigned to increase cooling efficiency, reduce cooling time, and increase output. The economics of the various modifications are being evaluated, but given the remarkable rise in world prices for cassava and the demands by European and Japanese importers for higher quality, it seems probable that many of the modifications will be accepted by Asian cassava processors.

The Singapore Institute of Standards and Industrial Research (SISIR) is guiding and coordinating a cooperative project in industrial operations research among a number of small factories that produce soy sauce or cereal noodles. The research team has surveyed more than 30 small-scale factories and has documented all of the apparently important operational factors including the time, human, and mechanical energy absorbed at different scales and stages of production. The results are demonstrating how small industries can improve the efficiency and economy of their operations and attain greater uniformity of product quality and consistency by relatively inexpensive modifications to existing technologies and procedures. The first results of the project were made known to interested scientists from other developing countries at a workshop held during the fall of 1980 in Singapore.

Animal Research

Relatively few projects in animal production have been supported in Asia but, with the arrival of a new associate director who has had long experience in Asia, the number is expected to increase. The few projects supported are devoted to the use of agricultural by-products in animal feedstuffs.

The Indonesian island of Bali supports approximately 380 000 head of cattle, most of which are used as draft animals with approximately 25 000 beef steers exported annually. When fed on local green forages of low nutritional value, the native cattle take 3.5–4 years to reach a market weight of 400 kg. Bali produces 170 000 t of cassava chips, 65 000 of rice bran, and 15 000 t of copra meal per year in addition to what is not recorded from small farms. It was believed that supplementary feeds based upon locally available agricultural by-products would accelerate growth rates. In feeding experiments conducted in farmers' fields at Petang by scientists from the University of Udayana, cattle fed only green forage showed daily weight gains of 30 g whereas those fed balanced by-product rations increased 380 g/day. The feeding systems used and the by-products available as ration supplements are being surveyed over a number of Bali villages and attention is now being given to further supplementation with forage from 42 potentially useful tree species. The results will be applicable to other areas in Southeast Asia with similar farm production patterns.

Cassava chips used as feed for swine.

At Mahidol University in Thailand, scientists are exploring means to use forest by-products and other lignocellulosic wastes, such as cereal straw, in animal feed. Ruminants are able to digest cellulose but not the compounds of lignin and cellulose, which constitute the thickened cell walls of most woody plants. On the other hand, lignocellulolytic fungi that cause white rot and other forms of decay in dead trees are able to hydrolyze lignocellulose. The Thai scientists have collected several hundred species of fungi from tropical soils and decaying wood and are isolating in pure culture those that grow fastest and increase the digestibility and microbial protein content of sugarcane bagasse, rice straw, and other lignocellulosic wastes. Fungi are being selected that display a high lignolytic and cellulolytic activity at tropical temperatures and that neither generate toxic materials nor present any hazard to human or animal health. The results will be useful in several projects dedicated to increasing animal production using processed agricultural wastes.

Forestry Research

One of the few forestry projects supported in Asia is of international significance. *Leucaena leucocephala* is a multipurpose leguminous tree that originated in Central America and appears widely adaptable throughout tropical countries. Following its spread by the Amerindian civilizations into Mexico, it probably first crossed the Atlantic in the late 16th or early 17th Century with the Spanish galleon trade to the Philippines from the west coast of Mexico. It became a favourite shade tree for several plantation crops and in due course it was recognized that *L. leucocephala* had the ability to fix nitrogen symbiotically with soil bacteria and to convert this nitrogen to leaf protein. *Leucocephala* is the most common of more than 50 reported species and it appears in many forms ranging from bush types suitable for browsing or intercropping to trees that grow to a height of nearly 20 m in 6 years, providing an excellent source of biomass. Being of high density, the wood is suitable for charcoal and among its many phenotypic forms leucaena presents valuable potential sources of fodder, feed, fertilizer, and fuel.

The Philippine Council of Agriculture and Resources Research (PCARR) has collected more than 120 leucaena types from 22 countries, which are now being evaluated silviculturally and in various uses. It has been shown that leucaena can be interplanted with tropical grasses as a browse forage. When leucaena was row-intercropped with maize, yields equivalent to maize fertilized with ammonium fertilizer resulted. Furthermore, some experiments suggest that row intercropping reduces infestation damage to maize by the corn borer, which seems unable to cross the leucaena barrier from one row of maize to the other. A high-yielding lowland rice variety in the Philippines, fertilized only with leucaena leaves, yielded between 7 and 9 t of grain per hectare. When leucaena leaves were applied to upland rice, yields of more than 4 t/ha were comparable to the same varieties fertilized with 80 : 30 : 30 NPK.

Consistent with its policy of encouraging research on plant species of traditional importance but which have been neglected by scientists, IDRC is beginning what promise to be two important networks in Asia. The first is devoted to rattan, a product of a large and diverse group of palms called Lepidocaryoideae, and the second to bamboo, produced from the giant grasses of the subfamily Bambusoideae, which appear in many phenotypic forms. Both rattan and bamboo have many uses among the rural people of Asia.

A project at the Forest Research Institute in Chittagong, Bangladesh, will select and evaluate local and exotic bamboo species; study methods of rapid propagation; and identify types with properties useful for food, structural, and artisanal craft purposes. It is believed that in addition to satisfying industrial and artisanal requirements, bamboo plantations can serve as impediments to soil erosion.

To facilitate the formation of research networks in rattan and bamboo, two workshops were held in Singapore, in 1979 and 1980 respectively, the proceedings of which have been published by IDRC (IDRC-155e and IDRC-159e).

Latin America and the Caribbean

AFNS has supported more than 50 projects in 20 countries in the region defined as Latin America, which includes Mexico, Central and South America, and the Caribbean.

The major physiographic features of the region are the Cordillera, composed of the Andes and the Sierra Madre mountains; the Brazilian and Guiana highlands in the continental northeast; the basins of the Amazon, Orinoco, and Plate rivers; and the islands of the Caribbean. In many areas soils are mostly lateritic and, therefore, of low inherent fertility.

The region is composed of four major life zones: the humid forests of parts of Brazil, Central America, and the islands; dry forests, cactus-scrub, and desert — especially in Mexico, Peru, Chile, and Argentina; savanna and grassland in Venezuela and Brazil; and the montane zones of the Cordillera. For the region as a whole, the land use pattern is 6% arable and permanent crops; 24% permanent pasture; 49% forest; and 21% other, including urban and waste. By comparison, North American and world proportions of cropland are about 11%.

Of Latin America's approximately 360 million people, more than two-thirds are dependent on farming as a major source of income, producing one-tenth of the world's output of food and fibre. Food and fibre crops account for more than two-thirds of Latin America's total exports. Since 1976, little progress has been made in increasing the per capita food production index of the region as a whole. Although Brazil, Argentina, and Colombia have increased per capita food production, the index has declined in several other areas.

It is predicted that by the end of this century, the urban proportion of Latin America's projected population of 525-600 million people will be 80-90%, compared with 60% in 1979. If food production and living conditions for the rural poor can be improved, then the pressure on the urban areas may be lessened.

The animal sciences program has been concentrated in Latin America and the Caribbean, most projects being devoted to the use of otherwise wasted by-products as animal feed, to pasture improvement, and to the husbandry and integration of native and adapted breeds into rural farming systems. A most encouraging activity in the fisheries program, has resulted in making food available from a large portion of the by-catch of fish caught by the shrimp trawlers off the Guyana coast.

The crops program has concentrated on cropping systems research, indigenous crops of subsistence farms including the ancient and traditional grain crop quinoa (*Chenopodium quinoa*), which formerly had received almost no research attention.

Table 5. Total appropriations and number of projects in Latin American and Caribbean countries.

Country	Crops and Cropping Systems		Fisheries		Animal Sciences		Forestry		Postproduction Systems	
	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects
Belize			147.3 (27%)	1 (33%)	404.3 (73%)	2 (67%)				
Bolivia	668.1 (79%)	2 (67%)					175.4 (21%)	1 (33%)		
Brazil	101 (19%)	2 (67%)	418.9 (81%)	1 (33%)						
Chile	456.4 (35%)	3 (43%)	280 (22%)	1 (14%)	296.8 (23%)	1 (14%)			253.3 (20%)	2 (29%)
Colombia	1539.4 (54%)	9 (64%)	236.8 (8%)	1 (7%)	1096 (38%)	4 (29%)				
Costa Rica	444 (69%)	3 (60%)			967 (31%)	2 (40%)				
Cuba			73.7 (100%)	1 (100%)						
Dominican Republic			140.1 (100%)	1 (100%)						
Ecuador			185.7 (100%)	1 (100%)						
El Salvador					385.2 (100%)	1 (100%)				
Guatemala					395.4 (30%)	2 (40%)	319 (24%)	1 (20%)	607.6 (46%)	2 (40%)
Guyana			748 (100%)	3 (100%)						
Honduras	226.6 (100%)	1 (100%)								

Jamaica	1175.7 (62%)	6 (67%)	227.7 (12%)	1 (11%)	502.5 (26%)	2 (22%)				
Mexico	194.9 (13%)	2 (29%)			1222.4 (82%)	4 (57%)	75.3 (5%)	1 (14%)		
Nicaragua	302.5 (100%)	1 (100%)								
Panama	76.1 (10%)	1 (25%)			516.3 (69%)	2 (50%)			160.5 (21%)	1 (25%)
Peru	398.5 (10%)	1 (8%)	212.8 (5%)	1 (8%)	1058.9 (25%)	4 (30%)	2119.1 (51%)	4 (30%)	359.2 (9%)	3 (24%)
St. Lucia	649.2 (79%)	2 (67%)	172.3 (21%)	1 (33%)						
Trinidad and Tobago	393.7 (71%)	5 (71%)			147.5 (27%)	1 (14.5%)			10.8 (2%)	1 (14.5%)

In contrast to the production research, which is the major focus of the forestry program in Africa, in Latin America there are abundant forests that are utilized in a wasteful and inefficient manner, therefore, the AFNS program concentration is on supporting the improvement of technologies for converting the immense diversity of tropical forest species into useful products. Table 5 summarizes the number and value of projects supported in the region.

Animal Research

On no other continent has the Division's animal sciences program been so broadly developed as in Latin America and the Caribbean. This is attributable, in part, to two successive associate directors having been stationed in Colombia, but it also reflects the importance of farm animals in Latin American farming systems. The projects in Latin America reflect the priorities referred to in the introduction and include several examples of pasture improvement, feeds from various by-products, and integrated production systems that concentrate upon native and well-adapted breeds.

The Sierra of the high Andes is an important ecological zone that extends almost the length of South America at an altitude often in excess of 3000 m above sea level. The Peruvian Sierra, covering 2.0×10^7 ha is where most of the cattle, sheep, and camilids are raised. The rate of weight gain is low in all these animals as a result of inadequate intakes of utilizable energy, digestible protein, and essential minerals from the native pastures available. The Peruvian government has attempted to reduce the outflow of foreign currency reserves used to import products by imposing a 15-day ban on meat each month.

Pasture Improvement

Ten years ago, an agrarian reform law created the Sociétés agricoles d'intérêt social (SAIS) to administer the large farms in the high Andes, expropriated by the Peruvian government, which are managed as cooperative enterprises by the former landless peasants. Though varying in structure and activity, each SAIS assists the *campesinos* in their cooperative societies to obtain credit and agricultural inputs, to plan their production, and market their produce. Because many Societies depend heavily upon livestock production, the improvement of pastures ranks as a high priority. In cooperation with members of an SAIS located in the Central Sierra (68% of whom are Amerindians, 29% are sharecroppers, and the remainder are permanent labourers), scientists at the National Agrarian University are conducting experiments to raise the quantity and quality of high-altitude pastures through cultivation of native and exotic forage grass and legume species.

The results of an agrosto-edaphic survey were mapped and the areas with greatest potential for pasture cultivation were identified. More than 120 sites, at which to test various systems of pasture management, were selected and characterized. Some 20 different grasses and legumes were subjected to agronomic trials at altitudes above 4000 m. An evaluation of comparative benefits from changing practices was made possible by a baseline survey of traditional animal raising and of prevailing socioeconomic conditions. Dry matter production of rainfed rye grass reached 20 t/ha providing an excess for conservation over grazing requirements. Combinations of rye grass with red and white clover yielded 18 t/ha at 15.2% protein compared with 1.5 t/ha at 5.7% protein of the surrounding native pastures. Sheep grazing on the improved pastures when compared with native pastures showed an increase in percentage birthrate and lambing rate, a significant decline in lamb mortality, and higher wool and meat production in both wethers and ewes.

Techniques for the recovery of degraded pastures include planting of *Pinus insignis*, provided from an afforestation project supported by IDRC, to act as wind breaks to protect fragile soils and the pastures growing on them. Nutritional evaluations are being made of several high-yielding pasture grasses after conservation and storage in the form of dry hay or silage. A study on the general health and resistance to parasitic diseases among animals grazing on the pastures is also included. Phosphorus deficiency is being alleviated by rock phosphate processing using techniques developed in the IFDC/CIAT project referred to later in this publication.

In sharp contrast to the coastal region of Peru where population density approaches 500 people/km^2 of arable land, the Peruvian Amazon carries an average population of 1.5 people/km^2. Consequently, there is a noticeable and steady migration from the coast across the Andes into the Amazon basin. The migrants settle in forest clearings where destruction of the vegetation causes rapid loss of soil fertility through leaching and increased acidity. These low-fertility soils are classed as andosols characterized by low phosphorus together with high iron and aluminum contents. There is reliable evidence to suggest that appropriate combinations of pasture grasses and forage legumes would protect these cleared lands from further erosion; improve soil fertility; and sustain the cattle population to provide employment, food, and income for the settled migrants. Increased livestock production would reduce the present heavy reliance upon imported meat and milk.

The Instituto Veterinario de Investigaciones Tropicales (IVITA) employs a well-trained scientific staff experienced in animal production research in the tropical Amazon. In a project started in 1979, IVITA scientists, together with SAIS cooperatives in the Amazon valley, are endeavouring to introduce adaptable pasture grasses and legumes; to establish efficient pasture management practices in Amazon forest clearings; to develop systems of grazing management, feed conservation, and supplementation; to design adequate disease control; and to study the economic and social implications of integrated cattle production systems for meat and milk.

The population density is less than 1 person/km^2 in the 7.0×10^8 ha of the Amazon basin that extend over six South American countries. A viable animal industry would provide food and employment and encourage greater settlement in this underdeveloped region.

Other pasture improvement projects are being supported in Mexico, the Caribbean, Belize, Chile, and Panama. Though the local conditions and specific objectives vary among these projects, the basic methodology is essentially similar. Each project begins with a detailed study of edaphic, climatic, social, and economic conditions together with a past history of livestock production in the areas of interest. Species of grasses and legumes, including native wild species and imported exotics, are planted in pure and mixed swards, their rate of growth measured and their dry matter content analyzed for nutrient composition, following which the most promising species and combinations are subjected to controlled grazing trials. Large-scale planting and grazing is followed by an analysis of critical factors including rate of animal body weight gain, milk production, carcass composition, and general health.

At several locations in Mexico, the national Institute for Agricultural Research has studied the rate of forage production among many species of grasses, legumes, and other crops and their influence upon milk production when fed as green forage, hay, or silage to local cattle and domestic goats. Because of the many factors involved, advice was sought in the design and interpretation of linear programing and simulation models that combined the technical, agronomic, and economic factors that influence forage crop production, utilization, and milk production.

In a cooperative project among scientists in the Caribbean and Belize an impressive germ plasm collection of native and exotic pasture crops has been assembled and evaluated over a variety of soil conditions. Several combinations that grow well and withstand intensive grazing, particularly on low pine ridge soils have been identified, the results quantified and analyzed. Of particular value is the wide range of forage species that comprise the Belize germ plasm collection.

The Catholic University of Chile is pursuing pasture improvement for meat and dairy livestock, and the University of Panama, using a similar methodology, seeks to increase milk, meat, and poultry production through cultivation of forage species of pigeon pea and leucaena, the multipurpose tree species described under the Asian forestry program. Progress has been made in increasing forage production and improving the quality of animal diets where native grasses are supplemented by the legume species described, fed as green forage, or conserved as hay or silage produced by acidification and the addition of molasses.

A team of veterinarians, agrostologists, animal nutritionists, and animal husbandry specialists is working with 800 head of Cebu and Holstein-Cebu crosses at the Panamanian Research Station of Cualaca. The purpose is to increase milk and meat production by improved pastures, conserved grasses, and legumes, supplemented with agricultural by-products. Panama imports more than 50% of its milk and because of the low nutritional quality of the established faragua grass, milk production and animal body weight gain are lower than can be realized through improved systems. During the first 2 years, improved feeding systems doubled annual milk production in the experimental herd, which excited the interest of the Bank for Agriculture and Development which, it is hoped, will finance the further development and exploitation of the research results.

A diagnostic survey of small farms in Costa Rica showed that 76% combined livestock production with annual and perennial crops; 97% of cattle producers raised the animals for milk and meat; milk represents 90% of the production value; grazing supplemented by farm by-products such as banana stems, cane stalks, and sugarcane by-products is the main source of feed; and that inadequate pasture production leading to overgrazing is a major constraint to increased production. In cooperation with Costa Rican farmers and at an experimental farm module designed to reproduce conditions typical of Costa Rican smallholders, scientists from Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) are pursuing improved production systems through improved pastures and the more efficient use of farm by-products and other rural wastes.

To feed local farm animals with agricultural and industrial by-products and waste materials is the objective of projects in Mexico and several Central American countries. Six Mexican research institutes, in a project coordinated by the National Council for Science and Technology, are cooperating to use various sugarcane by-products in feeds for beef and milk cattle. Conventional determinations of weight gain and milk production on various cane-derived diets are supported by more fundamental microbiological and biochemical examinations of the effect of high sugar intake on rumen composition. It was found that whole cane is not inferior to derinded cane provided the cane is chopped into particles ranging in size from between 3 and 20 mm. Feed efficiency was improved by a liquid anaerobic fermentation of molasses, bagasse, and inorganic nitrogen. The product, called Biofermel, when used as a supplement to pasture forage, sustained close to 1 kg/day in weight gains in 200 kg cattle. It also appeared that a toxic condition caused by high levels of molasses in the diet could be alleviated by the addition of glycerol. The overall results indicate the possibility of integrated feeding systems in the Mexican tropics using pasture forage during the rainy reason and processed cane together with preserved forage in the dry months.

Enormous quantities of coffee pulp, the fleshy material that surrounds the kernel of the coffee bean, are discarded in Central and South America, much of the pulp ending up as a pollutant in waterways. Coffee pulp contains a nutritionally attractive protein content and it has been calculated that the equivalent of about 100 000 t of protein are thus discarded every year. Because of residual caffeine and possibly other antinutrient polyphenols, coffee pulp when fed at levels above 20% of the diet caused reduced weight gain in young animals and lower milk production in dairy cows.

At the Instituto de Nutrición de Centro América y Panamá (INCAP), efforts are in progress to identify the polyphenolic antinutrients in coffee pulp, to develop processing techniques to eliminate or neutralize their adverse effect, and to develop compounded feeds with processed dried coffee pulp in combination with other agricultural by-products.

Techniques that appear to reduce the effect of antinutrients include aging of the dried pulp, ensiling of the pulp with other agricultural wastes before drying, and decaffeination by water washing. Research is continuing with livestock producers in the Central American region to apply the INCAP results into acceptable feeding systems. INCAP is also working to improve the husbandry of native swine that, in addition to their greater resistance to local infections, appear to convert feedstuffs, particularly low-grade protein, more efficiently than imported exotic animals.

Above 4000 m the barometric pressure is 40% that at sea level and frosts occur during 300 nights of the year. Only animals native and well adapted to these harsh conditions can survive. Among the few that can be husbanded are the indigenous camelids: the llamas, alpacas, and vicuñas. In Peru, veterinary and animal production specialists have begun a study of the physiology and efficiency of feed utilization by the native camelids. The alpaca and the llama, some 7 million of which are husbanded on the sparse grazing lands of the high Andes, provide the poor Amerindian populations with milk, meat, and fibre for clothing and a source of cash income. In common with most other native breeds, these animals have been neglected by research workers until now. The project will benefit from the Andean pastures research described above, but forage species will be selected for survival and growth at altitudes significantly higher than the Andean sheep

Llamas grazing on the hillsides of the high Andes.

and cattle can tolerate. Nutritional requirements, feeding habits, and the quality of existing and cultivated pastures at elevations above 4000 m are being examined to devise more efficient and intensive production systems for the domesticated camelids. Camelids suffer from parasitic gastroenteritis caused by intestinal worms, coccidiosis by intestinal protozoa, sarcoptic mange caused by mites and ticks, and enterotoxemia from infection of the intestine by *Clostridium perfringens*. A study will be made of a number of worms, the species of *Clostridium* bacteria, other intestinal and epidermal parasites that afflict the camelids, impair their health and the quality of their hair, and reduce their efficiency of feed conversion.

In Colombia and at universities in Bolivia, Costa Rica, Panama, and Peru, a small network of swine improvement projects was developed. Young scientists trained at CIAT were able to apply in their own countries the techniques learned. Though relatively modest in scope, each project has made progress in establishing swine production research centres and in developing feeding systems based upon local agricultural by-products. The foundation stock consisted of Durok, Hampshire, and Yorkshire lines crossed with local breeds.

Fisheries Research

Though the required institutional and professional capability is limited, the interest in increasing the supply of fish and aquatic plants for food is steadily growing throughout the Caribbean and Latin American countries.

Tropical Oyster Culture

At the University of the West Indies, tropical oyster culture appears to have benefited from related projects supported by IDRC in Asia and Africa. Techniques that use a cantilever type of raft and a grow-out basket developed in Japan show promise and the work is attracting the interest of both the Government of Jamaica and the Caribbean Development Bank.

In Colombia, on the Pacific coast in the Bays of Buenaventura and Malaga, the life cycle and biological characters of the mangrove crab and the mangrove cockle (*Anadara tuberculosa*) are being recorded by university scientists in cooperation with artisanal mangrove fishing communities. These investigations are preliminary to the eventual cultivation and farming of these two species, native to the region, increased harvests of which are desirable for the local food supply.

Simultaneously, on the Colombian Atlantic coast, an experimental station is being established and equipped for the intensive culture of tropical oysters, the ultimate objective being an oyster culture cooperative to provide financial support and marketing facilities to the coastal fishermen who eventually will cultivate the bivalves.

Bioecology and Environmental Factors

The coasts of Peru and Chile are renowned for the richness of their marine life. Scientists at the Universidad Nacional Agraria in Peru, in association with fishermen's organizations, are studying the bioecology and environmental factors that influence the survival and rate of growth of three native mulluscan species harvested for food by the coastal communities. Through a greater understanding of the life and feeding habits of these species it is intended to develop cultivation technologies in which floats, rafts, and bottom methods of culture will be compared.

In Chile, the biology, life cycles, and patterns of growth of several marine algae and invertebrates autochthonous to the region are being examined by biologists in cooperation with local fishermen. The upwelling of the Humboldt current stimulates one of the richest marine growths in the world. To obtain a larger and more consistent harvest a greater knowledge of the interrelated bioecological system is urgently needed first, to ensure adequate control of harvesting and conservation of important species and second, to identify those marine plants and invertebrates that appear amenable to culture. The eventual purpose is to develop a system of culture that integrates marine algae with mollusc and other invertebrates.

The fisheries unit in Belize is observing and recording the life history of the Caribbean conch (*Strombus gigas*) to lay a sound biological foundation for rational harvesting, effective management, and conservation of this valuable species. The observation includes stock assessments, growth rates, size at maturity, breeding habits and seasons, feeding, survival, and migratory habits. In addition to providing a basis for controlled harvesting and conservation, the data will serve to indicate the quantity of conch shells available for artisanal crafts and the feasibility of seed collection and mariculture of the conch.

A popular food fish harvested along the tropical Pacific coast of Latin America is the chame (*Dormitator latifrons*). A group of Ecuadorian agencies is investigating the relevant biology, life history, distribution, survival, and condition of the fish under traditional methods of capture. From the results, what appear as the most suitable systems of chame culture in fresh, brackish, and marine lagoons, will be compared. The studies will include breeding, survival and growth rate of juveniles, and feed requirements at all stages of growth and development.

An ambitious undertaking, which if successful could prove immensely beneficial to the Amazon Basin, is being conducted by five government and academic institutions in Brazil. Its purpose is to select and, through biological and environmental examinations, to breed and raise in captivity several species of fish native to the Amazon that are highly prized as food by the local people. Although more than 12 000 edible fish species are known to exist in the Amazon, in the past most attention has been given to the biology of ornamental aquarium fish for export. This is the first major attempt to cultivate native species for local consumption and the Government of Brazil has demonstrated its faith in the project's value by its large financial contribution. IDRC's involvement will provide relevant information and techniques and the dissemination of useful results to other Amazonian countries.

In Guyana the parastatal sugar corporation, in cooperation with the University of Guyana, is seeking to establish fish polyculture in flood-fallow sugarcane fields where it is a long-standing custom to flood the fields after the sugarcane is harvested. The aim during the flood-fallow period will be to breed and propagate several rapid-growing noncompetitive species including tilapia, carp, and hassar to increase the supply of food fish and income to the sugarcane growers.

Also in Guyana, the Ministry of National Development and Agriculture in cooperation with the Guyana Food Processors Ltd, are attempting to develop means of processing and marketing various species of fish that are presently discarded during shrimp trawler operations off the coast of Guyana. Valuable information has been gathered on the seasonal supplies of various species that make up the by-catch and in the development of appropriate processes and new products that utilize this by-catch. To expand these recent developments, the Guyana Food Processors Ltd has been able to attract $4 million from the European Economic Community (EEC) for new processing equipment and $17 million from the Inter-American Development Bank (IADB) to finance several new trawlers and to provide further technical assistance.

In the Dominican Republic, the Centro de Investigacion y Mejoramiento de la Producion Animal (CIMPA) hopes to establish fish farming combined with livestock production by pen and cage culture in inland lakes, irrigation canals, and coastal lagoons. Bioecological studies of native fish species will determine what seem to be the most suitable systems of enclosure culture for the species selected.

In a project recently begun, the St. Lucia Fisheries Management Unit together with a fishermen's cooperative, are examining the biology of, and the means to cultivate, native marine algae such as sea moss in conjunction with fish and shellfish. In many coastal communities seaweed extracts are

Sorting by-catch on a shrimp trawler off the coast of Guyana.

used in local foods and sold to commercial processors for chemical conversion to substances used by the food and pharmaceutical industries as gelling, stabilizing, and emulsifying agents. The annual harvest of sea moss in the Caribbean, once estimated at 5000 t dry weight, now barely reaches 100 t. The actual and forecast demand indicates the desirability of exploring the cultivation of important marine algae in association with finfish and shellfish. Experiments will be carried out in calm water bays using bottom racks and floating culture systems for different species. Growth rates of cultivated algae will be compared with natural growth rates at different coastal locations and environmental conditions. Growth rates of clones of preferred species will be compared in mixed and pure growth cultures. The influence of predators, competitors, commensals, and other ecological factors will be monitored.

Crops Research

The methodology developed and experience gained in cropping systems research in Asia is demonstrably helpful to the definition and implementation of a steadily increasing number of cropping and farming systems projects in Latin America. The Asian network benefited in leadership and concepts from the Division's early experience in Colombia where farming systems research was one of the first projects supported by AFNS.

The Caqueza Project

The Caqueza project began in 1971 when the Instituto Colombiano Agropecuario (ICA) sought IDRC's help in restructuring its integrated rural development program. The outcome of this ambitious project, which sought social and economic betterment together with increased productivity on small farms, has been comprehensively reported in the publication *Caqueza: Living Rural Development* (IDRC-107e). The project area was in the East Cundinamarca Valley where more than 75% of the population earn their living from agriculture on small farms, many located on hillsides at elevations above 2000 m. The most important crops are maize, various legumes, and potatoes, three or more crops being grown simultaneously, with harvesting taking several months. The project brought to light small farm technologies by which yields of maize and the other crops could be significantly increased. The rate of adoption was relatively rapid because all the research was undertaken in close cooperation with the rural community it was intended to benefit. The main purpose was to bring about significant improvement in the traditional and existing farming systems by providing better seed, improved agronomic practices, and supporting advisory services. Research that appeared to involve a higher than average risk was carried out on plots of land randomly selected from among the participating farms. Consequently, though the environment was typical and representative of the region, farmers were not invited to test or adopt innovations that had not been adequately screened. The project confirmed an attitude found almost universally among smallholder subsistence farmers — the desire to minimize risk rather than seek maximum production and profit where the latter involved high risk.

By illustrating the need first to understand fully the smallholders and their constraints before pursuing technological improvement, the project forged a partnership between Colombian research scientists and the smallholders and eventually led to a restructuring of ICA that emphasized farming systems rather than research by discrete and sometimes isolated disciplines. The methodology, later refined in Asia, called for much of the research to be undertaken in farmers' fields, on land and under conditions closely similar to those of the small farms.

The rural sector of Colombia was subsequently rezoned into 86 rural development areas, each consisting of roughly the same number of municipalities found within the Caqueza project and each area being serviced by ICA research, demonstration, and training staff.

The Caqueza project appears also to have influenced both the national university, which now offers higher degrees to broadly based research administrators, and the rural university whose small-farm research program is now supported by IDRC.

IDRC also supports ICA in an extensive multiple-cropping research project covering several regions of Colombia. Roughly 80% of the research is undertaken in farmers' fields, the remainder at ICA experimental stations. The means to increase and stabilize with minimum risk the total small-farm production of traditional crop combinations is being pursued at several locations. The combinations studied include: maize associated with species of climbing beans; potatoes with peas; sugarcane intercropped with food legumes; and combinations of plantains intercropped with maize, cassava, and food legumes. The ICA scientists cooperating with smallholder farmers are examining the agronomic and economic influence of a wide range of variables and will compare apparent improved technologies with traditional cultivation practices. Through training fellowships there will be cooperation with the cropping systems program at IRRI.

In Peru, the Universities of Puno, Cuzco, and Ayacucho are cooperating in cropping systems research with native farmers over a wide range of conditions in the Peruvian Andes. The crops are mainly indigenous and include potatoes, quinoa, and others tolerant of the high altitude. Experiments are being carried out both with individual farmers on their own plots and on community land cultivated by supervised school children. Though the methodology will borrow from experience in the Asian network and the Caqueza project, the agroclimatological and socioeconomic conditions of the rural poor of the high Andes makes this project unique in itself. That it is being undertaken cooperatively by three universities augurs well for the future orientation of their graduate and undergraduate training programs.

In the Cauca valley of Colombia, what can best be described as a rural university is pursuing a novel approach to training and small-farm research. In cooperation with smallholders and at the rural university's demonstration research farm, several aspects of local farming systems are being studied including the intercropping of bananas with legumes and squash; the integration of pig and poultry production using water hyacinth and agricultural by-products as feeding materials; perimeter fences and hedge rows as supports for horticultural crops, and Chinese chain pumps and simple hand pumps to supply water. The project is now being expanded to include an agricultural education component supported by IDRC's Social Sciences (SS) Division.

At the University of the West Indies greatly increased yields of pigeon pea were obtained by breeding a type with compact branching, which permitted a higher density of more closely spaced plants. The project also provided determinate pigeon pea types for mechanical harvesting and plants that matured throughout the year rather than only at the end of the year, which enabled smallholders to harvest manually over a relatively extended time period.

WINBAN, the Windward Islands Banana Growers' Association (Dominica, St. Lucia, St. Vincent, and Grenada), is seeking to increase the productivity of the more than 30 000 ha on which smallholders produce relatively low yields of bananas. Most of the banana crop is exported, but the islands import between 60 and 80% of their total food requirements. WINBAN's purpose is to increase local food production by intercropping cereal, legume, root, and other food crops among the banana plantations. The research has demonstrated suitable agronomic practices for mixed cropping that promise increases in economic return from systems that produce 2 t/ha of maize and 11 t/ha of sweet potato tubers, without significant loss in the yields of bananas with which they are intercropped. It was found that intercropping increased labour demand by 20-43%, capital investment by 4-11%, and net returns per hectare between 42 and 102% when cereal, legume, root, and oilseed crops in various combinations were row-intercropped with bananas and plantains. Plantains grow slower than bananas and, therefore, three cycles of intercrops can sometimes be grown before the plantain canopy closes. The influence of different food crop combinations upon the rate of banana ripening and soil fertility are subjects of particular interest. The importance of the project was set in sharp relief in 1980 by the severe hurricane damage sustained in the Windward Islands.

At the University of Panama, scientists are evaluating the influence on banana and plantain yields and soil fertility of a ground cover of nitrogen-fixing tropical legumes. There are 80 000 smallholders who grow bananas and plantains in Panama, largely for local consumption. To satisfy the banana plant's high nitrogen demand, farmers apply approximately 400 kg of nitrogenous fertilizer per hectare, as much as 25% of which may be washed away by heavy rainfall. It is hoped that the symbiotic generation of soil nitrogen by tropical legume species will prove more economic and as effective as chemical fertilizers in satisfying the plant's nutritional needs. In due course the legume cover may also sustain grazing animals.

Cropping systems projects involving smallholders in Honduras and Nicaragua are in progress in collaboration with CATIE. Detailed studies on farmers' production systems, management practices, resources of land, labour and capital, land use, credit availablility, and marketing practices have provided a valuable data base. Cropping patterns are being developed for both the high and low rainfall conditions that exist in different zones of Central America. In addition to rice, maize, sorghum, and several food legumes, live barrier strips of pineapples, mangroves, sisal, and deep-rooted pasture grasses are grown along the contours of steep hillsides to minimize soil erosion. Other crops of interest include sweet potatoes, cassava, and flax.

Quinoa

Quinoa (*Chenopodium quinoa*) grows in the Andean altiplano at altitudes between 3500 and 4200 m. Quinoa was cultivated as a major food staple before the evolution of the Inca empire and remains an important food crop throughout the high Andes of Bolivia, Peru, Ecuador, Colombia, Chile, and Argentina. In common with other food crops neglected by research workers, yields from traditional farming practices barely exceed 400 kg/ha. Scientists at the Bolivian Institute of Agricultural Technology have identified cultivars that, with slightly improved management, yield 1500 kg/ha and one superior cultivar that, with more intensive management systems, yields close to 3.5 t/ha. Almost all quinoa in the Andes is grown by smallholders for local consumption, often in combination with other food crops such as potatoes, barley, root crops, and food legumes. In addition to its tolerance to high altitudes, relatively poor soils, and low night temperatures, the seed of quinoa is notably more nutritious than any known cereal or food legume grain. As a proportion of the protein nitrogen present, the lysine in quinoa is much higher than in wheat and the sulfur amino acid content is more than double that in soybean protein.

The project in Bolivia has collected 1500 entries into a quinoa germ plasm bank, all entries of which are being evaluated for yield potential and

Intercropping quinoa and maize.

other desirable characters at several locations. Out of 120 of the most promising lines, 65 showed a yield potential in excess of 5 t/ha, including three that in one trial yielded more than 8 t of seed per hectare. The research will continue through breeding and selection to combine the characters of high yield with other essential traits and to provide the poor farmers of the Andes with more economic and productive systems of quinoa cultivation.

To extend the latitudinal and agroclimatic range of testing and in the hope of reintroducing quinoa to Colombia, from where it has almost entirely disappeared, superior quinoa lines are being evaluated at several locations by the National University of Colombia.

Over several years, through breeding, selection, and agronomic trials at various altitudes, scientists at CIMMYT have identified cultivars of sorghum sufficiently tolerant of low temperatures and high altitudes to be able to set seed at elevations above 2500 m. This is an important finding for sorghum farmers in the SAT whose farms are located at relatively high altitudes.

Triticale

Triticale is a hybrid produced by an intergeneric cross between the cereals wheat (*Triticum*) and rye (*Secale*). The first recorded wheat/rye hybrid was reported in 1873 and over the next century various botanists and plant breeders reported experiments in which wheat/rye hybrids were created. Until comparatively recently, genetic incompatibility, typical of intergeneric hybrids was displayed by all the wheat/rye crosses described. This incompatibility is evidenced in the first generation hybrid seedling being infertile in that it carries only a single set of wheat and a single set of rye chromosomes.

The advantage of a triticale hybrid was seen in its potential ability to inherit the desirable traits of wheat with the ruggedness of rye. Therefore, it was envisaged that through research one could overcome the mule-like infertility and create a grain with the acceptability to users of wheat combined with the tolerance of rye to low temperatures and light sandy soils and, therefore, an adaptability to marginal lands unsuited to wheat and other major cereals.

With financial support from CIDA a cooperative project was established between CIMMYT in Mexico, and the Universities of Manitoba and Guelph in Canada. The contributions of the Canadian universities to the success of the project are described later. CIMMYT's remarkable contribution has been described in several publications. Very briefly, what was accomplished included triticale hybrids bearing inheritable fertility; an increase in yield from being distinctly inferior to near equality with CIMMYT's best wheat types; an average protein-nitrogen content superior to that of CIMMYT's 10 best wheats; lysine content (as % of protein nitrogen) also superior to the 10 best wheats; and a significant improvement in grain quality — in 1970 many triticales displayed wrinkled grains, the average weight of seed of the 10 best triticales being about 69 kg/hl; by 1976 this had increased to almost 80 kg/hl.

So far the results of the CIMMYT research have been exploited more in developed than in developing countries but, as the grain receives more attention from cereal technologists, its acceptability will increase and triticale will add to the total cereal grain production of the Third World.

One of the more encouraging triticale projects is at the Catholic University of Chile whose scientists have reported yields ranging from 3.5 to 5.5 t/ha combined with relatively high protein contents. The research sites where triticale is grown cover almost the entire length of Chile, a total distance of close to 4000 km. Though in general the weight per unit volume of triticale seed has been lower than what is acceptable for standard wheat varieties, several triticale lines now approach the desirable test weight of 75 kg/hl. The Chileans report satisfactory acceptability of triticale flour in several cereal foods and, given triticale's apparent superior resistance to rust diseases that infect wheat, there is hope that triticale will eventually help to reduce Chile's dependence upon imported cereals.

Cassava

The genesis of and progress made in the world-wide cassava network that began in Colombia has been comprehensively documented in several IDRC publications (see Appendix 3). It began with a sizable grant from CIDA to CIAT together with a sum of $750 000 to be invested in complementary research in cassava in Canadian institutions, the whole research package being managed by IDRC.

Cassava, grown in more than 80 tropical countries, provides essential food energy to more than 300 million poor people. Following an extensive review of existing knowledge the team at CIAT collected more than 2000 cultivars from Latin America where cassava had its origin. Research on breeding, selection, propagation from true seed, and vegetative material, supported by agronomic, physiological, entomological, and pathological investigations has led to significant increases in yields of cassava roots by both smallholder and plantation growers.

Research in Canada made possible the propagation of disease-free material from infected plants by apical meristem tissue culture. Scientists at the University of Guelph identified tropical microorganisms capable of hydrolyzing and fermenting cassava mixed with inorganic nitrogen, the end product containing close to 35% crude protein on a dry weight basis. The research is continuing to refine the process of microbial enrichment and to design and construct simple fermentors in which protein-enriched cassava can be produced as an animal feed in tropical countries.

In addition to its management of CIDA funds, IDRC made sizable investments from its own budget in several cassava projects in Asia, Africa, and the Caribbean and Latin America. In Latin America the first support was given to modest cassava projects carried out by graduate students in Bolivia, Peru, and Costa Rica. Later projects were undertaken to modify and adapt the CIAT cassava technologies to conditions prevailing in Brazil; Peru; Ecuador; and, through a cooperative research project based at CIAT, in other interested countries of the Caribbean and Latin America. In Brazil, a rich source of wild cassava germ plasm, the Institute of Biological Sciences has collected several wild *Manihot* species, some of which were hybridized with cassava cultivars after screening.

Cassava research in Latin America has led to substantial increases in yields in farmers' fields. Before the program started, yields averaged between 10 and 15 t/ha. By applying improved cultivation systems, farmers in Colombia have achieved in excess of 30 t/ha and, with greater agronomic inputs, yields in excess of 50 t/ha are possible.

Progress was made in the biological control of several cassava predators. A species of Hymenoptera was identified that attacks the horn worm, a green slug-like creature that feeds voraciously on cassava leaves.

At the Commonwealth Institute of Biological Control (CIBC) of Trinidad, scientists studied the life cycle and population dynamics of the green cassava mite (*Mononychellus tanajoa*), which causes severe damage to the leaves of cassava. The CIBC has identified several insects that prey upon the mite including four Phytoseiids, two Cecidomyiids, one Coccinellid, and three Staphylinids, several of which are being transferred to Africa where the cassava green mite causes severe damage to cassava in several countries.

The Cassava Information Centre at CIAT, financed by the IS Division of IDRC, has made possible the worldwide dissemination of results from the cassava improvement research at CIAT and in many of the cooperating countries.

To reduce dependence on imported chemical fertilizers in developing countries, IDRC encourages research to make better use of locally available sources of plant nutrients. Phosphorus deficiency is widespread in many tropical soils. To further complicate matters, food plants absorb phosphorus from a relatively thin soil layer adjacent to their roots, no more than 15% and often as little as 5% of the phosphorus present in cultivated soil being used by the growing plant. Few developing countries with phosphorus-deficient soils own the facilities to manufacture chemical phosphate fertilizers. Many, however, have within their territories sizable deposits of rock phosphate in which, for the most part, the phosphorus is present in an insoluble form. From many of these rock phosphate deposits the phosphorus can be made available to growing plants by comparatively simple processing technologies.

IFDC and CIAT are cooperatively exploring how native rock phosphate deposits can remedy the phosphorus deficiency of the andosols, oxisols, and ultisols that cover large areas of tropical forest and savanna in Latin America. Extensive laboratory and field tests with various food and forage crops grown on these phosphorus-deficient soils demonstrate that phosphorus is liberated to the growing plants by such simple methods of rock phosphate treatment as fine grinding, concentration by water elution, and treatment with cheap inorganic acids. During the first year of application, treated rock phosphate stimulated slower growth rates than chemical superphosphates but, probably because of the slower rate of release of phosphorus, there was a greater carry over and greater stimulation of plant growth from treated rock phosphates during the second and subsequent years. The research is continuing on all methods of treatment and application, including the microbiological conversion of ground rock phosphate to suitably effective forms, and is being applied both to food crop and to pasture cultivation. As mentioned elsewhere, the experience gained in Latin America will be applied to a similar end in West Africa where soil phosphorus deficiency exists in close proximity to rock phosphate deposits.

Postproduction Systems Research

Utilization of By-Catch

From many of the world's oceans, shrimp trawlers unintentionally collect a large and diverse harvest of marine species, most of which are discarded as being much less economically important than shrimp. Most of this unwanted by-catch is jettisoned shortly before the trawler reaches the harbour causing excessive waste of a valuable protein source in addition to attracting predatory sharks to the inshore waters. It is estimated that at least 80 000 t of unwanted fish was dumped by trawlers that landed in Guyana during 1975. To prevent this protein waste and its attendant hazards, the Government of Guyana passed a law requiring that a significant quantity of the by-catch be landed. To make best use of the by-catch the Government of Guyana is directing a project designed to assess the quantities of the principal species in the by-catch from different seasons and ocean regions; separate the by-catch into appropriate categories; develop technologies to manufacture inexpensive deboned, minced, salted, and smoked fish; and develop fish products of higher value for the retail, hotel, and catering trades. A number of the objectives have been realized and are reported in several IDRC publications. During 1978 the following products of by-catch were distributed to Guyanese rural and city markets: 1200 t as fresh fish; approximately 100 t as fish fillets; and 30 t as salted, 27 t as smoked, and 10 t as pickled fish. Other forms generated from the pilot plant facilities include fish sausage, fish jam, and fresh-frozen minced fish blocks. The stability and acceptibility among consumers of each of the fish products is determined by staff and students at the Carnegie School of Home Economics who have also recommended suitable seasonings and other modifications to increase acceptability. Stimulated by a government restriction upon imported fish products, there is a rapidly growing and, because of limited processing facilities, unsatisfied demand for the products of the by-catch. An assessment of the marketing and distribution facilities available and necessary to meet demand is preparing for a larger commercialization of the by-catch technologies. (The project is the subject of an IDRC documentary film "Fish By-Catch . . . Bonus from the Sea".)

Drying and Storage

Technologists at the Universidad Nacional Agraria in Peru are studying the preservation of local marine fish including large sardine and mackerel, by improved systems of salting and drying. The fish dryer developed in the Philippines is being modified using various local agricultural wastes as heating fuel. A solar collector is also being examined as a heat source for the dryer.

Also in Peru, the food technology department of the National University, in cooperation with rural people in the high Andes, is studying traditional methods of producing *papa seca* in which harvested potatoes, surplus to immediate needs, are preserved by sun drying. The traditional technology gives a product that is highly variable in composition and frequently of an unhygienic quality. The food technologists, in cooperation with a community of farmers in the Muquiyauyo high valley, intend to standardize the procedure for potato dehydration through more efficient and uniform methods of grading, washing, peeling, chopping, drying, packing, and storing. The technical and economic efficiency of four drying systems are being compared: a controlled system of direct sun drying, mechanical hot-air drying over a range of temperatures and air velocities, indirect solar drying with wind and convection air currents, and indirect solar drying with mechanical air movement. The field research is supplemented by controlled laboratory tests and evaluations. If successful, the project will increase the supply and nutritional quality of dried potato, both for local consumption and for sale in nearby markets.

Among the food legumes grown in Latin America, a wide variability in nutritional composition, digestibility, and overall quality is demonstrable. At INCAP, scientists are studying the effects of genotypic and environmental differences and agronomic practices upon the nutritional quality; cooking properties; and acceptability of various species of *Phaseolus*, *Vigna*, and *Cajanus*. Their aim is to identify quantifiable physical and biochemical characters that relate to these qualities. Of equal interest are the changes in

The solar dryer used for potato drying in Peru.

quality (including "hardening" and increased cooking time) that occur during storage. More than 400 cultivars were screened and significant variations were found in weight of seed, water absorption (both before and after storage), seed hardness, proportion and degree of adhesion of seed coat, and protein content. Protein digestibility was lower in beige-, red-, and black-coated than in white-coated beans and analyses suggest that this may be caused by polyphenolic tannins. The reduced digestibility of the pigmented types was demonstrated in humans and farm and laboratory animals.

For many centuries, seeds of various species of lupin have been cultivated and eaten by the people of the Andes. Being leguminous, lupins fix atmospheric nitrogen, the seeds contain approximately 40% protein (dry weight basis) and the plants can be cultivated on marginal lands at relatively high altitudes. The Andean crops project described earlier, is developing systems for intercropping lupins with cereals and other food grains.

To increase the protein content of local diets, particularly foods formulated for weanlings and infants, Chile and other Latin American countries import substantial quantities of soybeans and soybean derivatives. Scientists at the Institute for Technological Research (INTEC) in Santiago are demonstrating that imported soybean materials may be replaced by processed lupin seeds, a highly desirable objective as more than 75% of the lupins in Chile are grown by the Mapuche Indians, one of the poorest segments of the population. Although barely 1500 ha in the Mapuche district is cultivated to lupins, it is conservatively estimated that 40 000 ha is suitable for lupin cultivation.

Some lupin types contain a toxic alkaloid, but the hazard can be reduced or eliminated through plant breeding and/or processing technologies. Lupin products already developed in the project include dehulled lupin beans, full fat and defatted lupin flour, textured lupin protein, and lupin protein concentrate. Pro-oxidant enzymes are present in lower proportions in lupins than in soybeans, consequently, full fat lupin products appear to have better storage properties. Estimates of demand, based upon growth extrapolations of present soybean imports, indicate a very large future market for processed lupin seed in protein-enriched cereal foods, milk substitutes for school and preschool children, and in formulated foods for infants to be distributed under the government's nutritional improvement program. For the latter purpose lupin flour is combined and processed with wheat, oats, and other grain flours. A dried milk analogue has been developed that will eventually be manufactured and distributed by the dairy industry. Arrangements have already been made with a dairy enterprise in southern Chile to process and distribute the milk analogues and dairy blends for wide-scale consumer tests. Experience in the African milling projects referred to earlier is assisting in the development of abrasive methods of dehulling lupin seeds.

The surplus of coffee pulp in Latin America has already been described. Where it is logistically and economically unsound to direct the coffee pulp to animal feed, it may be feasible by anaerobic fermentation to convert the pulp to methane and other combustible gases to fuel coffee bean dryers. The Instituto Centroamericano de Investigación y Technología (ICAITI) is exploring this possibility, principally for the benefit of small-scale coffee growers who cannot afford the established commercial coffee dryers priced at more than $20 000. For drying coffee beans ICAITI is adapting the flatbed rice dryer described under the Asian postharvest program, fueled by biogas generated from the fermentation of coffee pulp mixed with other organic materials. The objective is an inexpensive dryer with a capacity of up to 500 t/yr, and a modified flatbed dryer is under trial at a coffee producers' *beneficio* at Solola, some distance from Guatemala City, where biogas from coffee pulp is being compared with a diesel and wood-fueled burner. Initial results indicate that the methane biogas is produced more efficiently from composted coffee pulp. Consequently, simple composting sheds have been constructed immediately above the anaerobic digestors to permit easy transfer of the substrate after composting.

The Unión de Países Exportadores de Banano (UPEB) promotes research, development, improved production marketing, and distribution of bananas on behalf of its six member countries; Colombia, Costa Rica, Dominican Republic, Guatemala, Honduras, and Panama, which collectively supply more than half of the world's international trade in bananas. Most of the banana crop is shipped and eaten as fresh unprocessed fruit. For various reasons bananas that are nutritionally wholesome are graded unsuitable for export in quantities greater than can be consumed locally as fresh fruit. The need is apparent for inexpensive systems of processing to preserve and convert the low-grade fruit into acceptable foods. Research institutes in Guatemala and Costa Rica are cooperating to develop a technology close to the production sites, to convert bananas into a stable puree for sale to secondary processors as an ingredient for a variety of foods. The project is being undertaken by food technologists and production and marketing economists.

Forestry Research

Compared with those of other continents, the tropical rain forests of Latin America are more heterogeneous in species, there being relatively fewer numbers of any single species per unit area of forest. Of the more than 650 species identified botanically in the Andean subregion, barely 50 are used commercially and fewer than six are customarily harvested from any one location and are used mainly for export as ornamental woods. Much of the surrounding forest is destroyed or seriously damaged by logging operations, little economic benefit being derived from the nonexportable species.

In a project coordinated through the Junta del Acuerdo de Cartagena, six forestry research institutes in five countries — Bolivia, Colombia, Ecuador, Peru, and Venezuela — carried out an extensive study of the availability and properties of the secondary timber species present in considerable unused supply. The six institutes examined more than 100 species giving particular attention to the physical and mechanical properties that determine in what manner a timber may be used for structural and other industrial purposes. From the data collected, analyzed, and classified, the project scientists published a structural timber-grading system, directly related to indigenous species and the design of timber structures in Andean

Testing properties of tropical timbers.

Pact countries. The project determined conditions and standards for kiln drying; statistically reliable methods of pretest sampling; and prescribed the design of structural members, joints, and other fabrications for specific purposes. Throughout the Andean Pact countries, brick, steel, and cement were preferred over wood in the construction of houses and other buildings. As the cost of these materials rises, local timbers become more economically attractive. From the results obtained, several prototype houses have been designed and constructed that proved resistant to seismic shock from earthquake simulators. Several descriptive publications have been compiled and distributed for the information and guidance of architects, builders, and timber merchants.

Borrowing upon the experience of the Andean Pact project, Mexican scientists are developing a grading system for locally grown pine timbers to expand their use in wood frame and other structures.

Two related afforestation projects are being supported in Peru and Bolivia. Through species selection and improved silvicultural practices, each project hopes to establish rural forest plantations in the Andean highlands at elevations previously ignored by foresters. Species will be selected that are tolerant of prevailing adverse conditions; can be integrated with and protective of cultivated crops and pastures; and can provide timber for fuel, construction, and fodder for animals. Leguminous *Prosopis* species are of particular interest for animal feed. In both countries strategic tree plantations of selected species will conserve soil on hill slopes by preventing run-off erosion. In addition to the rural social demand, the Bolivian mining industry requires more than 50 000 t of wood charcoal annually for ore smelting.

At the Universidad del Valle in Guatemala, the biology and pattern of distribution of *Dendroctonus* beetle species are being investigated. These insects infest and cause devastation to nonresistant species of pine. Given a more intimate knowledge of the biology and life cycle of the beetle, biological systems of control could be introduced. Already one wasp-like insect and several Diptera have been identified as probable parasites.

Canada and Developed Countries

Almost every applied research program turns up difficult problems that require more fundamental investigation. Approximately 10% of the projects and 5% of the budget appropriations during the decade have been invested in Canadian expertise pursuing solutions to difficulties encountered in research supported in developing countries and IARCs (Table 6). Two of the largest investments were financed jointly by CIDA and IDRC for Canadian studies complementary to the research on cassava and triticale carried out at CIAT and CIMMYT respectively. Most of the significant Canadian results have been published in the open literature and, therefore, only a brief account will be presented in this text.

The largest investment in research in Canada fell within the cassava and triticale projects referred to earlier. Beginning in 1972, more than $800 000 provided from CIDA and IDRC funds was invested in some 25 cassava projects. One of the earliest was carried out by agricultural economists at Guelph who, in an 18-month study, projected future demand and market prospects for cassava as human food, animal feed, and industrial starch. In 1973, total world trade in dried cassava chips and pellets was worth approximately $100 million and the Guelph group forecasts exports valued at almost $500 million by 1980 and a total of 6×10^6 t by 1985. In actual fact, trade in cassava chips and pellets in 1979/1980 from Asia to the EEC countries amounted to close to $600 million. Exports to the EEC reached an all time high of 5.8×10^6 t in 1979. By agreement, exports of cassava chips and pellets to the EEC from Thailand will be restricted to a maximum of 6×10^6 t. The marketing study also pointed up the lack of relevant information on cassava production economics. Consequently, IDRC financed small studies in Brazil, Ecuador, India, Jamaica, and Thailand, which permitted a cross-country analysis of the economics of production.

Also at Guelph, plant physiologists examined the influence of environment on photosynthesis and cassava growth patterns and interspecies and intervarietal differences in photosynthetic efficiency. It was demonstrated that while cassava is not a highly efficient photosynthetic converter, it produces sizable yields because of the high proportion of the plant that is usable and the long growing period during which photosynthate transfer to the roots takes place.

Cassava suffers from a number of diseases, the most serious of which are bacterial blight and a mosaic leaf infection caused by a virus or mycoplasm. These diseases can spread from one country to another by the movement of infected material, a fact that seriously inhibits transfer of germ plasm. At the Prairie Regional Laboratory (PRL) in Saskatoon, a tissue culture technique was developed to propagate symptom-free material from

Table 6. Total appropriations and number of projects in Canada and developed countries.

	Crops and Cropping Systems		Fisheries		Animal Sciences		Forestry		Postproduction Systems	
Country	Appropriations ($,000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects
Canada	1913.2 (65%)	13 (42%)	237.6 (8%)	3 (10%)	541.2 (18%)	6 (20%)	15 (1%)	1 (3%)	235 (8%)	8 (25%)
United Kingdom[a]	399.6 (100%)	6 (100%)								
United States[b]	1423.8 (100%)	4 (100%)								

[a] Phytosanitary regulations forbade pursuit of the *Striga* research in Canada.
[b] Although the headquarters of the organization involved was in the USA the research was undertaken in Latin America.

Spreading cassava chips for sun drying near Khon Kaen, Thailand.

plants infected with cassava mosaic. The PRL scientists generated new plants by culturing the somatic tissue from the newly emerged apical meristem of a diseased plant. The tissue is cultured in a nutrient medium until it produces a shoot and root in which form it may be transplanted, the small plant being eventually transferred to a hydroponic medium in which further growth is generated. The tissue culture technique makes possible the generation of many young plants from a single parent and promises future hybridization through protoplast fusion.

At Guelph, several studies were undertaken to understand more clearly the dietary significance, the metabolism, and the effect on rat tissue of oral doses of linamarin, the toxic cyanogenic glucoside present in cassava root that, when hydrolyzed, liberates hydrocyanic acid. Traditionally, the linamarin is removed either by elution in water or by fermentation prior to cooking in an open pot when the hydrocyanic acid steam distills off. One of the objectives of the Guelph study was to determine the fate of linamarin when ingested before hydrolysis. The results of this and related studies supported by the Health Sciences (HS) Division form the basis of two IDRC publications (IDRC-010e and -136e). Other studies in Canada examined the effects of soil micronutrients and the possibility of establishing a chemotaxonomic classification based on phenolic differences in cassava plants.

One of the most interesting and productive experiments in microbial protein enrichment of starch arose from another project at Guelph in which many tropical soil organisms were screened to find one or more capable of both hydrolyzing and fermenting cassava starch in a single step to generate a high level of protein.

After screening several hundred tropical soil microorganisms a few were found that appeared to satisfy the objective. One in particular, *Aspergillus fumigatus*, is able to hydrolyze and ferment cassava in the presence of inorganic nitrogen at temperatures between 35 and 45°C and to increase the crude protein content, on a dry weight basis, to rougly 35%. Because the organism grows best at around pH 3.5, it suffers little competition from other microorganisms. The advantage of such an organism over food yeast, for example, is that the latter, in common with other temperate organisms, requires mechanical refrigeration in tropical countries to maintain the fermenting medium at optimum temperature. In the tropics the groundwater temperature is rarely, if ever, low enough to cool a yeast fermentor to the optimum of 25°C.

Because of the remote possibility that *Aspergillus fumigatus* might form aerosols and cause distress to the relatively small proportion of mankind who are susceptible to aspergillosis, other organisms are being examined including *Cephalosporium eichhorniae* whose growth is restricted to a sufficiently narrow range of temperature and pH that it would be unlikely to grow within the human body. This research is continuing, the objective being to establish, in one or more cassava-producing countries, a fermentor of adequate size to enrich cassava, and other plentiful carbohydrates, with microbial protein to a level suitable for feeding farm animals.

Most of the work on triticale took place at the University of Manitoba where, in addition to a genetic improvement program in cooperation with CIMMYT, scientists studied the biochemical and cytogenetic influences upon seed development and plant fertility. Using advanced techniques of embryo culture in which chromosomes were induced to double by treatment with colchicine, an extract of the autumn crocus, several hundred new amphiploids were generated from wheat and rye parents of different genetic backgrounds. These included hexaploids (from durum wheats) and octaploids (from bread-type wheats). The amphiploids at Manitoba included hexaploid/hexaploid and octaploid/hexaploid combinations.

The earlier research at CIMMYT and Manitoba concentrated upon triticales with a spring habit of growth. In many less developed countries, particularly those where triticale might be grown at high altitudes, there appeared to be a greater need for winter triticales that are planted in the autumn, carried through the winter as young seedlings to mature during the following summer. The University of Guelph is climatologically well suited to the development of winter triticales and over several years has made distinctive progress in this area. From many hundreds of lines screened and crossed the Guelph program has generated many useful triticales from winter/winter and winter/spring parents. Yields and seed quality now approach desirable targets for winter wheats and the winter triticales demonstrate good growth characters and disease resistance superior to wheat under conditions unfavourable to wheat production.

Triticale growing on a research farm near Winnipeg, Manitoba.

When the triticale program began, the early triticales were characterized by shriveled kernels and low inheritable fertility. Both of these defects have been largely overcome and now that triticale has been accepted in North America, there is hope that its acceptability in developing countries with agroclimates adverse to wheat but favourable to triticale production, will be enhanced and will encourage its wider adoption as a human food grown on marginal lands unsuited to better-known cereal grains.

Other crop science projects in Canada have included two studies to gain a better understanding of the biochemical and physiological mechanisms that confer greater tolerance to continuous or intermittent drought in sorghum. At the University of Laval, in cooperation with the sorghum improvement project in Senegal, various in-laboratory techniques of simulating drought in growth chambers were used to identify sorghum cultivars with superior tolerance. At the University of Saskatchewan, in cooperation with ICRISAT, progress has been made in identifying the plant hormones that appear to control drought tolerance in sorghum. A novel analytical technique based upon high-performance liquid chromatography makes possible the simultaneous determination of nanogram levels of the auxins, cytokinins, and abscissins. The analytical method is rapid and accurate and has been semiautomated to permit 24-h round-the-clock analyses. Sensitive detection monitors based upon UV absorption and fluorescence provide the accuracy necessary.

The project, which is being monitored by a team of internationally recognized authorities, promises to provide plant breeders with accurate biochemical indices from which to select the more drought-tolerant types from early generations of sorghum-breeding materials.

At ICRISAT, hormone analyses are carried out at various stages of growth on 10 cultivars of sorghum. Though the complete analytical cycle is necessary before conclusive results can be drawn, associations between hormone levels and indices of drought tolerance are appearing, large differences in abscissic acid content being recorded between cultivars under stress and the controls.

At Saskatoon, high leaf-water potential is associated with abscissic acid levels, and under drought stress abscissic acid and phaseic acid increase, while cytokinins and the auxin 3-indoleacetic acid levels decrease. Abscissic acid acts to inhibit growth whereas cytokinins and auxins stimulate growth, the former by cell division, the latter by cell expansion and elongation.

At the University of Manitoba a study started recently to identify sources of *Vicia faba* germ plasm resistant to Ascochyta blight, to establish the range of pathogen variability, and to study the nature and inheritance of resistance. This project is in cooperation with the legume improvement network at ICARDA and the Middle Eastern countries.

At the University of British Columbia a Filipino graduate student has investigated possible chemical exudates from certain tropical legumes that may inhibit the growth of other crops in multiple cropping systems. This subject of allelopathic plant/plant interactions is highly complex and deserving of greater attention by plant biochemists and physiologists.

At the University of Guelph, in cooperation with the animal diseases projects in East Africa, extensive new knowledge was acquired in the characterization of the anemia that occurs in trypanosome infections in cattle and in the mechanism of the immunological responses to these infections. The characteristic anemia was found to be attributable mainly to a significant increase in the rate of destruction of the red blood cells caused by a fixation on the surface of the cells that results from antigen-antibody combinations. The results indicate the probable difficulty of producing a vaccine from either attenuated live or dead trypanosomes.

The remarkable advances in induced spawning in cultivated fish species was made possible by a project carried out by the University of British Columbia, the British Columbia Research Foundation, the Fisheries Research Board of Canada, and a salmon cannery on Canada's west coast. Large quantities of pituitaries were extracted from salmon delivered to the canning factory, and using modifications of techniques developed in Canada, gonadotropin extracts of various concentrations were made and preserved. Data were collected on the yields, extraction efficiencies, and costs of the process. The extracts were delivered to several of the fish culture projects in Asia described earlier and provided the first materials with which to induce spawning from captive gravid female fish. The extracts also provided standards against which to compare pituitary gonadotropin extracts from species harvested in tropical countries.

At the University of Victoria biochemical and microscopic examination of the intestinal microflora of two carp species provided interesting information on the mechanisms of digestion and techniques by which to determine nutritional requirements.

In the postproduction sector reference has already been made to the cooperation between the PRL in Saskatchewan and several projects in Africa in the development of more efficient systems of abrasion milling of sorghum, millet, and various tropical legumes. In a related study, for the first time on record the polyphenolic tannin present in the seedcoats of pigmented sorghum was isolated and chemically characterized. The substance was identified as a procyanidin polymer typical of a family of compounds found in plants of a woody habit of growth. In addition to conferring the beneficial effect of increasing the resistance of sorghum to attack by birds, moulds, and various insects, the polyphenol has the adverse effect of reducing total and protein digestibility. Research at PRL is continuing in an attempt to develop abrasive methods of removing the outer layers of sorghum seeds high in polyphenols while leaving the relatively nutritious remainder intact for subsequent grinding.

The University of Saskatchewan cooperated with several projects in Africa in a systematic examination and comparison of the composition and properties of several cereal and legume flours and their products. These were produced using traditional household methods, rural mechanical milling processes, and were conducted under laboratory-controlled conditions.

A large body of data was assembled and analyzed and new light was thrown upon properties in cereal and legume flours essential to meet consumers' standards. In general it was demonstrated that mechanized systems suitable for rural industries were capable of producing flours as acceptable as those produced from traditional hand pounding. The studies included composite flours of mixed cereals and legumes that are used in the manufacture of bread, noodles, and a variety of snack foods.

As described earlier, the Division has helped lay the groundwork for rural grain milling enterprises in several countries of Africa and Asia. Also noticeable is a growing response to the AFNS recommendation that more attention be given to quality factors that influence utility and acceptability. It is inconvenient and indeed expensive to carry out trials of milling quality on a large scale. The PRL, therefore, developed a small laboratory unit known as a tangential abrasive dehulling device (TADD), which will simultaneously determine the response to abrasive decortication of eight different small (5-10 g) samples of cereal grains such as sorghum. The TADD gives two indices of milling quality: the abrasive hardness index — the time in seconds to remove 1% of the outer kernel, and the extraction rate based upon a flour colour reflectance measurement. TADD units have been delivered to several grain-milling and quality projects, and the results of comparative tests will be assembled and analyzed at PRL.

For some years it has been known that the traditional practice of long fermentation may be replaced by mechanical development, through high speed or intensive mixing, in the production of Western-type bread. It was also discovered that mechanical development permits the use of significantly weaker wheat flours containing lower than normal proportions of strong protein. At the University of Manitoba this knowledge was used to develop a mechanical development system of breadmaking in which up to 30% of sorghum, maize, or other nongluten-forming cereal flours could be added to wheat flour, the dough being developed by repeated folding and sheeting through rotating rollers. The technique is the basis by which bread is being made with wheat flour diluted with sorghum flour at the mill in Maiduguri and will be explored in other countries that import sizable quantities of wheat for breadmaking.

Training

It can be argued that research and development, in common with all intellectual activity, bring new knowledge and insight to those involved. Thus, the total AFNS program may be regarded as a learning or training activity. Embodied within the program, however, there is a substantial identifiable training component; more than 60% of all AFNS projects include formal (degree) or short-term training. The kind of training and number of trainees financed by IDRC in AFNS projects during the decade are shown in Table 7.

All the training provided from the AFNS budget has been inproject training in which the subjects studied and the research training undertaken are directly related to the project's objectives. In addition, a large number of students, particularly graduate students, pursuing theses have been employed in many projects financed from the recipient's contribution to IDRC-supported projects. As far as possible, graduate degree training has taken place within each project, the young scientists using project results in their theses presentations. Where university facilities are unavailable or inadequate in the trainee's home country, degree training has been provided either in another developing country, in Canada, or in some other economically developed country.

Noteworthy of "another developing country" mode of degree training are the minor millets and oilseeds projects in Bangladesh through which several students are pursuing PhD degrees in Indian universities, each on a different millet or oilseed crop; universities in the Lebanon and Egypt that have accepted students from other Middle Eastern countries; and the University of the Philippines (UPLB), which has trained students from a number of Asian and African countries in cropping systems. Of particular interest at UPLB are the overlapping theses in which graduate students from several countries study for MSc degrees using research data derived from

Table 7. Type of training and number of trainees in AFNS projects.

Type of training	No.	%
Diploma	91	8
BA/BSc	11	1
MA/MSc	308	28
PhD	56	5
Study tour/short course	513	46
On-the-job	132	12

different disciplinary aspects of cropping systems research in the same rural areas. The disciplines range from plant breeding and agronomic sciences to social sciences and thus inculcate in the graduates a spirit of cooperation and mutual interdependence.

As far as possible, training in Canada has consisted of formal courses of lectures and theoretical studies, the practical thesis research being carried out in the trainee's own country or region. Of particular interest are the cooperative training programs established between the sorghum improvement and postharvest projects in Senegal and Laval University and the animal diseases projects in East Africa and the University of Guelph.

Nondegree training takes many forms, including intensive short courses and visits to one or more research institutes to learn specific techniques. Close to 20% of all the trainees were enrolled in intensive courses at the IARCs. The signal success of the ICARDA legumes, the IRRI cropping systems, and the CIAT cassava training programs are referred to earlier.

In all sectors of the program short-term training has been provided in a variety of skills and techniques too numerous to describe. Training has also been given by visiting consultants and in training workshops. For example, the fisheries group has held training workshops in cage culture and bivalve culture; the African forestry network in silvicultural techniques; and the postproduction group in operations research, cereal and legume quality, and grain milling. Some of the workshops have been national, supported from a single project, others regional, and still others intercontinental.

In a few projects, including the sorghum polyphenols and tissue culture studies, postdoctoral fellows have been employed essentially as advanced level trainees, both learning and applying complex new techniques in the solution of particular problems. A good deal of preproject training has been provided by grants from IDRC's Fellowships Program.

One form of training that has not received the attention it deserves is training in research management, including program and project identification, planning, evaluation, and resource allocation. This is a matter discussed in more detail under "What Has Been Learned."

In summary, research training has represented a sizable proportion of the AFNS program. Though the numbers in Table 7 may suggest discrete and identifiable categories, a considerable degree of flexibility has been demonstrated, the guiding principle being to offer the form of training most apposite and appropriate to each project's objectives and each trainee's needs.

Publications

The authors and titles of all the publications generated within the Division during the decade are listed in Appendix 3. Some are the proceedings of workshops, others relate to one or more projects or are state-of-the-art reviews. Appendix 4 lists other publications that have been generated by AFNS staff over the decade.

Some of the IDRC publications are now out of print but all are available on microfiche. Copies of these publications and films on related subjects may be obtained from IDRC's Communications Division whose staff gave valuable guidance and assistance in their preparation.

Chapter 3

What Has Been Learned

We have titled this publication *A Decade of Learning*. The previous chapter outlines what was learned from research, some of it exceptional in quality and achievement, carried out by many scientists in developing countries. It was decided also to set down what the staff of AFNS has learned in managing the Division. Every member of the staff was invited to answer the question "What have we learned?" and the following is an edited distillation of the responses.

This material was compiled by the Director who is therefore responsible for the final interpretation, but it would be dishonest to imply unanimity of opinion and agreement on every issue. In a program as diverse as has been described it is difficult, indeed it would be misleading, to present what has been learned as a series of broad generalizations. Every project is different from the others and must be so regarded. Nevertheless, over the 10 years certain experiences seem to be of particular significance. It is these, together with a number of unresolved and uncertain matters, that are presented under the heading "What Has Been Learned."

Philosophy and Style

The purpose of the AFNS program is to strengthen the scientific capability of developing countries in the belief that every nation needs its own food and agricultural research service, staffed with scientists and technologists able to choose among the many alternative systems and technologies, those most relevant, appropriate, and readily adaptable to their country's needs and resources.

AFNS grants are given to specific projects; rarely is support offered to core budgets for unspecified activities. This chosen form of support requires an existing institutional structure and some trained staff and, therefore, builds upon institutional foundations created by others. A greater number of AFNS projects are therefore to be found in countries where relevant scientific competence and research organizations are established. Thus, over the decade, AFNS has financed 28 projects in the Philippines, 18 in Egypt, 17 in India, 14 in Colombia, 13 in Peru, and 12 in Kenya. Nevertheless, AFNS has maintained its original concern for the rural poor of the semi-arid tropics, particularly those of the Sahel whose countries are numbered among the least economically and scientifically developed, and a substantial investment was made during the decade in four Sahelian countries: Senegal, with six projects; Mali, with seven; Upper Volta, with five; and Niger, with four. In spite of our concern for the poorest of the poor, there are some countries in which the lack of political will and interest, combined with a negligible research facility, militate against AFNS being able to offer the help it would wish.

It is not the Division's custom to carry out extensive preproject feasibility studies but to rely upon recipients to define their project priorities. It is often necessary, particularly with young scientists, to temper enthusiasm with realism and to ensure, like politicians, that they practice the art of the possible. We try to avoid the temptation to chase new fashions and to desert what is basic and essential for what is spectacular.

It is our belief that applied research means research for human benefit. Therefore, in preparing project proposals, AFNS recommends that LDC scientists identify whom their research is intended to benefit. This has given rise to the criticism that AFNS expects too much of project scientists and that undue emphasis is given to who is to benefit rather than being satisfied with sound scientific achievement. Nevertheless, we continue to believe that scientific ingenuity and integrity need not be in conflict with serving humanity's needs. When so disposed, scientists can be both clever and useful.

In some countries, government research agencies appear more in line with rural development programs than are universities and though the Division has not consciously favoured government over academic institutions, it should be recorded that of the more than 200 active projects, 56% are carried out by government and parastatal, 32% by universities, and 12% by international and regional research institutions.

In general, research in faculties of agriculture and forestry appear more directly related to rural need and development than in some other disciplines, and many projects demonstrate direct cooperation between university scientists and rural communities.

Where legislation and motivation inspire cooperation with rural communities, support for university research serves to combine technical achievement with human development. Projects in which graduate students pursue their theses on real-life rural problems enhance technical skills and orient minds toward public service. Countries such as India, in which academic research is integrated with national agricultural programs, offer an example worthy of study by other nations.

A simplistic observation might suggest that AFNS-financed projects fall into two categories: technology development and systems research. Yet each is dependent upon the other; biological technologies are influenced by and must be in harmony with the physical, social, and economic environments and systems in which they are to function. It is, therefore, the Division's philosophy that all technologies must be developed, or at least modified and adapted, where they are to be applied.

IDRC, in common with other donors, must consciously avoid imposing its sense of technological priorities upon those it supports. The spectacular is more tantalizing than the mundane; slow uneven progress, inherent in research on traditional farming systems, makes less exciting reading in annual reports than the description of a miracle plant or a revolutionary technology. Yet many, particularly the poor, are reluctant to grow or to eat what is unfamiliar; the developing countries are littered with devices and transferred technologies that for one reason or another proved inappropriate or unacceptable. Recently a wise Egyptian wrote, in reference to aid programs: "As in all sales, the seller is more interested in selling what he has than what the buyer needs . . . . There is no sense in hunting flies with a gun because our trading partners are anxious to sell us the ammunition . . . . The solar technology suitable for an industrialized country may not be the best for a developing one."

Many ask why AFNS does not invest more in energy research. It can be argued that all AFNS funds are in support of energy research because, as recognized by Lavoisier, all biological change results from the chemical conversion of one form of energy to another. It is AFNS' philosophy that energy must be studied in relation to its application; in common with technology, it must be appropriate to its environment and use. Gasoline provides the motive energy for the world's privileged people. Wood is the energy source by which most rural poor cook their food and heat their homes, and their motive power is derived mainly from their own labour and farm animals.

The AFNS program, therefore, concentrates upon social forestry to provide trees for fuel and for feed and fodder for animals on small farms. In some projects efficient use is made of solar energy and combustible rural waste products in food dehydration and crop drying. In rural communities where mechanization is necessary to supplement human labour, research to provide economical renewable energy sources to drive agricultural machines will continue to be encouraged and a few projects are exploring the fermentation of various organic materials into combustible gases. It seems likely that the study on rural energy demand in Egypt will give rise to proposals to develop renewable energy from local resources. In some countries, the large-scale conversion of biomass such as aquatic weeds to combustible energy presents logistic and technical difficulties. Aquatic weeds usually contain less than 10% solids. If the weeds grow far away from the rural communities, more energy may be expended in removing excess water and in transporting the biomass to where the fuel is needed than is generated as combustible gas. Energy research, as much as any other, needs the attention of competent practical economists.

Given the wide diversity of need among countries, communities, and projects, within program limitations it has been necessary to maintain flexibility in style and organization. Though sympathetic consideration is accorded every project request, by giving priority to staple food crops, social forestry, aquaculture, animals on small farms, and rural postproduction systems, the AFNS staff has been better able to offer specialized advice and to build networks among projects in different countries that share a common interest. Though specific emphases have changed and will continue to change, the Division cannot and should not try to be all things to all people.

The preponderance of projects in countries where scientific research is well established has been noted. Projects in scientifically less developed countries demand greater staff time in their preparation and throughout their active life. Unless expatriates are introduced, a measure generally contrary to IDRC's style, the fulfillment of even modest objectives calls for a good deal of sympathetic advice and encouragement. Nevertheless, it is the least developed that stand in greatest need; they have the furthest to go in pursuit of technical, economic, and productive self-sufficiency. In the future, in cooperation with other donors possessing greater resources, it may be possible to devote more effort to research institution building in the scientifically least developed countries where the need for agricultural development is so evident and urgent.

Increased agricultural production comes from raising more on the same land or moving to land previously uncultivated. Because the latter usually entails the cultivation of less fertile or marginal land and the former the introduction of unfamiliar crop types and cultivation practices, both invite the farmer to increase his risk, because the novel invariably involves higher risk than the familiar. Subsistence farmers, like most poor people, prefer to avoid risk rather than to gamble on the uncertain promise of untested innovation.

In the AFNS systems methodology the farmer tests and judges the new against the old. Applied research carried out under the farmers' conditions tends to minimize eventual risk. By first understanding established farming systems in their entirety, innovations that promise greater returns to labour and land can be evaluated and the potential hazards weighed against potential benefits.

Project Formulation

Every project starts with a Project Summary, which describes first why the project is necessary, whom it seeks to benefit, who is to carry it out, its relation to other activities, and whatever else seems relevant to the general purpose. Next comes a statement of the objectives; then the methodology, which describes the systems, methods, and techniques by which the objectives will be pursued, with a proposed timetable of activities. The final section is the budget and budget notes, which prescribe, by line items, the amount requested for different capital and operating functions; which ones are to be administered by the recipient, which by the Centre; and what is to be the contribution in cash and kind of the recipient.

Institutional capacity and professional capability vary extensively among the 65 countries in which the projects have been undertaken and project formulation often resolves into deciding what is possible out of all that appears desirable. The needs and expectations from agricultural research and development are as diverse and comprehensive in the least developed as in the more developed nations. They all need to be fed and housed from their own resources. Thus, the choice of research priorities is more difficult among the least privileged, as is the danger of attempting so much that little is achieved. To guard against the latter, it is the Division's policy in every proposal to request a timetable of activities, in detail for the first year, more flexible in later years. Such timetables enable all concerned to balance what is to be attempted against the human and material resources available. It is difficult to accept seriously a proposal in which those to be responsible cannot present a timetable for the first year of activity.

The Project Summary forms the basis of a subsequent agreement and is the definitive document by which future progress is evaluated. The amount of time and care taken in preparing a Project Summary are reflected in the manner in which the research proceeds. Although subsequent political upheavals, bureaucratic changes of heart, and other adversities cannot be anticipated during project formulation, the time spent in thoughtful perceptive project planning is rarely wasted.

Because of the disposition toward applied research for rural development, project scientists are encouraged to discuss and develop project plans with the appropriate rural community. If a new machine is anticipated, the research planners are advised to discuss tentative designs with local manufacturers to ensure that what emerges can be produced economically with available resources.

It is recognized that reliable research cannot be accomplished without adequate equipment and it is IDRC's policy to provide such machines and instruments as are necessary to the project. Equipment surplus to need may prove more of a liability than an asset. It has to be installed, housed, and maintained, all of which absorb the limited resources of money and time. It is always necessary to make sure that equipment and machinery specified in the Project Summary can be operated and maintained at its intended place of use. Mainline power supply and voltage constancy are notably unreliable. Consequently, it is not an extravagance to provide voltage regulators or driving mechanisms independent of mainline supply. In almost all projects adequate spares of the more vulnerable components need to be supplied.

Access to professional economic advice is not always available. It was, therefore, necessary to create the Agricultural Economics Group within AFNS, a small team that assists in defining appropriate economic analysis as a component of the technical research projects. Advice is provided on basic procedures and technologies that can be usefully applied by scientists trained in other disciplines.

Perfect coordination of activities against a prescribed schedule is always difficult, particularly in countries where the political and economic environment is fragile and uncertain, and the Division's most consistent error has been to underestimate the time needed to accomplish all that the Project Summary proposed. Project time extensions are, therefore, not uncommon. Through a more critical comparison in many projects of what was achieved against the forecast timetable, it is hoped that more realistic scheduling will be realized in the future.

In general, project formulation boils down to exercising the art of the possible: distilling out of all that appears necessary, that which can be attempted with the resources available.

Technical Support and Evaluation

The main purpose of AFNS staff visits to projects is to provide encouragement and advice, particularly to young and inexperienced research workers, in scientific management, methods, and techniques. At the same time, it is necessary to monitor how well each project is progressing according to the prescribed plan and if it is not, to determine why. Consequently, the staff has been accused of running with the hares and chasing with the hounds. AFNS staff prefer to act as sympathetic cooperative partners not as policemen. In projects that fall short of expected achievement, the cause often results from inadequate political support or bureaucratic ineptitude. Whatever the apparent cause of shortcomings, it is generally preferable that they be discussed privately with those responsible, rather than being openly promulgated in a manner that might cause embarrassment.

"How do you evaluate projects?" is a question asked by many visitors to IDRC. Though what might be described as "in depth" evaluations have been made of a number of completed projects, evaluation is a continuing process from the time the project proposal is presented for consideration by AFNS, IDRC's Project Committee, and finally by the Board of Governors. Every visit made to a project includes elements of evaluation: how well is the research progressing when compared with the project plan and timetable?

Evaluation is a concept to be approached with sensitivity and a procedure to be applied with caution. Our purpose is to encourage, not to coerce; to discuss difficulties, not to dictate solutions. Harsh criticism, particularly if written into an evaluation report, can prove devastating to young scientists' self-confidence. Therefore, it is preferable to discuss difficulties and apparent weaknesses rather than to set them in type.

Equally, sympathetic judgment is needed to decide the best course of action in projects that appear to run less smoothly than was anticipated. It is not easy to decide how much help and guidance should be given before AFNS begins to dominate and direct the research.

It is proposed in the future to return to several projects 2 or 3 years after IDRC support has ended, to discover what subsequently transpired and what benefits from the research were realized.

Many visitors also ask which projects have succeeded and which have failed. It is rare indeed for any project to fail absolutely and to realize no part of the objectives prescribed. What is regarded as absolute success is very much dependent upon subjective judgment and interpretation. In most projects it is impossible to write objectives and to measure achievement with a quantitative precision that permits exact comparison of one with the other. By definition, applied research is research for human benefit, and it may take some time after the project is completed before the benefit is widely realized. Furthermore, success must be assessed relative to the human and material resources available. What is commendable from a relatively inexperienced research group might be wholly unsatisfactory from a well-established one. The essential basis of judgment is "Have they done the best they can with the resources available?" It will be our failure if we lose our ability to provide frequent, adequate, sensitive, and sympathetic assistance and guidance, particularly to those many scientists who work in intellectual isolation.

Each research project needs support long enough to test its value and demonstrate its worth to national governments and larger development agencies. To avoid committing excessive sums of money to projects that are essentially of long duration, most projects are financed in several phases, each phase lasting on average between 2 and 3 years. Satisfactory progress during the first phase normally ensures continuation through a second and sometimes a third phase. By IDRC assuming the major risk during the first phase, and continuing to share the risk in subsequent phases, a greater interest has been inspired among several of the governments responsible. In a number of cases recipient government contributions have increased during a second phase and scientists supported by IDRC in the early stages have been absorbed into succeeding government development plans.

Relations Among Projects and Recipients

Cooperation and frequent exchange of knowledge among projects that share a common interest and similar objectives is always encouraged. Various multiproject cooperatives have come to be called "networks." Some networks were created by scientists brought together from several countries who defined a large regional problem and agreed to share its constituent research components among their respective institutions. Other networks grew one project at a time, several being built around a specific commodity such as cassava or a methodology such as in cropping systems projects.

The comprehensive and complex cassava network began at CIAT and eventually embraced cassava-producing countries in Asia, Africa, and Latin America. It included studies of troublesome pests and diseases in the countries where they occur; improved methods of conservation, transformation, and utilization of cassava as food and feed; and was complemented by more fundamental research in Canada.

A network that draws upon the scientific resources of an international or regional research centre comes close to the ideal. Where no relevant international or regional centre exists, network advisers are needed to give scientific advice, to stimulate cooperation, intercommunication, and the regular flow of information and materials among constituent projects.

Cooperation among projects that share common interests offers many advantages. The planned and organized integration of scientific effort among developing countries makes for more impressive progress than the sum of individual isolated activities. Cooperative networks enable the scientifically strong to help partners with more limited resources. Thus, Bangladesh benefits from oilseeds and minor millets research carried out in India. Several Asian countries send young scientists to the University of the Philippines at Los Baños for training in cropping systems research. Research priorities for the regional aquaculture program were defined at a meeting of Asian biologists. The postharvest rice program in Asia and the social forestry cooperative program are guided by regular annual meetings of the countries involved.

Cooperation among Donors

Though rationalization and cooperation among donor agencies is not widely evident, a few notable exceptions are evident. One of the best examples of voluntary, informal cooperation among donors relatively unhindered by political constraint, is found in the CGIAR, a consortium of donors and developing countries who, collectively, support the IARCs. The flexibility of the CGIAR accommodates multilateral and bilateral government agencies, private foundations and various special funds. In addition to its collective support of the IARCs, the CGIAR provides a forum where new agricultural research initiatives can be set in motion. The cooperative post-production program in Southeast Asia, in which IDRC cooperates with several other donors, originated in informal meetings at the CGIAR. Through contacts within the CGIAR it is hoped that long-term, coordinated, multidonor support for agroforestry and aquaculture research can be stimulated.

The degree of freedom and flexibility granted by its Board of Governors permits IDRC to cooperate relatively easily with other donors and AFNS has acted as Executing Agency, on behalf of other donors, in several new cooperative research undertakings.

The Division has been less successful in stimulating cooperation with international and regional development banks and other agencies with large funds to invest in the exploitation of research results. Where investment has been attracted it has happened more in ad hoc fashion than as a result of deliberate planning. This is a weakness to which the AEG will in future devote more attention.

Only a small fraction of the world's scientific resources are drawn upon by the many development agencies. Outside these agencies there resides a very large and relatively untapped body of scientific expertise that needs to be organized and directed to serve the technical, economic, and social needs of developing countries. To draw upon this unharnessed reservoir of scientific experience, the International Council of Scientific Unions (ICSU) has created an International Commission on the Application of Science to Agriculture, Forestry and Aquaculture (CASAFA). Its purpose is to bring to the attention of national academies of science and international scientific unions embracing many scientific disciplines, urgent problems that could be solved given adequate research effort. Several countries have formed national committees to cooperate with CASAFA. AFNS accepted an invitation to provide the Chairman for CASAFA.

Cooperation with Canadians

At the Division's invitation an informal group of Canadian government and university scientists has met twice and published its response to CASAFA's first report and recommendations. The group indicated the fields of necessary inquiry in which Canada can offer competence. The valuable return on IDRC's modest investment in research in Canada is described earlier in this text. More Canadians than the Division's financial resources can accommodate would like to become partners in development. Although many cannot consider long-term commitments in overseas countries, it is hoped that the Cooperative Programs Unit (established at the end of 1980 to give developing countries greater access to the research and development capacity of Canadian institutions) will make it possible for more Canadian scientists to carry out research complementary to projects sustained by the Division in IARCs and developing countries.

In addition to complementary fundamental research, Canadian institutions can offer valuable training, particularly when formal lectures are given in Canada and the trainees are permitted to carry out the thesis research in their own countries.

Canadian scientists have much to teach but also much to learn from developing countries. With appropriate will and effort, Canadian scientific expertise could be more helpful to developing countries in the future.

Expatriate Advisers

Because its support is for research devised, defined, directed, and executed by scientists of and in developing countries, IDRC supplies comparatively few expatriates to act as resident scientific advisers. Best suited to IDRC's style are resident network advisers who provide an essential service already described. Because it is contrary to policy to supply project managers, the Division does not have to contend with the two-cooks-in-one kitchen syndrome that arises when expatriate managers are teamed with local "counterparts."

Occasionally, upon request, expatriate advisers have been attached to specific projects to fill a recognized gap in a research team until a local scientist could be trained to fill it. The preference has been for young graduates who, for the most part, adapt comparatively quickly to unfamiliar cultures and environments. Particularly commendable is the dedicated service given by several CUSO volunteers. The AFNS program owes much to CUSO for the friendly cooperation of CUSO management, the inproject participation of several CUSO volunteers, and for the sizable proportion of AFNS staff who were former CUSO volunteers.

Advisers who are not attached to an international or regional centre, or who are placed in countries where there is no IDRC Regional Office, suffer many disadvantages when compared with advisers supplied by bilateral agencies that have embassies or UN agencies that maintain country resident representatives. IDRC advisers fend for themselves in finding and furnishing accommodation and in dealing with local bureaucracies. In addition, many make professional sacrifices. Their main satisfaction must come from helping others, because the customary scientific recognition gained from personal presentation and publication of research results is frequently denied. Furthermore, service in developing countries does not appear to be considered particularly desirable to professional career advancement. Several young scientists who have worked as advisers overseas encountered difficulties in finding employment commensurate with their qualifications on returning to their homeland.

Although for administrative convenience, network advisers are best located at IDRC's Regional Offices, they gain more scientific stimulation when attached to an IARC or a developing country research institution. Understandably, some countries are reluctant to admit expatriate network advisers whose presence they have not requested and whose purpose is to serve not just their own but other countries in the network.

Though resident project advisers have been few, a greater number of specialist consultants have been employed on short-term assignments to advise on specific research methods and technologies. Specialist consultants offer a number of advantages over resident expatriates. One can choose from a larger professional reservoir in that little disruption to professional or family life ensues from relatively short advisory visits to projects. IDRC's international consultant roster includes mature, experienced people from universities, government, the private sector, and retired senior scientists among whom is numbered a former director general of an IARC. Consultants who are scientists of international reputation are generally held in high esteem, and their advice is usually taken seriously by those who formulate and administer policy. AFNS consultants are employed to advise on specific, clearly defined matters; rarely are they invited to define or formulate total projects. Negotiations concerning project definition and formulation are essentially the responsibility of IDRC staff.

Government Policy

Prime Minister Trudeau once stated that the role of politics is more delicate regarding technology than it is regarding population or capital. Because most AFNS funds are channeled to government or academic research institutions, project progress is highly dependent upon a favourable political will that inspires, not impedes; a political system in which applied research can survive and flourish; consistent political interest to ensure that research results are adequately tested, adapted, and applied for rural benefit; and bureaucratic behaviour that motivates and facilitates the integration of applied research with rural development.

The outcome of some projects has led directly to changes in government agricultural policy and in a few instances to a restructuring of national agricultural research and development organizations. Though the impediments imposed by political policy (or lack of policy) and by bureaucratic ineptitude can rarely be eliminated by biological research, successful scientific research can of itself bring about change in political attitude. Results from projects supported in Asia, Africa, and Latin America each in a different way, inspired governments to change their existing agricultural policies.

It is sad but true in several countries, that IDRC appears to place more trust and confidence in local scientists than do their own governments. The lip service paid to agricultural research and development in international fora is not always paralleled in overt political action. Until governments demonstrably recognize that agricultural research is fundamental to rural development, the rural poor will continue to be with us.

Research Management

In 1974 the following appeared in the Report of the (Canadian) Senate Special Committee on Science Policy: "When a scientist or technologist has been engaged in R&D activities for many years, he has usually become highly specialized in certain specific areas as a supplier of research services. He may be well qualified to generate new ideas in his own discipline or willing to respond enthusiastically to the challenges of an R&D program. A Research Manager, however, must have other skills, or develop them. He must appraise programs and to do so, he must be able to apply proper evaluative techniques. In other words, he must be primarily a good manager rather than a researcher."

In essence, IDRC invests in people and seeks to support competent dedicated project leaders. Efficient research management and direction is critical to every project in IDRC's program. IDRC's policy of support for projects planned, directed, and executed by scientists in LDCs places a heavier burden upon project leaders than is imposed by donors who provide project managers, administrative services, and deliver all the necessary equipment and capital resources.

In most countries, a serious shortage of scientists trained and experienced in research management is evident. In the Division's future program more attention needs to be given to training scientists in research management; in the planning and organization of research institutions, programs, and projects; in resource allocation and budgetary, personnel, and systems management; in communications systems; and in maintenance of a reliable corporate memory.

Budgets too often are regarded as a stick with which to beat recalcitrants rather than as predetermined, but not inflexible, schedules of intended disbursements against which to judge the rate of progress. The management of applied research does not lie simply in devising scientific techniques and methodologies but in a broad understanding of the ultimate purpose of the research; by whom and in what manner and system it is to be integrated and used. Effective applied research bears some analogy to market research which asks: For whom is the product intended? Is it appropriate and relevant to what is wanted? Are those for whom it is intended willing and able to accept, use, and benefit from the products the research will provide?

It was the Division's original intention that project leaders would purchase all equipment and materials; the ability to specify, order, and manage material resources being an essential component of research management. In spite of providing bank accounts in convertible currencies, the assumption that all recipients could select, purchase, and import the equipment necessary proved often impractical and unworkable. Some governments forbade access by their scientists to the convertible funds IDRC provided for purchase of equipment; unwieldy systems of competitive bidding, multiple agency approvals, and importation clearance regulations often led to unconscionable delays. Even when assured of convertible currency, some equipment suppliers were reluctant to deal directly with project directors. IDRC has, therefore, been obliged to purchase and deliver the necessary equipment to more projects than it would wish. The need is evident for a number of developing countries to revise their administrative procedures and regulations to reduce the delays in project implementation; to train then trust senior scientists to manage in the fullest sense, the projects for which they are held responsible.

Essential to research management is an understanding of systems methods. Several AFNS publications have emphasized the hazards of developing technologies without first comprehending the system in which they are to function. A systems approach is holistic rather than fragmented or piecemeal. It analyzes the system as a whole and seeks first to identify the restrictions and constraints to proposed beneficial changes within the system. Systems research calls more for an analytic and diagnostic than an intuitive intellect. A course of training in systems methodology seems desirable for all agricultural scientists. For those who aspire to research management it is indispensable.

Program and Project Cost

The average project cost over the decade is shown by disciplinary sector in Appendix 1 (Table 2). The proportions of the budget taken up by different program sectors and components are also tabulated in Appendix 1 (Table 3). Among program sectors, most noticeable is the increasing proportion of postproduction systems projects, from 16% in 1975-76 to 29% in 1979-80, suggesting that governments are gradually coming to realize the importance of postproduction systems — that there is little to be gained from higher crop yields and greater fish harvests if the increase is not delivered safely and economically to consumers.

Table 4 in Appendix 1 shows the relatively higher proportion of budgets devoted to training and capital equipment in Fisheries projects, indicating that facilities for aquacultural research are less advanced than for agricultural research. Table 4 also illustrates the relatively high Centre Administered Portion, particularly in Africa, as compared with Canadian institutions, reflecting the difficulties in purchasing and financial administration referred to above.

What can be purchased with an IDRC research dollar varies greatly among countries, institutions, and types of project. The most costly projects are in IARCs and other organizations whose scientists receive international salaries and allowances. Noticeable differences in salary scales and local costs are apparent among different developing countries, even among countries in the same geographical region.

Because most of the AFNS operating budget is disbursed in developing countries, inflation and the de facto devaluation of the Canadian dollar against many other currencies has caused a serious decline in effective purchasing power. The average cost per project has remained reasonably constant, in part because of the increased proportion of postproduction systems projects, the average cost of a postproduction project being about half that of most others. In general, food science, technology, nutrition, and small engineering projects require less investment in capital, research materials, and manpower than do farming systems, crop, livestock, or forestry improvement projects.

It seems inevitable that, for IDRC, the cost of operating at any constant level of activity will increase with time. Without a greater supply of financial and human resources, AFNS will continue to receive more requests for support than it can accept.

AFNS Staff

The Division started with a small group of highly qualified specialists who brought many years of collective experience from working in developing countries. These were the associate directors, the architects of the program. Gradually, specialist program officers were added, together with an Agricultural Economics Group and a few younger members of a more general scientific background. Most of the younger members came following service with CUSO and similar volunteer organizations.

It is the intention that well-qualified specialists significantly outnumber generalists, though the latter are essential, particularly in regional offices, to cope with local technical-administrative problems. It is also planned to maintain a much higher proportion of professional staff outside than inside the Ottawa headquarters. Those living in developing regions remain more aware of changes in the surrounding countries; those working from universities and research institutions are physically and intellectually closer to their scientific discipline. Little agricultural research is evident at IDRC headquarters.

Constant travel, which averaged 128 days per professional scientist per year, places a wearisome burden upon the staff. Long absence is disruptive of family life and the program owes much to the patience and tolerance of spouses and children. The burden of travel has been exacerbated as airlines reduce services to save money, and airports have become overcrowded from the monstrous wide-bodied jets. Travel to and from projects is more debilitating than scientific and administrative responsibilities. After several years without study leave and intellectual restoration, it is difficult to maintain the high level of scientific competence and flexible imaginative intellect necessary to anticipate and respond to the needs of the developing countries.

IDRC's style calls for a high degree of professional staff competence. There is little point in sending to projects staff advisers who are less well informed than those they seek to advise. The AFNS Division is fortunate that well-qualified international scientists chose to join and stay so long with the Centre. Because most corporate memories, however ingeniously recorded and documented, are of dubious reliability, one of the greatest assets to the AFNS program has been the remarkable stability of service to IDRC by its senior professional staff. In each AFNS program group there is at least one staff member who has been associated with the Division for between 5 and 9 years, a continuity that has provided a reliable in-house corporate memory and a continuing association and close relation with scientists in recipient projects. This constancy of service has contributed notably to a continuous decade of learning.

Cha 4

The Future

According to FAO data, food production grew more slowly than population in 58 out of 106 developing countries during the period 1970-1978. Clearly there is still much to be done and relatively little time in which to do it.

Self-sufficiency in food production requires self-sufficiency in a professional human resource able to originate, adapt, and apply technologies congenial to prevailing physical, social, and economic environments. Every nation needs its own agricultural research and development organization staffed by its own trained people.

IDRC's concentration upon indigenous scientific competence remains relatively unique among bilateral donors and is complementary to assistance programs that devote more to building the fabric of research institutions. Scientific self-sufficiency in a nation requires that its scientists be allowed to make their own decisions, to manage the resources available to them, and to learn by their own mistakes. To foster this end remains IDRC's primary purpose.

Research capacity, institutionally and professionally, varies greatly among the LDCs and how to strike a balance between support for the most scientifically advanced, those best able to work within IDRC's style, and those with least human resources, but whose countries are in greatest need, is not easy of resolution. As the demand for project support grows faster than the Division's available resources, difficult choices must be made in the balance between the most and the least scientifically developed countries; between support for relatively simple technological improvement versus more scientifically demanding but generally more productive agricultural systems research.

There seems to be little good reason to change dramatically existing priorities: projects dedicated to increasing food and fuel, to improving the quality of the diet, to raising disposable income; and the general well-being of rural people. Emphasis will continue to be given to crops and to land and aquatic livestock production that promise an increase in rural food supply; to postproduction systems that assure minimum loss and safe and economic delivery from the time and place of harvest to the time and place of consumption; and to the development of tree species and other economic sources of fuel that, unlike gasohol (gasoline supplemented with ethanol derived from edible carbohydrates) do not deplete food supplies for the poor to feed the automobiles of the relatively rich.

Continuing existing commitments preclude any sudden or dramatic change in program content. Still more research investment is needed to increase and stabilize on-farm yields of traditional acceptable cereals, legumes, oilseeds, bananas, plantains, and other crops of subsistence for the rural poor. Wild or exotic plants that are botanically or nutritionally intriguing but in little consumer demand, are not considered a high priority for the immediate future.

The AFNS staff structure is being adjusted to respond to the growing interest in cropping and farming systems research. Though integrated projects as complex as the Egyptian desert reclamation research are not expected to proliferate the world over, the gradual addition of elements from animal sciences, forestry, fisheries, or postproduction systems to cropping systems appears possible in several countries.

A continuing investment in aquaculture and mariculture, in the cultivation of aquatic plants and animals for food and to generate increased income is foreseen. The need is urgent, but greater than IDRC can sustain alone, for more basic research into reproductive physiology, nutritional requirements, pathology, and adaptation to environment at all stages of growth among all cultivated fish species. This need is recognized by CASAFA as deserving of international scientific attention. Multidonor support is also needed for an international aquaculture research centre, preferably in Asia, comparable in scope and capability to one of the IARCs, to provide new knowledge, reliable methodologies, and training for fisheries biologists.

The success of the by-catch project in Guyana has aroused wide interest. The Division is exploring ways to stimulate orderly investment in development of by-catch utilization together with a worldwide examination of the opportunities for by-catch processing and distribution.

In animal research, the improvement of pastures, forage, and recycling of wastes and by-products in small farming systems is of particular and growing interest. The methodologies that are being refined in several projects in Latin America will probably be adapted to local conditions in projects in Asia and later on the African continent.

Forestry projects, inevitably of long duration, will concentrate upon rural social needs. More research is needed on species survival and growth rates under different adverse ecological conditions from which recommendations can be made to satisfy various rural needs and identify which systems of silviculture are most economic under various prevailing conditions. While more complex essays in agroforestry await the formulation and testing of reliable methodologies by ICRAF, the expanded introduction of trees into selected farming systems is envisaged.

The postproduction sector will continue to expand and diversify. Efficient postproduction systems for cereals, legumes, oilseeds, fruit, vegetables, and the products of land and aquatic animals are not readily evident throughout the Third World. More postproduction systems projects are foreseen in which postharvest research is integrated with food crop, animal, and fisheries production improvement. A sizable unexplored opportunity exists to improve the efficiency of existing rural agroindustries through operations research — the systematic analysis of existing industries to determine by what means their productivity, technical, and economic efficiency can be improved. In most small rural manufacturing establishments, the available capacity is fully absorbed. Consequently, any new products to be manufactured need either (a) capital to increase existing manufacturing and distribution facilities, (b) elimination of existing products and processes to make way for new, or (c) greater efficiency of manufacturing and resource allocation to provide opportunity and make space for new ventures. Systematic operations research makes (c) possible without resort to (a) or (b). It is also through operations research in small industries that economies in energy use can be realized.

Systems research methods appear unfamiliar to many trained in discrete scientific disciplines. It will be necessary, therefore, to provide opportunities for training in general and systems research management in both production and postproduction sectors.

One of IDRC's specific objects is "to encourage generally the coordination of international development research." This in part we interpret as the need to coordinate the AFNS program with the activities of other agencies. As has been described, IDRC's flexibility of style permits relatively easy cooperation with other development agencies. It is intended to explore, more energetically, possibilities for cooperation with agencies whose resources and modes of action could complement those of AFNS. Particularly in the least developed countries, support for indigenous research needs to be combined with the building of the necessary institutions for research and training, together with investment in rural infrastructures. Discussions with other agencies have started and will be actively pursued particularly with development banks.

In summary, it is unlikely that the AFNS future priorities will change dramatically. The need continues for scientists to cooperate with rural people (1) to enhance the income of smallholder farmers, artisanal fishermen, and operators of small industries; (2) to improve systems of conservation of renewable resources upon which food production, distribution, and utilization depend; (3) to comprehend the concomitant components of cost, risk, and return that influence the acceptance of technological and systematic innovation; and (4) to encourage cooperation among countries and communities that share common interests and opportunities.

The next 10 years may prove extremely critical to the well-being and indeed to the survival of many people in the LDCs. Over most of Africa, per capita food production is declining. Urban migration further aggravates the need for higher farm productivity and more efficient postproduction systems of conservation and distribution.

Agriculture provides the sole sustenance and livelihood for the majority of people in rural Africa, Asia, the Middle East, and Latin America and the Caribbean. The investment in international agricultural research and development is minuscule compared with the money spent to improve automobiles and weapons of war. Yet World Bank staff Working Papers Nos. 360 and 361 give evidence of a substantial economic return to investment in agriculuture. Nevertheless, the benefits from agricultural research are slow to appear; agricultural development being a process of evolution assisted by human ingenuity and innovation. The "Green Revolution" is a misnomer coined by journalists not scientists.

This state of things calls for more not less encouragement to agricultural research, because only through agricultural research, development, and investment will the LDCs be freed from dependence upon food imports and be assured of higher rural employment and family income.

Every nation needs its cadre of research managers and scientists, people whose knowledge and experience command respect and are sought by those who shape political policy and make choices among many technological alternatives. Because agriculture dominates the economies and indeed determines the survival of so many developing nations, in no other sector is the ability to choose wisely more necessary.

We are not the helpless tools of impersonal forces. We can take a hand in shaping the future of things. Those who light a little candle in the darkness will help to make the whole sky aflame.

— *Radhakrishnan*

Epilogue

Epilogue

The report of the Brandt Commission informs us that "Eight hundred millions are estimated to be destitute in the Third World today . . . most of them by definition cannot afford an adequate diet . . . millions will either die from lack of food or have their physical development impaired . . . self-sufficiency in food must be the aim of the world's major regions."

From the statistics available from FAO, the International Food Policy Research Institute (IFPRI), and other reliable sources, world cereal production between 1976-77 and 1980-81 is estimated to have increased by about 5% while world population has increased by 9.5%. During the same period, cereal imports into all developing countries increased by 66%; into low-income LDCs by 143% of which the proportion provided from food aid has decreased by about 31%.

Over the same 4-year span, cereal stocks as a proportion of total world cereal consumption fell by 22%, the projected world cereal stock for 1981 being probably less than the stock in 1974 when the World Food Congress convened to draw attention to an impending universal food crisis.

The developing country deficit for staple foods, allowing only 10% over minimum food energy requirements, may well reach 1.85×10^8 t by 1990. The deficit could be greater if the USSR and the People's Republic of China significantly increase their imports of cereals, if serious drought or other climatic catastrophe occurs, if the developed countries of North America and Europe continue to destroy large areas of their best agricultural land by urbanization, and if myopic government and the Neronic wealthy continue to fiddle with their carburetors while millions seek food and to exercise greater concern for the appetites of their automobiles than for the hunger of the poor.

If the developing countries are to approach any degree of self-sufficiency they will need greater encouragement and support for agricultural research and development in the immediate future than in the past. An indigenous competence and capacity to carry out research to increase food available for all people is essential in almost every developing country. It is hoped that the foregoing illustrates the highly beneficial return to investment in applied research: the substantial increase in on-farm crop yields from cropping systems research in Sri Lanka; more protein from fish polyculture in India and conservation of the shrimp trawler by-catch in Guyana; greater small farm animal production by improved pastures combined with feed from by-products in Central and South America; more fuelwood, feed for animals, and soil enrichment by combining trees with food crops and farm animals in West Africa, the Middle East and Southeast Asia; stimulation to cereal production from rural grain mills in Nigeria and Botswana; and the recovery of the desert in Egypt by systems that combine tree shelters with hardy animal pastures and food crops.

It is equally the responsibility of those who prescribe policy in both developed and developing countries to insure the world's future with an investment in agricultural research adequate to provide sufficient food for all mankind. For as B.R. Sen proclaimed more than 20 years ago at the start of the Freedom From Hunger Campaign: "One man's hunger is every man's hunger."

The ultimate objective of AFNS is to help bring developing nations a step closer to self-sufficiency in scientific agriculture. In 1763 the Marquise du Deffand wrote to d'Alembert: "La distance n'y fait rien: Il n'y a que le premier pas qui coûte." (The distance is nothing: only the first step is difficult.) The first decade of AFNS was but a first step over a small section of the long distance to be traveled before the ultimate objective is reached. It was a decade in which much was learned.

Appendix 1

Cumulative Tables

Table 1. Alphabetical listing of projects (with project number) to 31 January 1981.

72-0099	Aerial Forest Survey (Surinam)
76-0126	Afforestation (Bolivia)
75-0120	Afforestation (Jordan)
74-0020	Afforestation (Kenya)
76-0090	Afforestation (Peru) Phase I
80-0028	Afforestation (Peru) Phase II
77-0145	Afforestation (Tanzania)
76-0008	Agrisilviculture (Ghana)
76-0040	Agro-Forestry (Cameroon)
76-0130	Agro-Forestry (IITA) Phase I
80-0130	Agro-Forestry (IITA) Phase II
76-0007	Agro-Forestry (Nigeria)
74-0049	Alfa Grass (Tunisia)
78-0035	Amazonian Production Systems (Peru)
78-0133	Andean Crops (Peru)
73-0062	Animal Diseases (ILRAD)
73-0061	Animal Production (ILCA)
75-0090	Animal Production Systems (CATIE) Phase I
79-0047	Animal Production Systems (CATIE) Phase II
76-0001	Aquaculture (Brazil)
77-0035	Aquaculture (Egypt)
73-0065	Aquaculture (India)
76-0157	Aquaculture (Sudan)
75-0034	Aquaculture (Turkey)
73-0123	Bacterial Blight (Nigeria)
79-0026	Bamboo (Bangladesh)
80-0017	Bamboo (Indonesia)
79-0156	Banana Processing (UPEB)
78-0042	Barley Improvement (Turkey)
77-0083	Beans and Maize Improvement (Burundi)
72-0094	Bois de Savane (Mali) Phase I
74-0165	Bois de Savane (Mali) Phase II
72-0093	Bois de Villages (Niger) Phase I
80-0076	Bois de Villages (Niger) Phase II
73-0113	Bovine Diseases (Guelph) Phase I
75-0040	Bovine Diseases (Guelph) Phase II
77-0018	Brise-Vent (Tunisia)
77-0087	By-Products (Bali)
76-0074	By-Products (Egypt) Phase I
80-0006	By-Products (Egypt) Phase II
78-0031	By-Products (Kenya)
73-0139	By-Products (Mexico) Phase I
76-0064	By-Products (Mexico) Phase II
77-0088	By-Products (Sudan)
79-0049	By-Products (Syria)
72-0115	By-Products Utilization (Guatemala) Phase I
74-0143	By-Products Utilization (Guatemala) Phase II
79-0160	Cage Culture (Dominican Republic)
79-0018	Cage Culture (Sri Lanka)
73-0058	Carps (Malaysia) Phase I
77-0051	Carps (Malaysia) Phase II
74-0056	Cassava (India)
73-0146	Cassava (Brazil) (CIAT)
74-0153	Cassava (Ecuador)
73-0043	Cassava (Indonesia) Phase I
76-0060	Cassava (Indonesia) Phase II
74-0046	Cassava (Malaysia)
74-0047	Cassava (Nigeria) Phase I
77-0034	Cassava (Nigeria) Phase II
74-0002	Cassava (Peru) (CIAT)
76-0105	Cassava (Zanzibar)
75-0123	Cassava Cooperative Research (Asia)
74-0162	Cassava Cooperative Research (Latin America)
76-0038	Cassava Germ Plasm (Brazil)
78-0024	Cassava Germ Plasm (PRL) Phase I
79-0062	Cassava Germ Plasm (PRL) Phase II

(continued)

76-0160	Cassava Mealybug (CIBC) Phase I
80-0116	Cassava Mealybug (CIBC) Phase II
75-0094	Cassava Microbiology (Guelph) Phase I
76-0120	Cassava Microbiology (Guelph) Phase II
78-0130	Cassava Microbiology (Guelph) Phase III
73-0136	Cassava Mites (Trinidad) (CIBC) Phase I
75-0026	Cassava Mites (Trinidad) (CIBC) Phase II
79-0065	Cassava Mites (Trinidad) (CIBC) Phase III
74-0060	Cassava Nutrition (Thailand) Phase I
78-0026	Cassava Nutrition (Thailand) Phase II
74-0016	Cassava Processing (Thailand) Phase I
76-0037	Cassava Processing (Thailand) Phase II
75-0048	Casuarina (Egypt) Phase I
80-0027	Casuarina (Egypt) Phase II
77-0004	Cereal Processing (Senegal)
78-0091	Chame Culture (Ecuador)
77-0106	Charcoal Stoves (Tanzania)
71-0081	CIAT Outreach (Latin America) Phase I
72-0125	CIAT Outreach (Latin America) Phase II
76-0134	Cold-Tolerant Sorghum (ICRISAT) Phase I
78-0092	Cold-Tolerant Sorghum (ICRISAT) Phase II
71-0020	Composite Flours (Manitoba) Phase I
74-0040	Composite Flours (Manitoba) Phase II
79-0097	Conch Optimization (Belize)
76-0003	Cowpea Processing (Ghana)
76-0077	Cowpea Processing (Nigeria)
77-0159	Cowpea Storage (Upper Volta)
79-0007	Cowpea Storage (Sierra Leone)
78-0027	Crop Drying (Guatemala)
76-0127	Crop Intensification (Syria) Phase I
80-0121	Crop Intensification (Syria) Phase II
75-0122	Crop Rotations (Kenya)
74-0019	Cropping Systems (Bangladesh) Phase I
78-0064	Cropping Systems (Bangladesh) Phase II
77-0086	Cropping Systems (Honduras) Phase I
79-0145	Cropping Systems (Honduras) Phase II
74-0157	Cropping Systems (Indonesia) Phase I
77-0010	Cropping Systems (Indonesia) Phase II
72-0086	Cropping Systems (ICRISAT)
74-0053	Cropping Systems (IRRI) Phase I
76-0087	Cropping Systems (IRRI) Phase II
77-0086	Cropping Systems (Nicaragua) (CATIE) Phase I
80-0114	Cropping Systems (Nicaragua) Phase II
75-0107	Cropping Systems (Sri Lanka) Phase I
78-0050	Cropping Systems (Sri Lanka) Phase II
76-0083	Cropping Systems (Thailand) Phase I
78-0049	Cropping Systems (Thailand) Phase II
77-0050	Cropping Systems (Togo)
77-0074	Cropping Systems (WINBAN) Phase I
80-0120	Cropping Systems (WINBAN) Phase II
78-0095	Cropping Systems Outreach (IRRI)
77-0046	Dairy/Beef Feeding Systems (Panama)
79-0120	Desert Farming Systems (Egypt)
72-0101	Drought Resistance (Laval University) Phase I
74-0107	Drought Resistance (Laval University) Phase II
78-0046	Drought Resistance Crops (CATIE)
73-0129	Drought Tolerance (Saskatchewan) Phase I
79-0064	Drought Tolerance (Saskatchewan) Phase II
74-0138	Dryland Agriculture (ICARDA)
78-0056	Faba Beans (Egypt) Phase I
80-0125	Faba Beans (Egypt) Phase II
80-0009	Faba Beans Diseases (University of Manitoba)
77-0058	Farming Systems (Mali)
79-0173	Farming Systems (Tanzania)

(continued)

(Table 1 continued)

76-0152	Fertilizer Development (IFDC) Phase I
78-0088	Fertilizer Development (IFDC) Phase II
80-0003	Fertilizer Development (IFDC) Phase III
77-0017	Fertilizer Efficiency (Egypt)
76-0045	Fish Culture (Singapore) Phase I
80-0057	Fish Culture (Singapore) Phase II
76-0061	Fish Culture (University of Victoria)
73-0147	Fish Parasites (Indonesia)
79-0085	Fish Parasites (Malaysia)
79-0069	Fish Parasites (Philippines)
75-0103	Fish Pituitary Extracts (B.C. Research)
76-0086	Fish Processing (India)
79-0111	Fish Processing (Indonesia)
79-0110	Fish Processing (Mali)
80-0066	Fish Processing (Peru)
74-0079	Fish Processing (Philippines) Phase I
78-0110	Fish Processing (Philippines) Phase II
80-0137	Fish Processing (Philippines) Phase III
75-0036	Fish Processing (Thailand)
73-0035	Fish Products (Guyana) Phase I
78-0034	Fish Products (Guyana) Phase II
79-0091	Flood Fallow Aquaculture (Guyana)
73-0042	Food from Grains (Lebanon)
76-0132	Food Grain Improvement (Sri Lanka) Phase I
80-0082	Food Grain Improvement (Sri Lanka) Phase II
79-0027	Food Legume Drought Tolerance (IITA/Niger)
77-0073	Food Legume Improvement (Egypt) Phase I
80-0118	Food Legume Improvement (Egypt) Phase II
77-0060	Food Legume Improvement (Sudan)
79-0172	Food Legume Insect Control (Upper Volta University)
74-0128	Food Legumes (IITA/Upper Volta) Phase I
79-0038	Food Legumes (IITA/Upper Volta) Phase II
78-0040	Food Legumes (Mali)
77-0009	Food Legumes (Niger)
74-0090	Food Legumes (Pakistan)
77-0102	Food Legumes (Sierra Leone)
78-0048	Food Legumes (Turkey)
73-0051	Food Legumes Processing (PRL) Phase I
74-0168	Food Legumes Processing (PRL) Phase II
73-0032	Food Legumes Utilization (Saskatchewan)
78-0078	Food Processing (Thailand)
80-0138	Food Processing Equipment (Thailand)
76-0020	Forestry Cooperative Research (Africa)
74-0009	Forestry Technology (Andean Pact) Phase I
78-0073	Forestry Technology (Andean Pact) Phase II
77-0082	Fuelwood Plantations (Malawi)
78-0104	Gomme Arabique et Boisements Pastoraux (Senegal) Phase II
73-0069	Gonadotropin (UBC)
74-0159	Grain Legume Quality (INCAP)
78-0043	Grain Legumes (Algeria) Phase II
77-0048	Grain Legumes (Bangladesh) Phase I
79-0134	Grain Legumes (Bangladesh) Phase II
71-0078	Grain Legumes (Caribbean) Phase I
74-0160	Grain Legumes (Caribbean) Phase II
76-0191	Grain Legumes (Caribbean) Phase III
77-0101	Grain Legumes (ICARDA) Phase I
79-0144	Grain Legumes (ICARDA) Phase II
73-0013	Grain Legumes (ICRISAT) Phase I
74-0161	Grain Legumes (ICRISAT) Phase II
78-0023	Grain Milling (Botswana)
71-0019	Grain Milling Systems (Guelph)
72-0003	Grain Milling and Utilization (Nigeria) Phase I
73-0128	Grain Milling and Utilization (Nigeria) Phase II
73-0009	Grain Storage (Ghana)
75-0021	Grain Storage (Swaziland)
79-0017	Groundnut Improvement (Mozambique)
80-0128	Groundnut Shellers (Thailand)
72-0096	Gum Arabic (Senegal)
80-0131	Highland Oil Crops Improvement (Ethiopia)

(continued)

75-0135	Home Processed Legumes (Thailand) Phase I
79-0107	Home Processed Legumes (Thailand) Phase II
75-0045	Household Grain Processing (India)
79-0099	Inland Fisheries (Indonesia)
75-0035	Inland Fisheries (Sarawak)
76-0103	Insect Resistance (ICIPE)
78-0112	Intercropping (Swaziland)
72-0025	Intercropping (Tanzania) Phase I
74-0087	Intercropping (Tanzania) Phase II
76-0136	International Council for Research in Agroforestry (ICRAF) Phase I
78-0001	International Council for Research in Agroforestry (ICRAF) Phase II
79-0043	International Council for Research in Agroforestry (ICRAF) Phase III
80-0032	International Council for Research in Agroforestry (ICRAF) Phase IV
80-0107	Invertebrates/Seaweeds (Chile)
73-0115	Irrigated Forest Plantations (Mali)
80-0012	Isabela Post-Harvest System (Philippines)
74-0029	Land Reclamation (Sudan)
79-0098	Langosta (Cuba)
80-0127	Legume Post-Harvest Technology (Bangladesh)
80-0062	Legume Processing (Bangladesh)
75-0136	Legume Processing (Indonesia) Phase I
80-0065	Legume Processing (Indonesia) Phase II
74-0080	Legume Processing (Philippines) Phase I
75-0075	Legume Processing (Philippines) Phase II
79-0101	Legumes Under Bananas (UPEB)
80-0021	Lentile and Chick-pea Improvement and Mechanization (Jordan)
76-0115	Leucaena (Philippines)
79-0137	Lignocellulolytic Fungi (Thailand)
78-0007	Lupino (Chile) Phase I
79-0108	Lupino (Chile) Phase II
77-0110	Mariculture (Colombia)
78-0090	Mariculture (Peru)
72-0112	Microbiological Enrichment (Malaysia)
74-0146	Milkfish (SEAFDEC) Phase I
78-0033	Milkfish (SEAFDEC) Phase II
79-0140	Millets (Bangladesh)
75-0072	Millets (India)
79-0082	Millet Threshers (Mali)
79-0021	Multiple Cropping (ICA) (Colombia)
71-0107	Multiple Cropping (IRRI) (Philippines) Phase I
73-0014	Multiple Cropping (IRRI) (Philippines) Phase II
75-0086	Multiple Cropping (UPLB)
72-0006	Multiple Cropping (Thailand)
77-0121	Mussel Culture (Singapore)
75-0114	Mustard (India)
78-0058	Native Swine (El Salvador)
78-0044	Oilseeds (Egypt)
79-0104	Oilseeds (Sri Lanka)
80-0102	Oilseeds (Sudan)
78-0051	Onion Drying (Niger)
75-0112	Orobanche Control (Egypt)
74-0119	Orobanche Control (ICARDA) Phase I
78-0041	Orobanche Control (ICARDA) Phase II
78-0085	Orobanche/Striga (Sussex)
71-0039	Osmotic Dehydration (CDA)
72-0004	Osmotic Dehydration (UWI)
76-0057	Oyster Culture (Jamaica)
74-0113	Oyster Culture (Sabah)
73-0008	Oyster Culture (Sierra Leone) Phase I
77-0146	Oyster Culture (Sierra Leone) Phase II
77-0021	Oyster Culture (Sudan)
78-0036	Pasture Development (Chile)
76-0131	Pasture Legumes (Belize) Phase I
79-0003	Pasture Legumes (Belize) Phase II
71-0006	Pasture Legumes (Caribbean) Phase I
75-0002	Pasture Legumes (Caribbean) Phase II
77-0007	Pasture Legumes (Caribbean) Phase III
77-0125	Pasture Legumes (ICARDA)
78-0032	Pasture Legumes (Panama)
75-0042	Pasture Management (Mexico) Phase I
78-0135	Pasture Management (Mexico) Phase II

(continued)

76-0144	Pasture Management (Peru) Phase I
80-0058	Pasture Management (Peru) Phase II
80-0011	Phosphate Fertilizers (IFDC/West Africa)
75-0131	Pigeon Peas (Kenya) Phase I
79-0063	Pigeon Peas (Kenya) Phase II
77-0008	Pine Beetle (Guatemala)
77-0042	Pisciculture (Rwanda)
79-0050	Pisciculture (Togo)
78-0039	Plantains (Cameroon)
73-0063	Plant by Plant Interactions (UBC)
75-0043	Polyphenols (Sheffield) Phase I
76-0102	Polyphenols (Sheffield) Phase II
76-0047	Post-Harvest Rice Systems (Korea) Phase I
78-0053	Post-Harvest Rice Systems (Korea) Phase II
80-0059	Post-Harvest Rice Systems (Korea) Phase III
74-0123	Post-Harvest Rice Technology (Indonesia) Phase I
78-0115	Post-Harvest Rice Technology (Indonesia) Phase II
74-0124	Post-Harvest Rice Technology (Phils-NGA-UPLB) Phase I
78-0114	Post-Harvest Rice Technology (Phils-NGA) Phase II
80-0014	Post-Harvest Rice Technology (Phils-UPLB) Phase II
74-0122	Post-Harvest Rice Technology (Singapore)
74-0120	Post-Harvest Rice Technology (Thailand)
75-0073	Post-Harvest Systems Research and Development (S.E.A.) Phase I
79-0139	Post-Harvest Systems Research and Development (S.E.A.) Phase II
73-0148	Post-Harvest Technology (India)
76-0026	Post-Harvest Technology (Senegal) Phase I
79-0066	Post-Harvest Technology (Senegal) Phase II
79-0124	Potato Dehydration (Peru)
74-0006	Potato Processing (CIP)
79-0024	Process Improvement (Singapore)
77-0147	Prosopis (Sudan)
79-0142	Pulses and Groundnuts (Tanzania)
76-0078	Quinoa (Bolivia) Phase I
80-0115	Quinoa (Bolivia) Phase II
78-0107	Quinoa Introduction (Colombia)
74-0003	Rangeland Reforestation (Senegal) Phase I
75-0032	Rapeseed (India)
71-0093	Research Priorities (Caribbean) Phase I
73-0145	Rice Research (WARDA) Phase I
78-0047	Rice Research (WARDA) Phase II
71-0079	Root Crops (Caribbean) Phase I
75-0001	Root Crops (Caribbean) Phase II
79-0040	Root Crops (Congo-Brazzaville)
74-0074	Root Crops (Philippines)
75-0041	Root Crops (Cameroon) Phase I
79-0087	Root Crops (Cameroon/IITA) Phase II
77-0049	Root Crops (Sri Lanka)
71-0005	Rural Development (Colombia) Phase I
72-0124	Rural Development (Colombia) Phase II
71-0106	Rural Fisheries (Ghana)
80-0072	Rural University (Colombia)
75-0097	Safflower (India)
80-0002	Sea Moss (St. Lucia)
74-0058	Semi-Arid Crops (Thailand)
75-0098	Sesame (India)
73-0143	Sesame (Israel)
79-0077	Shea Butter (Mali)
73-0114	Shelterbelts (Nigeria)
75-0028	Small Farm Equipment (Egypt) Phase I
79-0112	Small Farm Equipment (Egypt) Phase II
76-0091	Small Farm Equipment (Ghana) Phase I
80-0013	Small Farm Equipment (Ghana) Phase II
78-0103	Small Farm Modules (Colombia)
78-0113	Solar Crop Dryers (Sierra Leone)
76-0111	Solar Dehydration (Egypt) Phase I
80-0126	Solar Dehydration (Egypt) Phase II
77-0162	Solar Rice Drying (Thailand) Phase I
80-0060	Solar Rice Drying (Thailand) Phase II
72-0073	Sorghum-CIMMYT (Mexico) Phase I
74-0132	Sorghum-CIMMYT (Mexico) Phase II
72-0011	Sorghum (Senegal) Phase I

(continued)

(Table 1 concluded)

75-0088	Sorghum (Senegal) Phase II	78-0006	Striga (Upper Volta) (ICRISAT)
79-0094	Sorghum (Senegal) Phase III	76-0075	Summer Forage (Egypt)
80-0103	Sorghum (Somalia)	74-0144	Tilapia (Kenya)
72-0054	Sorghum/Finger Millet and Pigeon Peas (Uganda) Phase I	78-0065	Timber Grading (Mexico)
75-0110	Sorghum/Finger Millet and Pigeon Peas (Uganda) Phase II	79-0105	Triticale and Small Grains (Sri Lanka)
72-0095	Sorghum Improvement (Ethiopia) Phase I	73-0012	Triticale (Chile) Phase I
74-0023	Sorghum Improvement (Ethiopia) Phase II	76-0088	Triticale (Chile) Phase II
79-0016	Sorghum Improvement (Ethiopia) Phase III	79-0052	Triticale (Chile) Phase III
73-0041	Sorghum/Maize (Papua New Guinea)	74-0004	Triticale (India)
75-0019	Sorghum/Maize Hybrid (PRL)	73-0050	Triticale (Kenya)
72-0051	Sorghum/Millets (Uganda) Phase I	74-0142	Triticale (Lebanon)
75-0116	Sorghum/Millets (Uganda) Phase II	76-0149	Triticale (Manitoba)
80-0056	Sorghum/Millets (Uganda) Phase III	73-0033	Triticale Legumes (Algeria) Phase I
78-0116	Sorghum/Millets/Cowpea Utilization (Upper Volta)	72-0024	Triticale Outreach (Ethiopia) Phase I
73-0010	Sorghum/Millet/Legumes (ALAD) Phase I	76-0052	Triticale Outreach (Ethiopia) Phase II
75-0031	Sorghum/Millet/Legumes (ALAD) Phase II	79-0042	Triticale Utilization (Kenya)
78-0008	Sorghum Millets Milling and Quality (PRL)	72-0126	Trypanosomiasis (Guelph)
75-0137	Sorghum Milling (Botswana)	73-0101	Trypanosomiasis (Kenya) Phase I
78-0054	Sorghum Milling (Sudan)	74-0163	Trypanosomiasis (Kenya) Phase II
79-0093	Sorghum Milling (Tanzania)	79-0109	Upland Rice Storage (Sierra Leone)
75-0037	Sorghum Triticale/Oilseeds (Rwanda)	74-0054	Varietal Screening (Philippines) Phase I
80-0010	Sorghum Utilization (Ethiopia)	78-0045	Varietal Screening (Philippines) Phase II
80-0129	Sorghum Utilization (Tanzania)	79-0019	Vegetables (Kenya)
80-0109	South American Camelids (Peru)	80-0064	Vegetable Dehydration (Zambia)
77-0041	Striga (Sudan)	78-0055	Village Level Rice Milling (Thailand)
73-0015	Striga (Sussex) Phase I	74-0121	Wet Paddies Handling (Malaysia)
75-0065	Striga (Sussex) Phase II	79-0022	Wild Cassava (Brazil)
76-0101	Striga (Sussex) Phase III	74-0026	Winter Triticale (Guelph) Phase I
		76-0148	Winter Triticale (Guelph) Phase II
		77-0081	Winter Triticale (Guelph) Phase III
		72-0091	Wood Cement Products (Ghana)

Table 2. AFNS division fiscal summary.

	Crops and Cropping Systems		Animal Sciences		Fisheries		Forestry		Postproduction Systems		Total	
	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects	Appropriations ($ '000)	No. of projects
1971-72	869	5	82	1	527	1	—	—	199	5	1677	12
1972-73	3541	13	470	4	—	—	393	4	—	—	4404	21
1973-74	2592	13	1255	6	1038	5	506	3	739	6	6130	33
1974-75	4156	11	787	4	826	1	1923	5	363	6	8055	27
1975-76	5491	21	2153	6	718	5	583	3	948	7	9893	42
1976-77	4794	21	1480	5	803	4	2378	8	1452	9	10907	47
1977-78	5823	23	1610	7	1713	9	1136	6	487	5	10769	50
1978-79	6304	25	1425	5	907	3	735	3	1521	17	10892	53
1979-80	5911	23	1369	7	1172	8	861	4	1866	17	11178	59
1980-81[a]	5935	21	1295	4	1324	6	1352	6	2090	19	11996	56

[a]To the end of the third-quarter of the fiscal year.

Table 3. Cumulative AFNS project appropriations and number of projects to December 1980 ($ '000).

	Appropriations ($ '000)	%	No. of projects	%
Program				
Crops and Cropping Systems	45741	53.3	176	44.1
Fisheries	9028	10.5	42	10.5
Animal Sciences	11925	13.9	49	12.2
Forestry	9674	11.2	42	10.5
Postproduction Systems	9664	11.1	91	22.7
Total	86032	100.0	400	100.0
Region				
Africa	23316	27.2	110	27.5
Asia	24735	28.7	107	26.8
Middle East and North Africa	12997	15.1	50	12.5
Latin America and Caribbean	20264	23.6	92	23.0
Canada and Developed	4720	5.4	41	10.2
Total	86032	100.0	400	100.0

Table 4. Ratios for selected AFNS project budget variables to the total project grant, on both a regional and a program basis.

	Region						Program				
	All projects	Africa	Asia	Latin America	Middle East and North Africa	Canada and Developed	Animal Sciences	Crops and Cropping Systems	Fisheries	Forestry	Post-production Systems
Centre-administered portion/ total grant	29	38	27	21.6	30	11.6	25.5	24.4	37.4	37.8	32.5
Recipient-administered portion/ total grant	71	62	73	78.4	70	88.4	74.5	75.6	62.6	62.2	67.5
Consultancies/total grant	3.5	4.5	3.7	3.6	4.4	0.6	3.7	1.6	8.2	6.7	5.4
Training/total grant	10.5	10.5	13.4	11.2	11.5	1.3	12.3	11	13.1	6.5	7.2
Capital equipment/ total grant	13	14	15	11.2	14.3	6.7	9.9	10	26.6	12.6	17.5
Salaries and allowances/ total grant	34	37	31.5	35.1	28.5	58.7	33.4	39	20.1	28.5	29.2
Travel/total grant	6.5	7	6.3	7	7.2	3.9	5.7	6.9	4	6.1	8
Research expenses/ total grant	19	18.5	18	19	19.2	17.3	21.7	16.7	15.8	29	20.4
Publications/total grant	1.2	1.5	1.3	1.8	1.6	0.13	1	1.2	2.1	2.1	1.6
Contingency/total grant	6.3	7	6.4	7.6	6.1	6.5	6.9	5.7	6.4	6.4	8.8
Average value of project including supplement ($ '000)	213	208	245	211	248	97	238	251	218	226	96
Average length of project including extension (months)	34	38	38	33	35	23	34.5	34	35.3	38.3	30.6

Appendix 2

International Agricultural Research Centres

Centro Internacional de Agricultura Tropical (CIAT), Apartado Aéreo 6713, Cali, Colombia. (Major research programs: cassava, field beans, rice, and tropical pastures)

Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), Londres 40, México 6, D.F., México. (Major research programs: maize and wheat)

Centro Internacional de la Papa (CIP), Apartado 5969, Lima, Peru. (Major research program: potato)

International Board for Plant Genetic Resources (IBPGR), Crop Ecology and Genetic Resources Unit, Food and Agriculture Organization of the United Nations, Via delle Terme de Caracalla, 00100 Rome, Italy.

International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 114/5055, Beirut, Lebanon. (Major research programs: farming systems; cereals; food legumes including broad beans, lentils, and chick-peas; and forage crops)

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), 1-11-256, Begumpet, Hyderabad 500016, A.P., India. (Major research programs: chick-pea, pigeon pea, pearl millet, sorghum, groundnut, and farming systems)

International Food Policy Research Institute (IFPRI), 1776 Massachusetts Avenue, N.W., Washington, D.C. 20036, USA.

International Institute of Tropical Agriculture (IITA), P.M.B. 5320, Ibadan, Nigeria. (Major research programs: farming systems; maize; rice; roots and tubers including sweet potatoes, cassava, and yams; and food legumes including cowpeas, lima beans, and soybeans)

International Livestock Centre for Africa (ILCA), P.O. Box 5689, Addis Ababa, Ethiopia. (Major research program: livestock production systems)

International Laboratory for Research on Animal Diseases (ILRAD), P.O. Box 30709, Nairobi, Kenya. (Major research programs: trypanosomiasis and theileriosis)

International Rice Research Institute (IRRI), P.O. Box 933, Manila, Philippines. (Major research program: rice)

International Service for National Agricultural Research (ISNAR), P.O. Box 93375, 2509 AJ, The Hague, Netherlands.

West Africa Rice Development Association (WARDA), E.J. Roye Memorial Building, P.O. Box 1019, Monrovia, Liberia. (Major research program: rice)

Appendix 3

AFNS Publications from 1970 to 1980

***IDRC-004e**
Osmotic dehydration: a cheap and simple method of preserving mangoes, bananas and plantains. G.W. Hope and D.G. Vitale. Ottawa, 1972, 12p.

***IDRC-010e**
Chronic cassava toxicity: proceedings of an interdisciplinary workshop, London, England, 29-30 January 1973. Barry Nestel and Reginald MacIntyre, ed. Ottawa, 1973, 162p.

***IDRC-015e**
Aquaculture in Southeast Asia: report of a seminar at the Freshwater Fishery Research Station, Malacca, West Malaysia, 17-25 April 1973. IDRC, Ottawa, 1973. 22p.

***IDRC-016e**
Consumer food utilization in the semi-arid tropics of Africa: report of an interdisciplinary workshop, Zaria, Nigeria, 30 April-4 May 1973. IDRC. Ottawa, 1973, 16p.

IDRC-017e
Natural durability and preservation of one hundred tropical African woods. Yves Fortin and Jean Poliquin. Ottawa, 1976, 131p. (Also available in French *IDRC-017f)

***IDRC-020e**
Cassava utilization and potential markets. Truman P. Phillips. Ottawa, 1973, 182p.

IDRC-021e
Nutritive value of triticale protein. Joseph H. Hulse and Evangeline M. Laing. Ottawa, 1974, 183p.

***IDRC-022e**
Consumer preference study in grain utilization, Maiduguri, Nigeria. Jean Steckle and Linda Ewanyk. Ottawa, 1974, 47p.

IDRC-023e (revised edition)
Directory of food science and technology in Southeast Asia. E.V. Araullo, compiler. Ottawa, 1975, 267p.

IDRC-024e
Triticale: proceedings of an international symposium, El Batan, Mexico, 1-3 October 1973. Reginald MacIntyre and Marilyn Campbell, ed. Ottawa, 1974, 250p.

***IDRC-026e**
Food crop research for the semi-arid tropics: report of a workshop on the physiology and biochemistry of drought resistance and its application to breeding productive plant varieties, University of Saskatchewan, Saskatoon, Canada, 22-24 March 1973. Michael Brandreth. Ottawa, 1974, 16p.

*Available in microfiche only.

IDRC-029e
International Development Research Centre programs in agriculture, fisheries, forestry and food science: reviewed at a symposium, Ottawa, 12 September 1973. IDRC. Ottawa, 1974, 55p.

***IDRC-031e**
Cassava processing and storage: proceedings of an interdisciplinary workshop, Pattaya, Thailand, 17-19 April 1974. E.V. Araullo, Barry Nestel, and Marilyn Campbell, ed. Ottawa, 1974, 125p.

***IDRC-033e**
Interaction of agriculture with food science: proceedings of an interdisciplinary symposium, Singapore, 22-24 February 1974. Reginald MacIntyre, ed. Ottawa, 1974, 166p.

***IDRC-036e**
Current trends in cassava research. Barry Nestel. Ottawa, 1974, 32p.

***IDRC-040s**
Triticale: resumenes de los ensayos presentados durante un simposio internacional, El Batan, Mexico, 1 al 3 de octubre de 1973. CIID. Ottawa, 1975, 31p.

***IDRC-041e**
Stable tropical fish products: report on a workshop, Bangkok, Thailand, 8-12 October 1974. Marilyn Campbell. Ottawa, 1975, 27p.

IDRC-049e
The international exchange and testing of cassava germ plasm: proceedings of an interdisciplinary workshop held at CIAT, Palmira, Colombia, 4-6 February 1975. Barry Nestel and Reginald MacIntyre, ed. Ottawa, 1975, 74p. (Also available in Spanish *IDRC-049s)

***IDRC-052e**
Tropical oyster culture: a selected bibliography: D.B. Quayle. Ottawa, 1975, 40p.

***IDRC-053e**
Rice: postharvest technology. E.V. Araullo, D. de Padua, and Michael Graham, ed. Ottawa, 1976, 396p.

***IDRC-055e**
Cowpeas: home preparation and use in West Africa. Florence E. Dovlo, Caroline E. Williams, and Laraba Zoaka. Ottawa, 1976, 96p.

***IDRC-057e**
Hidden waters in arid lands: report of a workshop on groundwater research needs in arid and semi-arid zones, held in Paris, France, 25 November 1974. L.A. Heindl, ed. Ottawa, 1975, 18p.

***IDRC-058e**
Removing constraints to small farm production: the Caqueza project: H.G. Zandstra, K.G. Swanberg, and C.A. Zulberti. Ottawa, 1976, 32p. (Also available in Spanish *IDRC-058s)

IDRC-059e
Cassava: the development of an international research network. Barry Nestel and James Cock. Ottawa, 1976, 70p.

***IDRC-062e**
Hidden harvest: a systems approach to postharvest technology. David Spurgeon. Ottawa, 1976, 36p. (Also available in French *IDRC-062f)

***IDRC-063e**
The international exchange and testing of cassava germ plasm in Africa: proceedings of an interdisciplinary workshop at IITA, Ibadan, Nigeria, 17-21 November 1975. Eugene Terry and Reginald MacIntyre, ed. Ottawa, 1976, 59p.

***IDRC-071e**
African cassava mosaic: report of an interdisciplinary workshop held at Muguga, Kenya, 19-22 February 1976. Barry L. Nestel, ed. Ottawa, 1976, 48p.

***IDRC-076e**
Intercropping in semi-arid areas: report of a symposium held at the Faculty of Agriculture, Forestry and Veterinary Science, University of Dar es Salaam, Morogoro, Tanzania, 10-12 May 1976. J.H. Monyo, A.D.R. Ker, and Marilyn Campbell, ed. Ottawa, 1976, 72p.

IDRC-078s
Investigaciones en comunicación para el desarrollo rural en América Latina: bibliografía. L.R. Beltrán S., G. Isaza V., F. Ramirez P. Bogota, 1976, 87p.

***IDRC-080e**
Proceedings of the fourth symposium of the International Society for Tropical Root Crops held at CIAT, Cali, Colombia, 1-7 August 1976. J. Cock, R. MacIntyre, and M. Graham, ed. Ottawa, 1977, 277p.

***IDRC-084e**
Trees, food, and people: land management in the tropics. J.G. Bene, H.W. Beall, and A. Coté. Ottawa, 1977, 52p. (Also available in French IDRC-084f and Spanish IDRC-084s)

IDRC-086e
Theileriosis: report of a workshop held in Nairobi, Kenya, 7-9 December 1976. J.B. Henson and M. Campbell, ed. Ottawa, 1977, 112p.

***IDRC-089e**
Agriculture, Food and Nutrition Sciences Division: the first five years. IDRC. Ottawa, 1977, 49p. (Also available in Spanish *IDRC-089s)

***IDRC-091s**
Resúmenes de los trabajos presentados durante el cuarto simposio de la Sociedad Internacional de Raíces Comestibles Tropicales celebrado en el CIAT, Cali, Colombia, 1-7 agosto 1976. J. Cock, R. MacIntyre, y M. Graham, ed. Bogota, 1977, 60p.

***IDRC-094e**
Trees for people: an account of the forestry research program supported by the International Development Research Centre. C. Sanger, G. Lessard, and G. Poulsen. Ottawa, 1977, 52p. (Also available in French IDRC-094f)

***IDRC-095e**
Cassava as animal feed: proceedings of a workshop held at the University of Guelph, 18-20 April 1977. B. Nestel and M. Graham, ed. Ottawa, 1977, 147p.

***IDRC-096e**
Cassava bacterial blight: report of an interdisciplinary workshop held at IITA, Ibadan, Nigeria, 1-4 November 1976. G. Persley, E.R. Terry, and R. MacIntyre, ed. Ottawa, 1977, 36p.

***IDRC-101e**
Man and tree in tropical Africa: three essays on the role of trees in the African environment. G. Poulsen. Ottawa, 1978, 31p.

IDRC-107e
Caqueza: living rural development. H. Zandstra, K. Swanberg, C. Zulberti, and B. Nestel. Ottawa, 1979, 321p. (Casebound) (Also available in Spanish IDRC-107s)

IDRC-108e
Coffee pulp: composition, technology, and utilization. J.E. Braham and R. Bressani, ed. Ottawa, 1979, 95p. (Also available in Spanish *IDRC-108s)

IDRC-114e
Cassava harvesting and processing: proceedings of a workshop held at CIAT, Cali, Colombia, 24-28 April 1978. E.J. Weber, J.H. Cock, and A. Chouinard, ed. Ottawa, 1978, 84p.

IDRC-115e
Fisheries and aquaculture in the People's Republic of China. G.I. Pritchard. Ottawa, 1980, 32p.

***IDRC-120e**
Fish farming: an account of the aquaculture research program supported by the International Development Research Centre. B. Stanley, W.H. Allsopp, and F.B. Davy. Ottawa, 1978, 40p. (Also available in French IDRC-120f)

IDRC-121s
Mujer rural y desarrollo: nuevo enfoque de la educación del hogar en América Latina. C. Cebotarev. Bogota, 1979, 188p.

IDRC-123e
Sorghum and millet: food production and use. Report of a workshop held in Nairobi, Kenya, 4-7 July 1978. S. Vogel and M. Graham, ed. Ottawa, 1979, 64p.

***IDRC-124s**
La quinua y la kañiwa: cultivos andinos. CIID. Bogota, 1979, 228 p.

IDRC-126e
Food legume improvement and development: proceedings of a workshop held at the University of Aleppo, Syria, 2-7 May 1978. G.C. Hawtin and G.J. Chancellor, ed. Ottawa, 1979, 216p.

IDRC-132e
Pathogenicity of trypanosomes: proceedings of a workshop held at Nairobi, Kenya, 20-30 November 1978. G. Losos and A. Chouinard, ed. Ottawa, 1979, 216p.

IDRC-134e
Standardization of analytical methodology for feeds: proceedings of a workshop held in Ottawa, Canada, 12-14 March 1979. W.J. Pigden, C.C. Balch, and M. Graham, ed. Ottawa, 1980, 128p.

IDRC-135e
A partly annotated bibliography on infections, parasites, and diseases of African wild animals. L. Karstad. Ottawa, 1979, 111p.

IDRC-139e
Diseases of fish cultured for food in Southeast Asia: report of a workshop held in Cisarua, Bogor, Indonesia, 28 November-1 December 1978. B. Davy and M. Graham, ed. Ottawa, 1979, 32p.

IDRC-142e
Intercropping with cassava: proceedings of an international workshop held at Trivandrum, India, 27 November-1 December 1978. E. Weber, B. Nestel, and M. Campbell, ed. Ottawa, 1979, 144p.

IDRC-143e
Food or famine: an account of the crop science program supported by the International Development Research Centre. A.D.R. Ker. Ottawa, 1979, 79p.

IDRC-145e
Polyphenols in cereals and legumes: proceedings of a symposium held during the 36th annual meeting of the Institute of Food Technologists, St. Louis, Missouri, 10-13 June 1979. J.H. Hulse, ed. Ottawa, 1979, 72p.

IDRC-146e
Food systems: an account of the postproduction systems program supported by the International Development Research Centre. R.S. Forrest, W. Edwardson, S. Vogel, and G. Yaciuk. Ottawa, 1979, 72p.

IDRC-151e
Cassava cultural practices: proceedings of a workshop held in Salvador, Bahía, Brazil, 17-21 March 1980. E. J. Weber, J.C. Toro M., and M. Graham, ed. Ottawa, 1980, 152p.

IDRC-152e
An end to pounding: a new mechanical flour milling system in use in Africa. P. Eastman. Ottawa, 1980, 64p.

IDRC-155e
Rattan: a report of a workshop held in Singapore, 4-6 June 1979. IDRC. Ottawa, 1980, 76p.

IDRC-158f
Le rôle des arbres au Sahel : compte rendu colloque tenu à Dakar (Sénégal) du 5 au 10 novembre 1979. CRDI. Ottawa, 1980, 92p.

IDRC-159e
Bamboo research in Asia: proceedings of a workshop held in Singapore, 28-30 May 1980. G. Lessard and A. Chouinard, ed. Ottawa, 1980, 228p.

***IDRC-TS1e**
Food legume processing and utilization (with special emphasis on application in developing countries). Alvin Siegel and Brian Fawcett. Ottawa, 1976, 88p. (Also available in French IDRC-TS1f)

***IDRC-TS2e**
Maiduguri mill project: grain milling and utilization in West Africa. IDRC. Ottawa, 1976, 16p. (Also available in French *IDRC-TS2f)

IDRC-TS7e
Nutritional standards and methods of evaluation for food legume breeders. J.H. Hulse, K.O. Rachie, and L.W. Billingsley. Ottawa, 1977, 100p.

IDRC-TS21e
The theory and practice of induced breeding in fish. B.J. Harvey and W.S. Hoar. Ottawa, 1979, 48p. (Also available in French IDRC-TS21f and Spanish IDRC-TS21s)

IDRC-TS17e
Tropical oysters: culture and methods. D.B. Quayle. Ottawa, 1980, 80p. (Also available in French IDRC-TS17f and Spanish IDRC-TS17s)

Appendix 4

Other Publications by AFNS Staff

Allsopp, W.H.L.
"African fisheries: their problems and opportunities and their role in the Sahelian famine/Problèmes et perspectives de la pêche en Afrique: son rôle dans la famine au Sahel" — Prepared for the United Nations in New York, N.Y., July 1974. ST/SSO/ 30-74-28185 ST.

"Management strategies in some problematic tropical fisheries" — Published in 'Unifying Concepts in Ecology', van Dobben, W.H. and Lowe-McConnell, R.H., ed., The Hague, Junk B.V., 1975. 252-262.

"Problems and perspectives of tropical fisheries" — Published in 'The Melanesian Environment — Report of the Waigini Seminar', Winslow, J.H., ed., Australian National University Press, Canberra 1975. 222-235.

"The utilization of the by-catch of fish from shrimp trawling in tropical areas" — Prepared for the Conference on Handling, Processing and Marketing of Tropical Fish, Tropical Products Institute, London, 5-9 July 1976. Published in the 'Proceedings' of the Conference.

"Self-managed development" — Interview by the Centre for the Study of Democratic Institutions. Published in 'World Issues', December 1977-January 1978.

"Some fisheries options for food supply increase in the Caribbean Atlantic" — Presented at an Interciencia Symposium on Marine Sciences in the Americas. Published in 'Interciencia', February 1978.

"Ecological aspects of cage culture of fish" — Working paper presented at the Workshop on Floating Cages and Net Pen Enclosures, SEAFDEC/IDRC — Tigbauan, Iloilo, Philippines, February 12-21, 1979. 20 p. (mimeo).

Araullo, E.V.
"Post-harvest rice technology (Southeast Asia)" — Published in 'Rice Report 1975', Barber, S., Mitsuda, H., Desikachar, R., ed. Working party on rice utilization, IUFOST. Instituto Agroquimica y Technologia de Alimentos, Valencia, Spain.

Daniels, W.D., MacCormac, C., and Hulse, J.H.
"Collaboration in agricultural research" — Presented to the Agricultural Economists, University of Guelph, 15 August 1977. Published in 'Canadian Journal of Agricultural Economists', August 1977.

Doggett, Hugh
"The improvement of sorghum in East Africa" — Paper read to a workshop on Sorghum in the Seventies, Hyderabad, India, October 1971. Published in 'Sorghum in the Seventies', Rao and House, ed., Oxford and IBH, 1972.

"Breeding for resistance to sorghum shoot-fly in Uganda" — Presented at a workshop on Control of Sorghum Shoot-fly, Hyderabad, India, November 1971. Published in 'Control of Sorghum Shoot-fly', Jotwani and Young, ed., Oxford and IBH, 1972.

"Recurrent selection in sorghum populations" — Published in 'Heredity', London, Vol. 28, no. 1, February 1972.

"International aspects of sorghum research" — Forward to the 'Proceedings of the Fourth Eastern Africa Cereals Workshop (Tecwyn, Jones, ed.) East African Agricultural and Forestry Journal', Nairobi, Vol. 39, no. 6, June 1973.

"New direction in world cereals research: crops of the semi-arid tropics" — Presented at a symposium sponsored by the American Association of Cereal Chemists and IDRC, Montreal, 22 October 1974. Published in the 'AACC Journal', October/74.

"Progress in breeding for quality protein in other cereals" — Address to session of CIMMYT Conference on breeding cereals for improved protein, Mexico, December 4-8, 1972. Published in 'High Quality Protein Maize', Dowden, Hutchinson and Ross, ed., 1975.

"The history of the sorghum crop" — Chapter in 'Crop Plant Evolution', Simmons and Longmans, ed., 1975.

"Quality improvement in sorghum and millets" — Prepared for the International Association for Cereal Chemistry Conference, Vienna, 11 May 1976. Published in 'Proceedings of the International Association for Cereal Chemistry Conference', 1976.

"Sorghum bicolor (Gramineae, Andropogoneae)" — Published in 'Evolution of Crop Plants', Simmonds, N.W., ed., 1976.

Doggett, Hugh and Majisu, B.N.

"Fertility improvement in autotetraploid sorghum" — Published in 'Euphytica', 1972.

"The yield stability of sorghum varieties and hybrids in East African environments" — Published in 'East African Forestry Journal', 1972.

Forrest, R.S.

"Coordination of post-production systems in semi-arid Africa" — Published in 'Report of the Regional Workshop on Post-harvest Losses' by Commonwealth Secretariat, Food Production and Rural Development Division, 1977. pp. 65-74.

Hulse, J.H.

"Increasing food by reducing waste" — Presented at the 3rd International Congress of Food Science and Technology, SOS/7, Washington, D.C., 9-14 August 1970. Published in 'Proceedings of Congress of Food Science and Technology', 1970.

"Nutritional management — a weak link in international development" — Presented to the Nutrition Society of Canada, Toronto, June 1971. Published by 'Nutrition Society of Canada', 1971.

"The purpose and objectives of IDRC" — Presented at the Institute of Food Science and Technology, United Kingdom, 17 February 1972. Published in the 'Journal of the Institute of Food Science and Technology', 1972.

"The relevance of food aid and food research in international development" — Paper read to the Society of Chemical Industry, Leeds, England, 11 July 1972. Published in 'Chemistry and Industry', 20 January 1973.

"The household scientists in international development" — Presented to the Faculty of Household Science, University of Toronto, 11 November 1972. Published in 'Canadian Home Economics Journal', April 1973, Vol. 23 no. 2.

"Development and evaluation of new proteins" — Chairman's closing remarks to the session on Development and Evaluation of New Proteins, Symposium on the Contribution of Chemistry to Food Supplies, Hamburg, FDR., 20-31 August 1973. Published in 'The Contribution of Chemistry to Food Supplies', August 1973.

"Triticale and developing nations. Triticale: first man-made cereal" — Presented at the AACC Symposium, St. Louis, Missouri, 5 November 1973. Published in 'American Association of Cereal Chemists Inc.', 1974. pp. 2-8.

"Contre la faim dans le monde: le projet Triticale" — Published in 'La Recherche', Paris, Vol. 5 no. 42, février 1974. pp. 188-190.

"Research and development in advanced countries and transfer of results for industrial development to developing countries" — Presented at the IV International

Congress of Food Science and Technology, Madrid, Spain, 26 September 1974. Published in 'Proceedings'.

"Les propriétés du triticale" — Article paru dans 'Encylopedia Universalis', France, le 30 septembre 1974. pp. 425-429.

"The new miracle grain/triticale: la nouvelle céréale miracle" — 5 July 1974. Published in 'Cooperation Canada', no. 16, September/October 1974. pp. 18-22.

"The protein enrichment of bread and baked products" — Published in 'New Protein Foods', Vol. 1A, Altschul, Aaron M., ed., Academic Press Inc., 1974. pp. 156-230.

"Problems of nutritional quality of pigeon pea and chick-pea and prospects of research" — Presented at ICRISAT Workshop on Grain Legumes, India, 13-15 January 1975. Published in 'Proceedings'.

"Food processing problems and potential" — Presented at the INCAP Conference in Guatemala City, 3 December 1974. Published in 'Nutrition and Agricultural Development — Significance and Potential for the Tropics', Scrimshaw, N.S. and Béhar, M., ed., printed by Plenum Publishing Corp., 1976. pp. 215-233.

"Protein methods for cereal breeders as related to human nutritional requirements" — Published in 'Advances in Cereal Science and Technology', Pomeranz, Y., ed., AACC, 1976. Chapter written by the UN-PAG Working Group on Protein Methods for Cereal Breeders.

"Research management" — Presented at AFNS staff meeting in March 1976 and published in 'Agricultural Research Management', Volume II, SEARCA, 1977.

"The international agricultural research system" — Presented to the Royal Society of Canada, 23 August 1977. Published by 'Royal Society of Canada'.

"Post-harvest systems" — Interview published in 'CERES', November/December 1977.

"Food research — for whose benefit?" — Presented as the Keynote Address for the 21st Conference of the Canadian Institute of Food Science and Technology (CIFST) held in Edmonton 25-28 June 1978. Published in 'CIFST Journal' in October 1978. pp. A93-A96.

"The food scientist in international development" — Talk to the Australian Institute of Food Science and Technology (AIFST) Annual Conference, held in Melbourne, Australia in May 1978. Published in 'Food Technology in Australia', September 1978. pp. 354-358.

"Human implications of protein utilization" — Paper presented to the International Symposium on Protein Utilization, 13-16 August 1978, University of Guelph, Guelph, Ont. 33p. (mimeo). Published in 'Utilization of World Protein Resources', Food and Nutrition Press Inc., 1981.

"Research and post-production systems" — Presented at International Symposium on Advances in Food Production Systems for Arid and Semi-Arid Lands. Kuwait, 19-23 May 1980. Published in 'Advances in Food-Producing Systems for Arid and Semi-Arid Lands', Part B, Academic Press, 1981.

"World food resources: an overview" — Presented to the Australian Academy of Tech. Sciences Fourth Invitation Symposium, Food Resources of Australia, 21 October 1980. Published in 'Food Resources of Australia', AATS, 1981.

Hulse, J.H. and Daniels, W.D.

"Economics of transfer" — Presented to the Western Hemisphere Nutrition Congress IV, Bal Harbour, Florida, 20 August 1974. Published in 'LIFE Newsletter' of Sept. 1974 and in 'Proceedings, Western Hemisphere Nutrition Congress IV', White, Philip L. and Selvey, Nancy, ed., Publishing Sciences Group, Inc., Acton, Mass., 1975. Copyright 1975 by the American Medical Association. pp. 271-277.

Hulse, J.H. and Fawcett, B.D.

"Nutritionally fortified cereals foods" — Presented at 5th International Grains Industry Program, Canadian International Grains Institute, Winnipeg, Manitoba, 17 September 1975. Published by 'Canadian International Grains Institute', 1975.

Hulse, J.H., Fawcett, B.D., and Daniels, W.D.
"Protein supplements — world production and trade" — Presented at the Oilseed and Pulse Crops Symposium, University of Manitoba, 20-23 May 1975. Published in Harapiak, John T., ed., 'Oilseed and Pulse Crops in Western Canada — A Symposium'. Calgary: Western Cooperative Fertilizers Ltd., 1975. pp. 1-60.

Hulse, J.H., Laing, E.M., and Pearson, O.E.
"The composition and nutritional value of sorghum and the millets," Academic Press 1981.

Hulse, J.H. and Pearson, O.E.
"How nutrition priorities can be integrated into crop improvement programs" — Presented at the XIth International Congress of Nutrition held in Rio de Janeiro, Brazil, 27 August-1 September 1978. Published in 'UNU Food and Nutrition Bulletin', Vol. 2, No. 1, January 1980 and 'Nutrition and Food Science Series', Proceedings, Vol. 2, Plenum Press.

Hulse, J.H. and Scott, R.B.
"Can the people of the world be fed? What is Canada's role?" — Published in 'Canada's Role in Feeding the People of the World', Conference Report. Club of Guelph, 1977.

Hulse, J.H. and Spurgeon, D.
"Triticale" — Published in Scientific American, August 1974, Vol. 231, no. 2, pp. 72-80.

Ker, A.D.R., Moorse, M.W., Watts, E.R., and Gill, B.N.
"Agriculture in East Africa: an introduction to principles and practices" — Edward Arnold (Publishers) Ltd., London 1978. 218 p.

Kishk, F., et al.
"Hydrolysis of methylparathion insecticide in soils" — Published in 'Journal of Agricultural Food Chemistry', 24(2), pp. 305-307, Mar/Apr 1976.

"Methylparathion hydrolase activity in some Egyptian soils and fractions" — Published in the 'Alexandria Journal of Agricultural Research', Volume 24, 1976. pp. 435-440.

"Mineralogical and chemical composition of the clay fraction of some Nile alluvial soils in Egypt" — Published in 'Chemical Geology', 17(4), pp. 295-305, 1976.

"Agronomic and quality performance of different wheat varieties and their response to micronutrient Fkliar application" — Published in the 'Alexandria Journal of Agricultural Research, (accepted March 19, 1977).

"Mineral element composition of perennial vegetation in relation to soil types in the northeastern corner of the western desert of Egypt" — Published in the 'Botanical Gazette', Chicago, U.S.A., June 1977.

"Adsorption of methylparathion by soils" — Published in 'Bulletin of Environmental Contamination and Toxicology', 22(6), pp. 733-738, 1979.

"Ion and solvent selectivity of zeolite A in mixed media. An extension of the Gibbs-Donnan model" — Published in 'Journal of Physics and Chemistry', 83(21), pp. 2743-2751, 1979.

"Sorption-desorption characteristics of methylparathion by clays" — Published in 'Archives of Environmental contamination Toxicology', 8(6), pp. 637-645, 1979.

Nestel, B.L.
"The dilemma of Caribbean agriculture" — Presented at the OCPLACS Seminar held at Guelph University on 6 March 1971. Reprinted in 'Estelas', Vol. 1, 1971. pp. 9-12.

"The veterinarian in Latin America" — Presented to the Central Ontario Veterinarian Association Meeting, Brockville, 2 October 1971.

"Economics aspects of animal production in developing countries" — Presented at the Third World Conference on Animal Production in Melbourne, Australia, 23-29 May 1973. Published in 'Proceedings'.

"Cassava — a crop with a future? / Après le Blé et le Riz — le 'Manioc miracle'?" — Published in 'Cooperation Canada', CIDA, Ottawa, no. 13, March/April 1974. pp. 9-16.

"World animal production and feed supplies" — Opening address, Tropical Products Institute, International Conference on Animal Feeds of Tropical and Subtropical Origin, London, April 1974. Published in 'Proceedings'.

"Battling to fill 4 billion bellies" — Published in 'Sunday Times', London, July 1974. pp. 63-64.

"Agricultural research as a component of foreign aid" — Australian Broadcasting Corporation Guest of Honour talk, 1 December 1975. Published by 'ABC Sydney', Australia.

"World cassava research — a review" — Lecture given at Central Tuber Crops Research Institute, Trivandrum, India, 23 September 1975 and published in Journal of Root Crops, Vol. 2, 1976. pp. 10-13.

Nestel, B.L., Pratt, D.J., Thome, M., and Tribe, D.E.
"Animal production and research in tropical Africa" — Report of the Task Force commissioned by the Consultative Group on International Agricultural Research, 1972 — Washington.

Scott, R.B., and Hulse, J.H.
"Can the people of the world be fed? What is Canada's role?" — Presented at the 4th Meeting of the Club of Guelph, 6 November 1976. Published by K.W. Hammond, 'Club of Guelph', 1977 and reprinted by kind permission in 'CIFST Journal' Vol. 10, no. 4, 1978.

Siegel, Alvin
"Stabilization of anthocyanins in frozen tart cherries by blanching" — Published in 'Journal of Food Science', 1971.

Siegel, A., Bhumiratana, A., and Lineback, D.R.
"Development, acceptability and nutritional evaluation of high-protein soy-supplemented rice noodles for Thai children" — Published in 'Cereal Chemistry', November/December 1975, Vol. 52, no. 6, published by the 'American Association of Cereal Chemists', Inc. pp. 801-812.

Weber, E.J.
"Program thrusts of the IDRC toward accelerating agricultural development" — Published in the SEARCA International Workshop on 'Accelerating Agricultural Development', Los Baños, Philippines, 26-30 April 1976.

"The Inca's ancient answer to food shortage, Chenopodium quinoa, field crop" — Published in 'Nature', 272 (5653), 486, 1978.

Yaciuk, Gordon
"Méthodologie de l'enquête sur la technologie post-récolte en milieu paysan — résultats et discussions des résultats" — Publié par 'l'Institut Sénégalais de Recherches Agronomiques', Dakar, Sénégal, juillet 1977.

"L'approche systemique pour la technique post-récolte au Sahel", Extrait de 'L'amélioration des systémes post-récolte en Afrique de l'ouest', Paris, Agence de Coopération Culturelle et Technique, 1980.

"L'approche systémique pour la technologie post-récolte au Sahel" — Document présenté au séminaire de l'Institut de Sahel/ACCT/GASGA. Bamako, avril 1979. 23p. mimeo (21p. Appendice).

Yaciuk, Gordon, Muir, W.E., and Sinha, R.N.
"Effects on temperature and insect and mite populations of turning and transferring

farm-stored wheat" — Published in 'Canadian Agricultural Engineering', Vol. 19, no. 1, June 1977.

"Climate in relation to deterioration of stored grain, a multivariate study" — Published in 'Oceologia', 12(1), pp. 69-88, 1973.

"A simulation model of temperatures in stored grain" — Published in 'Journal of Agricultural Engineering Research', 20(3), pp. 245-258, 1975.

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE • CENTRE DE RECHERCHES POUR LE DÉVELOPPEMENT INTERNATIONAL

CANADA