rnational Agricultural Research and Human Nutrition

edited by
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International Food Policy Research Institute
UN Administrative Committee on Co-ordination/
Sub-Committee on Nutrition

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Washington, D.C.

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Sub-Committee on Nutrition
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Foreword

The alleviating of absolute poverty and related ills, such as insufficient food intake and malnutrition, is one of the most important tasks facing mankind. Agricultural research and technological change are of prime importance in efforts to expand food production, generate economic growth, and reduce poverty. They are also important in efforts to alleviate hunger and malnutrition. A better understanding of the complex interaction between agricultural research and human nutrition as provided by this book is likely to facilitate explicit consideration of nutritional goals in the design of future agricultural research and related public policies.

As will be seen from this collection of papers, the international agricultural research centers (IARCs) are undertaking a series of activities directed toward a better understanding of the way both international and national agricultural research can effectively assist in the alleviation of malnutrition. A discussion of these activities led to a set of recommendations for further action. We strongly support these recommendations and note that they are part of a position paper now being developed by the directors of the international agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR). We also urge national agricultural research institutions to consider these recommendations.

This book presents a great deal of information about the work by and the accomplishments of the IARCs supported by or associated with the CGIAR and provides many illustrations of the way nutritional goals can be incorporated into the design and planning of agricultural research, whether it is undertaken by local, national, or international institutions.

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The workshop planning committee wish to extend their sincere appreciation to George Beaton and Robert Tripp for serving as rapporteurs during the workshop and providing an excellent set of notes of workshop discussions. The outstanding hospitality extended by Dr. and Mrs. Brumby and the staff of the International Livestock Centre for Africa (ILCA), together with the efficiency of ILCA in providing logistic support, made the workshop a pleasant experience for all participants.

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Overview

This book presents a comprehensive review of the nutrition-related activities undertaken by the international agricultural research centers (IARCs) supported by or associated with the Consultative Group on International Agricultural Research (CGIAR) and suggests ways in which local, national, and international agricultural research institutions can incorporate goals of improving human nutrition into research design and planning. Because hunger and malnutrition are closely linked with poverty, the content of the book also provides a great deal of evidence of the way the work of the centers relates to the poor, whether farmers, workers, or consumers.

The content of this book was discussed at a workshop sponsored by the UN Administrative Committee on Co-ordination/Sub-Committee on Nutrition (ACC/SCN) and the participating IARCs. The workshop was organized by the International Food Policy Research Institute (IFPRI) and the ACC/SCN and was held at the International Livestock Centre for Africa (ILCA), February 29-March 2, 1984. Its purposes were to discuss methods now being used by the IARCs for incorporating nutritional goals into agricultural research and to explore ways of further integrating nutrition concerns into the planning and execution of agricultural research. Participants in the workshop included economists, other social scientists, nutritionists, and agricultural scientists from 12 of the 13 centers supported by the CGIAR and from outside the CGIAR.

The focus of the workshop was on current and prospective methods for strengthening the effect of agricultural research on nutrition rather than an assessment of its actual effect. This book presents a brief summary of workshop discussions and recommendations (Chapter 2), followed by an overview of the interactions between agricultural research and human nutrition (Chapter 3). Papers prepared by each of the participating centers on nutrition-related activities are shown in Chapters 4-16. Five experts were asked to synthesize the center papers, each focusing on one aspect that was common to all of them. These syntheses, together with comments on some of the papers, are presented in Chapters 17-21.

1
Introduction

International agricultural research has facilitated rapid increases in food production in many developing countries. While production of more food may be needed for self-sustained improvements in nutrition, it is unlikely to be enough by itself. Insufficient intake of food is caused to a large extent by insufficient purchasing power among certain population groups. Production of more food may increase the purchasing power of the poor by increasing the incomes of producers and rural workers and reducing the prices of food to consumers; the extent to which this will occur, however, depends on the increase in the production of particular commodities and the way in which this is done. Likewise, the extent to which greater purchasing power improves nutrition is influenced by the way in which food production is expanded. Thus the effect of agricultural research on nutrition depends both on the nature and design of the research and on the public policies that are in effect. This implies that if nutritional goals are explicitly considered when decisions about the design and modification of agricultural research and public policies are made, the nutritional effect may be greater than if it were assumed that nutritional goals would be met if production were simply increased.

This fact is recognized by the international agricultural research institutes. They have taken several approaches to the incorporation of nutritional considerations into their research planning and execution. More can be done, however, in examination of still other approaches that might help the IARCs and national agricultural research institutions achieve nutritional goals and others.

It was against this background that the United Nations Administrative Committee on Co-ordination/Sub-Committee on Nutrition (ACC/SCN) approached the chairman of the directors of the international agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR) to explore ways of collaborating. Following an initial discussion between the center directors and members of the ACC/SCN working group on nutrition in agriculture, a decision was made to hold a joint workshop to examine present and potential approaches to the incorporation of nutritional goals into international agricultural research. The workshop was to provide a forum for discussing and sharing experiences among these centers and with selected outside experts regarding methods of incorporating nutritional goals into the planning and execution of international agricultural research, exploring ways of increasing the effect of international agricultural research on food consumption and

nutrition, and identifying specific ways of heightening that effect, which the centers might undertake individually or jointly.

In preparing for the workshop, each of the participating centers--the Asian Vegetable Research and Development Centre (AVRDC) and all centers supported by the CGIAR except the West African Rice Development Association (WARDA)--developed a paper in which the center activities in each of four areas of decisionmaking in which nutritional concerns might be incorporated were discussed. These areas are

1. The establishment of commodity priorities.
2. The specification of desired changes in commodity characteristics.
3. The specification of desired technology characteristics.
4. The choice of production systems to be researched.

Each center was also asked to report any evidence of the nutritional effect of its research so far. The focus of the papers was on the approaches used, without any attempt to evaluate the effects. A synthesis of these papers was prepared for each of the four areas of decisionmaking and another was made of the available information on actual nutritional effects. The workshop, which included staff members of the IARCs and experts from outside the CGIAR system, was organized around these five syntheses and a conceptual paper that gave an overview of the ways in which agricultural research may affect nutrition. A list of the participants is given in Appendix 1; the agenda of the workshop is given in Appendix 2.

This report consists of a brief summary of the discussions and recommendations of the workshop followed by the papers themselves. An overview of the ways in which agricultural research may influence human nutrition is offered in Chapter 3. In Chapters 4-16 past and current activities of each of the IARCs are reviewed. The five syntheses, together with comments offered at the workshop, are presented in Chapters 17-21.

2
Summary of Workshop Discussions and Recommendations

Nutritional Effect of International Agricultural Research: Current Evidence

The contributions made by agricultural research to increases in food production and farm incomes are generally expected to improve nutritional status. As will be seen in Chapter 17, however, quantitative estimates of nutritional effects are scarce and none of the international agricultural research centers have made comprehensive estimates. Greater knowledge of the way research has influenced human nutrition, both globally and in selected countries or regions, would be useful to document the effects and provide guidelines for future research and public policy. It was recommended that the IARCs begin efforts to estimate the effects of agricultural research on human nutrition globally or in selected countries, commodities, and research programs. Since the methodology for such research has not yet been fully developed, it was further recommended that emphasis be placed initially on the development and testing of analytical methodology. It was proposed that IFPRI should take the lead in this effort and explore the feasibility of collaborating with the CGIAR secretariat in its impact study.

No attempts should be made to estimate the effects of work by the IARCs separately from those of research done under national programs. Any such attempts would be artificial and self-defeating. Ideally, nutritional effects would be assessed under national programs, and the proposed initiative of the IARCs should be regarded as an effort to assist in getting such assessments under way by developing and testing methodologies and illustrating their usefulness for both national and international research programs.

Commodity Priorities

The nutritional effects of research on one commodity may be quite different from those of research on another, so the choice of commodities as subjects for research and the allocation of research resources among commodities have important implications for nutrition. While commodity priorities are determined when a center is created, changes in the emphasis given to certain commodities in the work of some centers and within the CGIAR as a whole are clearly possible and have been made several times.

The commodity priorities of the individual centers and the system as a whole reflect nutritional considerations in that high priority is given to staple food commodities that provide a large share of the

total calories and protein available in developing countries. As will be seen in Chapter 3, however, the critical issue for nutrition is the way intakes of calories and nutrients by the malnourished and those at risk of becoming malnourished are affected. In order to predict the effects of present and possible future commodity priorities on nutrition it is essential to estimate their effects on the diets of the poor. The basic data that would be needed to make such estimates are not readily available to the IARCs, and, as will be shown in Chapter 18, although several centers have undertaken work in this area, a need to expand these efforts and include more systematic collection and analysis of data for broader coverage of commodities and countries was recognized in the workshop. It was therefore recommended that the IARCs undertake or promote collection and analysis of data to provide an estimate of the relative importance of each important commodity in the diet, the expenditures for food, the income of the rural and urban poor and malnourished, and the way in which the poor and malnourished adjust their consumption of food in response to changes in their incomes and in food prices. This would provide an indicator for determining the way changes in commodity priorities in agricultural research might affect the real incomes and nutritional status of the poor and malnourished and would add assessments of nutrition and poverty to the indicators now being used to determine the emphasis that is to be given to each commodity.

A study of the diets of households some of whose members are malnourished, what food they produce, and how their consumption of calories and nutrients is likely to change in response to changes in prices and incomes brought about by technological change in the production of the principal commodities would be useful as decisions concerning commodity priorities, technology design, and production systems are made in the future by each of the centers and by the system as a whole. Many of the centers have undertaken studies in this area (see Chapters 4-16 and a synthesis in Chapter 18). Most of these studies, however, are limited to the commodities on which research is being done by the center in question. Furthermore, they tend to be limited to one or a few countries or regions within countries. An integrated study is needed, in which all centers would participate and which would draw on data already available, such as the consumption surveys undertaken in many countries during the last 10 years.

The usefulness of this kind of information would probably be even greater for national agricultural research institutions than for the international centers. The importance of the various commodities in the diets of the poor may vary among countries covered by the IARCs and within individual countries. Location-specific situations are best dealt with by national institutions. While it is suggested that the IARCs take the initiative in collecting data, it is important that it be shared with national institutions. This can be done both directly and through collaboration with international institutions having offices in the various developing countries, such as the Food and Agriculture Organization of the United Nations (FAO).

It should be noted that the aforementioned data would provide only one of a number of criteria to be considered in determining the allocation of research resources to individual commodities. How to deal with the trade-offs between the achievement of nutritional goals and others--that is, how to decide what weight should be given to

each--is a question that could not be answered at this workshop. A similarly difficult question is that of dealing with the interaction between agricultural research and public policies such as those concerning food prices. The effects of the one clearly depend on the state of the other. To assume that policies now in effect will not change may be as misguided as to assume that policies will be changed in such a way as to maximize the nutritional effects of research results. Efforts should be made to help governments choose the most appropriate combination of technological change and public policy.

No attempt was made during the workshop to identify high-priority commodities or to assess whether present commodity priorities of the IARCs are optimal from a nutritional point of view. It was suggested in workshop discussions, however, that the IARCs and the Technical Advisory Committee (TAC) examine whether certain classes of commodities such as nutritious commodities high in calories, legumes for the wet tropics, and commodities of particular value in providing food security for poor farmers, could be given greater emphasis in the research agenda.

Commodity Characteristics

It was repeatedly pointed out that solutions to present nutrition problems should be considered in relation to diet rather than to particular commodities. The desirability of changing the nutritional characteristics of certain commodities should therefore be considered in relation to the effects of changes in the composition of the diet. In some instances dietary deficiencies can best be alleviated through changes in individual commodities. In others diversifying a diet and increasing consumption of commodities already available offer the best solution.

Another important point is that farmers will adopt new technology only if they believe that it is in their best interest to do so. Thus, if the nutritional characteristics of a given commodity are improved at the expense of characteristics such as yield, consumer acceptance as reflected in prices, and resistance to pests that the farmer sees as more important, the nutritionally improved materials may not be adopted.

Participants in the workshop recognized the importance of diagnosing and specifying the nutrition problem separately from a possible solution. The best approach to the alleviation of protein deficiency in a diet made up largely of cassava, for example, may not be the development of high-protein cassava. What is important is to determine whether changing the nutritional characteristics of a given commodity or increasing consumption of traditional commodities is more likely to alleviate dietary deficiencies once they have been identified.

Six commodity characteristics with important implications for nutrition were identified (see the discussion following Chapter 19): content and bioavailability of nutrients, density of nutrients and energy, palatability and acceptability to consumers, preparation requirements, storage characteristics, and affordability. These characteristics are being considered to varying degrees by the IARCs (see Chapters 4-16 and a synthesis in Chapter 19). Efforts to increase nutrient content should include attempts to determine digestibility,

and research toward development of effective methods of determining digestibility by human beings should be continued. Differences between the content of nutrients and their availability should be detected and antinutrient factors identified. Low density of energy and nutrients in the diets of young children is a significant cause of malnutrition. It is suggested that efforts be made to increase the energy density of nutritious foods customarily eaten by young children.

It was pointed out that nutrient content may change with the environment in which a crop is grown. This introduces a certain margin of error in evaluations of materials for nutrient content.

Acceptability to consumers may be closely linked with nutritional effects, particularly when acceptance is associated with income but not with nutritional quality. Less liked but nutritious commodities tend to provide cheaper calories and nutrients to the poor because they are not so much in demand among population groups with higher incomes. This point is illustrated by findings from a CIAT study in Cali, Colombia, that small beans are considered inferior to beans of normal size because of their appearance, not their nutritional value (see Chapter 4). They therefore command a lower price and are consumed primarily by the poor.

Storage characteristics should be considered with the aim of reducing physical losses as well as deterring deterioration of the nutritional quality. Interaction between breeding and selection of plants and research on postharvest technology is important to assure efficiency and to limit losses in storage and processing. It was recommended that the IARCs explore ways in which work on postharvest technology could be broadened to include prevention of storage losses and deterioration of nutritional quality, various marketing losses, and losses in home and village processing, thereby improving the nutritional effects of their research activities.

When the achievement of certain changes in breeding and selection of materials conflicts with the achievement of goals such as increasing yields and resistance to certain pests, trade-offs need to be considered. Establishing criteria for making choices in such instances is difficult. After some discussion, it was decided that this matter would not be pursued any further at the workshop. The approaches and issues to be taken into account vary and a single set of criteria does not appear to be called for. It was agreed that in the final stages of germ-plasm development to generate information on the nutritional composition and antinutritional factors and make it available to all concerned would be desirable. It was recommended that as materials approach release by the IARCs, the centers should signal any results of tests for nutrient and antinutrient content that indicate content below normally acceptable standards.

Technology Characteristics

Technology characteristics influence human nutrition in at least four ways. First, the nature of the technology used is an important determinant of the amount of a particular commodity that is produced and the cost of producing it. Second, how much is gained by rural households with malnourished members from the use of new technology depends on the suitability of the technology to the production

environment controlled by these households and on its effect on employment. It is therefore important to identify the production environments most commonly controlled by these households. Development and testing of technology for such environments would help assure a large, positive effect on rural nutrition. Third, since seasonal and irregular fluctuations in the availability and prices of food and in incomes are important factors in malnutrition in many rural areas, new technology that helps reduce these fluctuations contributes to the improvement of nutrition. High priority has been placed in international agricultural research on reduction of lodging losses and the length of growing seasons, on increasing resistance to pests, and on other factors that increase yields while reducing the risk of partial or total crop failure and diminishing seasonal fluctuations. Fourth, the interaction between technology characteristics and household decisionmaking and allocation of labor may have consequences for nutrition. A particularly important element of this issue is the extent to which women in low-income farm households participate in decisions regarding the adoption of technology and the allocation of labor. Also important is the effect of technological change on the amount of time women allocate to such activities as child care--including breast-feeding--and food preparation. Activities of the centers that affect the interactions between human nutrition and technology characteristics will be summarized in Chapter 20.

Production Systems

The primary question here is how can research contribute to the design of production systems in agriculture that will permit malnourished members of farm households to increase their intake of dietary elements in which they are deficient during nutritionally critical periods? Many of the questions raised in the foregoing discussion of commodity priorities and technology characteristics are also relevant to decisions concerning production systems.

Although some centers--ICRISAT is one--have undertaken nutrition-related studies among farmers participating in farming-systems research (see Chapter 9), few attempts to integrate nutritional considerations into research on farming systems have been made, and an effective methodology has not yet been developed and tested (see Chapter 21 for a synthesis of these activities). Yet participants in the workshop judged that in areas in which low-income farm households suffer from nutritional deficiencies, explicit consideration of ways in which farming systems can meet nutritional goals might bring substantial returns. It was recommended that the IARCs explore the possibility of incorporating nutritional considerations more effectively into research on farming systems. To begin such efforts it is proposed that one or more meetings or workshops of interested IARC farming-systems researchers and experts from outside the IARCs be held to identify the most appropriate approach or approaches, including specification of the data needed, key parameters, analyses, and possibly field testing (case studies) involving one or more centers and outside experts. A review of present knowledge about several related issues such as intrahousehold allocation of resources and decisionmaking; the function of women in farming systems; nutrition

awareness; seasonality in the availability of food, nutritional status, incomes, and other variables; the effect of shifts from semisubsistence farming to cash cropping; and the function of animals in farming systems should be considered as part of this overall effort.

Since the appropriateness of specific farming systems depends on several factors, some of which are likely to be location-specific, the IARCs should focus on the development and testing of methodologies that may be useful for national institutions, although in some instances the empirical results are likely to be useful to the IARCs in their own design of technology. One critical set of issues, which the participants thought should be dealt with in the design of study methodology, is the extent to which the nature and causes of present nutritional problems are to be studied and whether the possible solutions to these problems that are outside the scope of farming systems, such as food supplementation, primary health care, and price and land tenure policies, should be considered. Closely related is the question whether research on farming systems by a particular center should be limited to the commodities included in its mandate. From a nutritional point of view, it is important that all farm activities that influence nutrition be considered.

Centerwide Considerations

In addition to activities linked with each of the four areas of decisionmaking, a series of activities of general centerwide importance was also considered during the workshop.

There was general agreement that better human nutrition is--and should be--one of the goals of the work of the IARCs. This is explicitly stated in the mandates of some centers and is implicit in the mandates of the others. This point is stressed in all the papers. A recommendation to make this goal explicit in the mandate of all IARCs was considered, but in view of the difficulties involved in changing mandates and the importance of the way in which the mandate is interpreted, it was decided to recommend instead that those IARCs that have not already done so make explicit in the interpretation of their mandates, but not necessarily in the mandates themselves, that due consideration be given to nutritional considerations in center activities. As centers review their mandates in the future they may wish to make the goal of improving nutrition explicit if it is not already.

Although a great deal is being done by the IARCs to link agricultural research to improvement of nutrition, most centers appear to have limited expertise in nutrition, and ways of strengthening their expertise were discussed. In view of the great variation among the mandates, work programs, staffing patterns, and nutrition expertise of the several centers, no single approach to the strengthening of expertise in nutrition is likely to be the best for all the centers. It was recommended that the IARCs review their needs and opportunities for strengthening their nutrition expertise, specifically considering the addition of short-term or long-term staff members, consultants, advisory committees, and so forth and communicate these needs to institutions and individuals, such as ACC/SCN, FAO, and bilateral donor agencies, that may be able to provide resources to help meet those needs.

To further strengthen the interaction with nutritional experts outside the IARCs, it was recommended that the IARCs explore the feasibility and potential usefulness of establishing or strengthening links with nutrition institutions and related agencies that can provide nutrition support services, collaborate with the centers, or exchange information with them. It was further recommended that each center name a staff member as contact person for the exchange of information about nutrition and that one of the persons or centers serve as coordinator. This information network would assure that information on center activities related to nutrition is distributed to all centers, collaborating national agricultural research institutions, and other interested parties. It would maintain contact with and receive from institutions outside the centers, such as ACC/SCN, FAO, the World Health Organization (WHO), and regional and national nutrition institutes information about nutrition that is relevant to the work of the IARCs, and it would assure that the momentum reached during the workshop is maintained. Each contact person would disseminate information within the center, facilitate contact between staff and management of the center and experts outside the center, and take initiatives on any activities related to nutrition that the center deemed appropriate.

While the foregoing refers to a strengthening of nutritional expertise in the individual centers, this matter was also discussed as it concerns the system as a whole. It was felt that nutrition expertise now available in the system is limited and that efforts by the IARCs to strengthen their resources in this area would benefit from a similar strengthening in the system as a whole. It was recommended that the TAC consider strengthening its nutrition expertise through the use of consultants, by establishing a nutrition advisory committee, by appointing one or more members well informed about nutritional issues, or by some other means.

Since the nature and causes of nutrition problems differ among countries and population groups within countries, it is important that national agricultural research institutions be heavily involved in efforts to strengthen the interaction between human nutrition and agricultural research. Although the IARCs are taking the lead, the majority of the future activities needed may well be undertaken by national institutions because each IARC covers a number of countries with a variety of nutrition problems. It was recommended that the IARCs strengthen the exchange on nutritional issues with national agricultural research institutions in order to incorporate nutritional considerations more effectively in research planning at the national level as well as the international.

One potentially effective way of incorporating nutritional concerns into national agricultural research is through training of staff of national institutions. It was recommended that the IARCs consider the incorporation of issues related to the interaction between human nutrition and agriculture into their training programs on production, farming systems, research management, and other appropriate subjects.

The interaction between agricultural research and government food policy in alleviating nutritional problems was discussed on several occasions during the workshop. The interaction between the two is clearly of great importance in efforts to reduce nutritional deficiencies. It was recommended that current research by IFPRI on the effects of selected food policies on nutrition and the interaction

between nutrition and agriculture be continued and that other centers communicate to IFPRI related research needs as they are identified in efforts to strengthen the nutritional effects of agricultural research.

Summary of Recommendations for Follow-up Activities

It was recommended that:

1. The IARCs begin research to estimate the effects of past agricul-cultural research on human nutrition either globally or for selected countries, commodities, and research programs, with initial emphasis on the development and testing of appropriate analytical methodology. The feasibility of collaboration in the CGIAR impact study now under way should be explored.

2. Those IARCs that have not already done so make it explicit in the interpretation of their mandates that due consideration be given to nutritional issues.

3. The IARCs and TAC explore whether certain classes of commodities that have particular nutritional value could be given more emphasis in the research agenda.

4. The IARCs undertake or promote the collection and analysis of data to provide an estimate of the relative importance of each major food commodity in the diets, expenditures for food, and incomes of the rural and urban poor and malnourished and of the adjustments that the poor and malnourished make in their consumption of food in response to changes in incomes and food prices.

5. As materials approach release by the IARCs, the centers signal any results from the testing for nutrient and antinutrient content that indicate that the content is below normally acceptable standards.

6. The IARCs explore whether and how nutritional considerations can be incorporated more effectively into farming-systems research. To begin such efforts it was proposed that one or more meetings or workshops of interested IARC farming-systems researchers and experts from outside the IARCs be held to identify the most appropriate approach or approaches, including the specification of the data needed, key parameters, analyses, and possibly field testing (case studies) involving one or more centers and outside experts.

7. The IARCs explore ways in which more extensive work by the centers or others on postharvest technology, including prevention of storage losses and deterioration of the nutritional quality, various marketing losses, and losses in home and village processing, could enhance the nutritional effects of IARC activities.

8. Each center name a staff member as contact person for the exchange of information about nutrition and that one of the persons

or centers serve as coordinator on a long-term or annual rotating basis. This information network would assure that information on center activities related to nutrition is distributed to all centers, collaborating national agricultural research institutions, and other interested parties. It would maintain contact with and receive information about nutrition that is of interest to the IARCs from institutions outside the centers, such as ACC/SCN, FAO, WHO, and regional and national nutrition institutes. And it would assure that the momentum built up during the workshop is maintained.

9. The IARCs explore the feasibility and potential usefulness of establishing or strengthening links with nutrition institutions and related agencies that can provide support services, collaborate with the centers, or exchange information of benefit to the centers.

10. The IARCs review their needs and opportunities for strengthening the availability of nutrition expertise, including the addition of short-term or long-term staff members, consultants, advisory committees, and so forth, and communicate such needs to institutions and individuals such as the ACC/SCN, FAO, and bilateral donor agencies that may be able to provide resources to help meet those needs.

11. The IARCs strengthen the exchange on nutritional issues with national agricultural research institutions in order to incorporate nutritional considerations more effectively into research planning at the national level as well as the international.

12. The IARCs consider the incorporation of issues related to the interaction between human nutrition and agriculture into their training programs on production, farming systems, research management, and other subjects.

13. Research now being done by IFPRI on the effects of selected food policies on nutrition and the interaction between nutrition and agriculture be continued and that other centers communicate their research needs to IFPRI as they are identified in efforts to strengthen the effects of agricultural research on nutrition.

14. Consideration be given by TAC to strengthen its nutrition expertise through the use of consultants, a nutrition advisory committee, appointment of one or more TAC members with strong knowledge of nutritional issues, or by some other means.

3
Incorporating Nutritional Goals into the Design of International Agricultural Research — An Overview*

Per Pinstrup-Andersen

International agricultural research has facilitated rapid expansion in food production and productivity in many developing countries. Although some have questioned whether the poor have obtained their fair share of the benefits, it is now documented beyond reasonable doubt that urban as well as rural poor in general would have been considerably worse off without the "green revolution."[1] This is not to argue that research aimed at expanding food production and improving productivity has been or should be considered an ideal substitute for other policies to improve the lot of the poor. Increasing rural income and providing more abundant and less expensive food are only some of the elements of a successful effort to improve living standards among the poor. Without other essential elements, including appropriate government policies, many of the poor may be bypassed, and some may be worse off as a consequence of the changes brought about through agricultural research.

A review of a large number of studies of the equity effects of the green revolution shows clearly that the extent to which poor people gain or lose from the introduction of new agricultural technology is affected significantly by the present distribution of ownership of productive resources, access to modern inputs, the structure of the market, and the presence or absence of various related policies along with commodity priorities in research, technology characteristics, and other elements of research strategies.[2] Thus, although agricultural production research per se should not be expected to eliminate skewed distribution of income and associated problems such as poverty and malnutrition, its effects, both positive and negative, on the poor

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* This is a revised version of a paper presented at the meeting of the directors of the Centers of the Consultative Group on International Agricultural Research, Washington, D.C., November 5, 1982, and published in Food and Nutrition Bulletin 5 (October 1983).

[1] Per Pinstrup-Andersen, Agricultural Research and Technology in Economic Development (London and New York: Longman, 1982).

[2] Ibid.

and their nutritional status can be highly significant and is likely to depend to some extent on decisions made by the research community. It is for this reason that the nutrition implications must be explicitly considered in decisionmaking on agricultural research if the positive effects are to be enhanced and the negative effects avoided.

Direct nutrition intervention programs such as feeding programs for preschool children may help reduce nutritional deficiencies. To be effective, however, they are often excessively costly. Furthermore, because they frequently do not in time become self-sustaining, their effectiveness may depend on a continued outlay of public funds. Thus, while such programs may provide a partial solution to the nutritional problem in the short run, a long-term self-sustaining solution must be sought through broader development efforts that will eventually reduce, perhaps even eliminate, the need for direct nutrition intervention programs. Agricultural research and related policies offer great opportunities for such long-term nutritional improvements, principally through higher incomes to low-income producers and agricultural workers, lower unit costs of production and thus lower food prices to low-income consumers, or both.

To realize these opportunities fully, nutritional issues must be explicitly considered when agricultural research is planned, and due consideration must be given to potential nutrition effects of alternative research priorities and technology characteristics. If such consideration is not given, positive nutrition effects may not be fully realized, and negative effects may be overlooked or ignored. This is not to suggest that nutritional goals should take priority over other goals of agricultural research, but that they should be explicitly considered along with other goals. If the nutritional effects of alternative research strategies are estimated, it is possible that positive nutrition effects may be enhanced and negative effects reduced without unacceptable losses in the achievement of other goals.

Positive nutrition effects of modifications in research strategies may exceed the effects of direct intervention programs whereas negative effects may cancel them. Thus, ignoring the potential nutrition effects of modifying agricultural research and related projects and policies while promoting direct nutrition intervention programs makes little sense even in the short run.

The purpose of this paper is to suggest a conceptual framework for discussing how the nutritional effects can be incorporated into the planning of international agricultural research and how such effects can be assessed. I shall therefore attempt to identify ways in which the nutritional effects of agricultural research come about and how they can be enhanced. It is hoped that the paper will serve as a background against which the various center papers and syntheses can be discussed.

THE LINKAGES

Agricultural production research influences human nutrition through its effects on

1. Incomes acquired by households at risk of having malnourished or undernourished members.
2. The prices they must pay for food commodities.

3. The nature of the production systems among semisubsistence farmers.
4. Risk and fluctuations in food production, storage, prices, and incomes.
5. The nutrient composition of the foods available to malnourished households.
6. The composition of household income, intrahousehold income and budget control, and the allocation of women's time.
7. The demand for labor.
8. Expenditures of human energy.
9. Infectious diseases.

Although the reasons for calorie-protein deficiencies differ among countries and population groups, the primary reasons are likely to be low household incomes, insufficient food, and high food prices. Changes in any of these three factors are likely to influence food consumption. From a nutritional point of view, only changes in food consumption by households within which some or all members are now malnourished or in which the risk of malnutrition is significant are of interest. Thus, changes in food supplies affect the nutritional status only to the extent that the food consumption of malnourished or at-risk individuals is affected. The degree to which expanded food production is translated into expanded food consumption by the malnourished varies depending on the crop or livestock species of which production is expanded, the nature of the technology that brings about the expansion, and who produces the increase. Thus, using total production expansion as a proxy for nutritional effect is likely to be misleading.

Incomes and Food Prices

Changes in the incomes of households in which some members are malnourished and the food prices that these households face influence their ability to obtain food and may also influence the relative costs of the various food commodities and the cost of food in relation to other goods that compete for the household budget.

Food consumption by the poor--particularly the urban poor and those rural poor who do not produce part or all of the food they consume--is highly sensitive to changes in prices of individual food commodities. Thus, changes in food prices and their fluctuation in time are of particular interest from a nutritional point of view. High price levels and severe price fluctuations are much more harmful to the poor than to the better-off consumers. On the other hand, low price levels may have severe negative nutrition effects among rural poor who depend on food production for their incomes, whether they are producers or farm labor. Furthermore, the long-run nutrition effects of low food prices on both the urban and the rural poor may be severe because of the disincentive effects in food production.

The effect of expanding production on food prices--and therefore on urban and some rural malnutrition--depends on a number of factors, particularly foreign trade policies and price policies. If free trade is maintained and domestic food prices reflect international prices, expanding production of tradable commodities is unlikely to cause significant reductions in prices other than perhaps short-term local

reductions caused by ineffective marketing and transport facilities.[3] In those instances, the effect on the nutrition of the urban poor may be negligible. On the other hand, if domestic prices are insulated from international prices--as they frequently are--and are permitted to adjust to reflect the additional domestic supply, then the nutritional status of the urban poor and those rural poor who do not derive their incomes from the production of the commodities for which prices are declining may be significantly improved because their purchasing power increases and food becomes less expensive in relation to other goods. The effect on those of the rural poor who derive their incomes from the production of such commodities will be positive in the former instance and negative in the latter.

Whether the agricultural research community may influence foreign trade and price policies is not at issue. Rather, what is important in the context of this paper is that agricultural research may facilitate a reduction in the unit cost of production, thus generating an economic surplus that can be captured by the producer, landless labor, or the consumer--in the form of lower food prices--or shared in some proportion among the three groups. The distribution of this surplus will be determined largely by policies outside the reach of the research community, although research decisions regarding commodity priorities and technology characteristics will also have their effects. What is of even greater importance from a nutrition perspective is the distribution of benefits between malnourished and well nourished in each of the three sectors--consumers, labor, and producers. Again, decisions about commodity priorities in research and about technology characteristics as well as about policies are likely to influence the distribution of benefits and thus human nutrition.

The Production System, Risk, and Fluctuations

A considerable proportion of present malnutrition is found among households that produce most or all of the food they consume--the semisubsistence farm households. Changes in the cropping systems of those households that influence the amounts and kinds of food produced and the fluctuations in the availability of food during the year may be much more important than changes in food prices. Agricultural research may change the crop mix and the cropping patterns to meet the nutritional requirements of the semisubsistence farm family better. It may also bring about a deterioration of the nutritional situation of these families.

Traditional systems have been developed, modified, and adapted throughout a long period to meet the goals of farmers, including implicit or explicit nutritional goals, within existing ecological conditions and constraints outside the farm. Agricultural research may remove some of the constraints and thus greatly improve the living standards, including the nutritional status of the farm families. To assure success in such efforts, however, it is important to understand

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[3] Prices may decline initially, reflecting transaction costs, in countries that shift from being net importers to being net exporters.

why farmers use existing systems and what the repercussions would be if the systems were changed. This requires farming systems research and on-farm testing of various systems, including those traditionally used by low-income farmers.[4]

Research and policies that cause a shift from mixed cropping systems to monocropping should be carefully watched for possible negative nutritional effects. This is particularly important for activities that promote substitution of a cash crop for a mixture of food crops traditionally produced for home consumption. This is not to argue that the nutritional effects of such projects are usually or always negative. The additional incomes generated within the farm household and the associated expansion of food purchase may fully compensate for the loss in consumption of own produce and provide for additional real incomes that can be used for improvements in nutrition or other desired welfare gains. But increasing risk associated with monocropping, local price increases for traditional foods caused by the change from semisubsistence food production to cash-crop production and inefficient food-marketing systems and a number of other factors may produce a nutritional effect smaller than expected or even negative.[5]

Calorie-protein deficiencies, particularly among the rural poor, often are a result of fluctuations--both seasonal and irregular--in food prices, incomes of the malnourished, and the availability of food. Depending on its nature, agricultural research may contribute to this problem--through substitution of monocropping for mixed cropping, for example, in situations in which present policies and rural infrastructure are unable to deal effectively with such a change--or it may alleviate the problem by improving production or storage systems or making available improved crop varieties, such as varieties that permit a more appropriate crop rotation, pest- and disease-resistant varieties, and varieties with more stable yields under difficult and variable climatic regimes.

Nutrient Composition

Agricultural research may also influence human nutrition through improvements in the nutrient composition of a particular crop. Improvements in the protein quality of maize and sorghum are a case in point. In the past, the nutritional implications of agricultural research were frequently assessed on the basis of the extent to which

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[4] For additional discussion, see Bede N. Okigbo, "Introducing Nutritional Considerations into Research and Training in Farming Systems," paper presented at the ACC/SCN Symposium Introducing Nutritional Considerations into Agricultural and Rural Development, Rome, March 2, 1981.

[5] For a discussion of the nutritional effects of shifts from semisubsistence to cash crop production, see Per Pinstrup-Andersen, "The Impact of Export Crop Production on Human Nutrition," in Nutrition and Development, ed. Margaret Biswas and Per Pinstrup-Andersen (London: Oxford University Press, 1984).

the nutritional composition of a given food was improved. At the extreme, there was an underlying goal of making the nutritional characteristics of an individual food match as closely as possible the nutritional needs of people as if that food did not enter into a multiple-commodity diet. The result of such emphasis was clearly misleading guidance for agricultural research. What is important is not whether greater intake of nutrients by the malnourished is a result of the improved nutrient composition of a particular food, more nutrients from a larger quantity, or a more appropriate dietary mix of various foods. What counts is greater intakes from the diet as a whole. In some instances, this is best accomplished by modifying the nutritional composition of particular commodities; in others it is more efficiently done by making available more and cheaper foods that will add up to an adequate diet.

Intrahousehold Factors

Agricultural research may influence human nutrition through changes in the composition of household income--from own production to cash, for example; in control of intrahousehold income and budgets--by changing the share controlled by women as new technology is introduced in food production on semisubsistence farms; and in the allocation of women's time--by changing the demand for women's time in food production and processing and thus changing the time available for food preparation and child care.

The effect on these factors--and thus on nutritional status--may vary among agricultural research strategies. They should therefore be explicitly considered in research planning. Current understanding of the relevant processes is still deficient, however, and additional research is needed to assist in clarifying the way agricultural research planning can best deal with this issue.

INCORPORATION OF NUTRITIONAL GOALS INTO AGRICULTURAL RESEARCH PLANNING

In view of these linkages between agricultural research and human nutrition, what can international agricultural research centers do to assure that nutritional goals are considered along with other goals in the planning of their programs and other activities? There are four areas of decisionmaking in which nutritional concerns might be incorporated:

1. Establishment of commodity priorities.
2. Specification of desired changes in the characteristics of certain commodities.
3. Specification of desired technology characteristics.
4. Choice of production systems to be researched.

Each of these four areas is discussed briefly below, with emphasis on the principal nutrition-related issues, the way nutritional goals could be explicitly considered, and the type of information needed. Current efforts by the international agricultural research centers in each of these areas are discussed in papers by the various centers and in the synthesis papers.

Commodity Priorities

The key issue here is the change in total calorie and nutrient intakes by the malnourished that would come about as a consequence of the introduction of yield-expanding or yield-stabilizing technology for particular crops or species of livestock. This would be determined primarily by the relative importance of the crop or livestock species in the total diet of the malnourished and their reaction to changes in the price of the commodity, the extent to which farm households with malnourished members produced the crop or livestock species, the extent to which additional employment was created, and existing price and trade policies.

If malnutrition is found primarily among those who do not participate in the production of food--that is, urban and some rural consumers--research emphasis should be placed on commodities that occupy a large share of the food budgets of these consumers and for which price reductions would lead to increased consumption of the particular commodity or to substitutions among foods to bring about relatively large increases in total intakes of calories or of the nutrients in which they are deficient, or both.

If, on the other hand, nutritional deficiencies are primarily found among low-income agricultural producers, research emphasis should be placed on commodities that would generate more income for these households, reduce risks and seasonal fluctuations, or make more food available to them from their own production. Since international agricultural research serves a number of countries and since the relative importance of malnutrition among consumers and producers differs from one country to another, priorities among commodities in international agricultural research cannot usually be limited to one or the other. Ideally, from a nutritional point of view, emphasis would be on commodities that occupy a large share of the budgets of households with malnourished members and for which reductions in prices would bring about a large increase in total intakes of calories and protein by those households, that occupy a large share of the resources, both land and labor, owned or controlled by farm households with malnourished members, and that generate employment and incomes for the landless poor, primarily labor and rural services.

While the "nutritionally ideal" combination of commodities may be unattainable because of conflicts with desires to achieve other goals or for other reasons, attempts to move toward such an ideal may nevertheless be feasible. Their success will depend on the availability of information on the foods consumed and produced by households with malnourished members, the way these households would adjust their intakes of food in response to changes in prices of individual food commodities and incomes, and the commodity-related employment of rural landless poor and the probable effects of technological change.

The information now available provides some general idea of what poor people eat. It is deficient at best, however, and partly for that reason the use of such information in planning agricultural research policy has been an exception to the general rule of using average consumption figures for the population as a whole. But average figures are not particularly useful for estimating nutrition effects because they do not adequately reflect consumption by the malnourished.

Similarly, reported household reactions to changes in prices and incomes as measured by the price and income elasticities of demand usually reflect the population as a whole. Since the concern is for households with malnourished members, the parameters must be relevant for these households. In societies in which the distribution of income is highly skewed, and there is considerable malnutrition, average estimates are not likely to represent the behavior of households with malnourished members. Thus, the relevant parameters must be estimated by population group.

Reliable estimates of such parameters specifically for groups of households with malnourished members are of recent origin and their use has been limited. During the last few years, however, there has been a considerable increase in research efforts to estimate demand parameters by income stratum, and there are now reliable estimates for a small number of countries.

Although usually each research institute is charged with a certain portfolio of commodities, it is nevertheless possible to alter the budget allocation to each of these commodities. Furthermore, relative emphasis on various commodities within the research system as a whole is an important consideration for which additional information would be useful. Efforts by the international agricultural research institutes to obtain relevant information in this general area are discussed in other papers prepared for this workshop.

Commodity Characteristics

As stated earlier, the important question concerning nutrition is whether total intakes of digestible nutrients by an individual are sufficient and not whether any particular nutrient originates from one food or from another. In most instances, foods now being consumed by the malnourished are capable of providing an adequate diet if consumed in sufficient quantities and appropriate combinations. Thus, improving nutritional characteristics of foods now being consumed by the malnourished is not essential to eliminate malnutrition. This does not mean, however, that potential nutritional gains from the improvement of traditional foods should be ignored in agricultural research. A modest research input into the testing of promising material for the breeding and selection of such things as protein content, quality, digestibility, oil content, and digestibility of available nutrients may facilitate a more appropriate choice of such material without unacceptable reductions in the achievement of other goals such as better yields and greater yield stability. Such testing of commodities that show large genetic variation in a particular nutrition-related characteristic critical to those who traditionally consume the commodity is especially important.

Increasing the energy density of foods that show large genetic variation in oil content and that are traditionally principal sources of calories for calorie-deficient population groups is a case in point. Improving the quality, quantity, or digestibility of the protein content of food that presents large genetic variation in these characteristics and that is an important component of diets with specific protein deficiencies is another example, provided that the additional protein is expected to be available at a lower price than the cheapest alternative source acceptable to the consumer.

In addition to nutrient composition, attention should be given to characteristics that influence the acceptability and real cost of a particular commodity to low-income consumers--its cooking quality, texture, and color, for example. Reducing processing and preparation time in homes in which the time of women is limited without increasing unit cost may be of some importance.

Decisionmaking in this area requires five types of information. First, it is important to know whether a particular food is an important element of the diets of people who suffer from other nutritional problems than a combined calorie-protein deficiency that could be overcome simply by expanding consumption of the particular food. This could be learned by investigating the consumption patterns of the malnourished, as discussed under commodity priorities. Second, information is needed about consumer preferences regarding the characteristics of a particular commodity, such as its cooking quality, color, and texture, how these preferences vary among income groups, and how they may change if nutrient contents are changed. Third, information on genetic variation in the particular nutrition-related characteristics is important. Fourth, the actual testing will provide guidelines for breeding and selection. Finally, implications of changing commodity characteristics of other parts of the food system--spoilage problems associated with higher oil content and their effects on the costs of processing and distribution, for example--should be anticipated and included in the estimation of nutritional effects.

Technology Characteristics

Research decisions determine or influence the nature of the resultant technology, which in turn influences human nutrition in at least four ways. First, the nature of the technology is an important determinant of how much more is produced of a particular commodity and at what cost; the nutrition implications were discussed under commodity priorities. Second, the extent to which rural households with malnourished members gain from new technology depends on whether the technology is suited to the production environments controlled by these households and on its effect on employment. Thus, identification of the production environments most commonly controlled by these households along with explicit specification of the production environments to which particular technology designs are best suited would be useful in efforts to incorporate nutrition concerns in the decisions that influence the nature of the technology to be developed.[6]

Third, since seasonal and irregular fluctuations in the availability and prices of food and in incomes contribute significantly to malnutrition in many rural areas, new technology that facilitates reduction of such fluctuations would be preferable from a nutritional point of view. In international agricultural research, high priority has long been given to reducing lodging losses, increasing resistance

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[6] The interaction between the nature of new technology and distribution of control over production environments and the relationship to benefit distribution is discussed further in Pinstrup-Andersen, Agricultural Research and Technology, pp. 124-132.

to pests, adapting commodities to improved cropping patterns, and other factors that increase yields while reducing the risk of crop failure and diminishing seasonal fluctuations, thus serving nutritional goals as well as others.

Finally, the interaction between technology characteristics and household decisionmaking and allocation of labor may be an important consideration from a nutritional point of view. Particularly important is the extent to which women in low-income farm households participate in making decisions regarding the adoption of technology and the allocation of labor and the way technological change affects the allocation of women's time to other nutrition-related activities, such as child care--including breast-feeding--and food preparation. These issues have traditionally been ignored in the design of technology.

Although research on this topic is of recent origin and is still limited, it is clear that women have a considerable share in making decisions regarding adoption of technology and allocation of labor on low-income farms and that ignoring this fact may lead to misspecification of technology.[7] There is also some evidence of the trade-off between greater demand for women's time in agriculture and reduced allocation of labor to child care and food preparation.[8] The most important issues appear to be whether the low-income farm household is able to capture the benefits from new technology only if women allocate more time to the crop, whether these women are willing and able to allocate additional time, and what the nutrition implications are of such changes in allocation of time, possibly away from child care, cooking, food gathering, water bearing, and care of livestock.

The effect of technological change on the distribution of control of the household budget between men and women and the resultant effects on food consumption and nutrition is another important issue that deserves additional attention from the research community.

Production Systems

From a nutritional perspective, the key issue for research on production systems is how existing systems can be changed so that malnourished members of farm and rural labor households can increase their intakes of dietary elements such as calories, protein, and vitamins during critical periods whether from household production or from purchase. Many of the issues raised in the foregoing discussion of commodity priorities and technology characteristics--production

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[7] Irene Tinker, New Technologies for Food Chain Activities: The Imperative of Equity for Women (Washington, D.C.: U.S. Agency for International Development, 1979); Christine Jones, "Women's Labor Allocation and Irrigated Rice Production in North Cameroon," paper presented at the Conference of the International Association of Agricultural Economists, Jakarta, August-September 1982; and Jane I. Guyer, "Household Budgets and Women's Incomes," Working Paper No. 28, African Studies Center, Boston University, Boston, Mass., 1980.

[8] Barry M. Popkin,"Time Allocation of the Mother and Child Nutrition," Ecology of Food and Nutrition 9 (1980): 1-14.

environments, risk, seasonal fluctuations, and household decision-making--are also relevant to decisions about production systems.

The effects of changes in existing systems on the ability of the household to meet its nutritional requirements from its own production should be assessed. This is not to argue that research on production systems should be focused solely on subsistence food production. Rather, the focus should be on an appropriate mix of cash and subsistence crops to meet nutritional needs, whether from its own production or from purchase--while general expansions in real household incomes are sought. Local marketing inefficiencies, the inability of the household to deal effectively with rapid transition from a semi-subsistence economy to a cash economy, and related factors may render traditional economic criteria ineffective in assuring nutritionally appropriate changes in existing production systems. The question is not whether but how rural transformation should be promoted. Arguments that rural transformation based on technological change is generally disadvantageous to the rural poor conflicts with the empirical evidence. A great deal can be done to avoid hardships on the poor and to enhance positive effects. Agricultural research can do some, public policies and institutional changes must do most.

4
Nutritional Objectives in Agricultural Research — The Case of CIAT*

Douglas H. Pachico

Centro Internacional de Agricultura Tropical (CIAT) sees its primary function as that of developing food production technology in order to increase food output, improve nutrition among the malnourished, and increase farm income.[1] Although better nutrition occupies an important position among these objectives, it is clear that other factors also enter into the decisionmaking of CIAT. Expansion of the agricultural frontier in the acid infertile soils of Latin America, for example, is a primary concern of the CIAT pasture program,[2] and the bean and cassava programs are both concerned with intensifying production within the small-farm sector.[3] Though of undisputed importance, nutritional goals are nonetheless weighed in the context of other socioeconomic objectives.

Because these other objectives have in fact been considered in decisionmaking at CIAT, a discussion of priorities for nutrition and research can provide only a partial understanding of the way research priorities have been set. Nevertheless, it is useful to assess the influence of nutritional objectives in determining priorities. At CIAT they have historically been regarded alongside the policy that "CIAT gives special emphasis to Latin America."[4] The CIAT cassava program has for some years devoted growing attention to Asia, however,

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[1] Centro Internacional de Agricultura Tropical (CIAT), CIAT in the 1980s. A Long Range Plan for the Centro Internacional de Agricultura Tropical (Cali: CIAT, 1981), p. 1.

[2] CIAT, Tropical Pastures Program Annual Report 1980 (Cali: CIAT, 1980), p. 6.

[3] CIAT, CIAT in the 1980s, pp. 30-31.

[4] Ibid., p. 1.

and the bean program has been doing the same in Africa. While recognition of the nutritional significance of beans in Africa and cassava in Asia is growing, particular concern for Latin America dates from the initial conception of CIAT.[5] Consequently, assessment of the extent and nature of malnutrition in Latin America has long been a particularly important element of CIAT's planning and research.

NUTRITION AND COMMODITY PRIORITIES AT CIAT

The diversity in the importance of different foods in the diets of Latin American countries is reflected in the thinking that led to the original definition of CIAT's mandate. "[CIAT] would not be concerned with a single crop or enterprise."[6] In its original conception, CIAT would work on grain legumes, such as beans, cowpeas, pigeon peas, and soybeans; cereals--maize and rice; livestock--beef and swine; and starchy staples, such as cassava, plantains, sweet potatoes, and yams. Although this array of commodities includes a number of foods of nutritional importance in the region, it clearly represents a highly ambitious research agenda. Commodity priorities were gradually refined so that by 1980 CIAT was working on its current portfolio of commodities: beans, cassava, rice, and tropical pastures for beef production.

Although better nutrition is but one aspect of the multidimensional objective of CIAT, each of its commodities has a particular nutritional function. Beans are an important source of protein in Brazil, Central America, and Mexico. Bean consumption is highest among the poor and in rural areas, and it is often a significant source of calories. Since beans are a small-farmer crop, improved bean technology could contribute to nutrition by increasing the incomes of small farmers. Beans are also of great nutritional importance in parts of eastern and southern Africa.

In Brazil, Colombia, and Venezuela, where extensive savannahs offer scope for technology to improve pastures, expenditures for beef and dairy products are large, even among the poor, and consumption of these products rises sharply with income. Beef consumption also tends to be higher in urban areas than in rural. Beef and dairy products together are not only important as sources of protein, but in countries such as Colombia and Venezuela they also provide more than 10 percent of total calories.

Cassava is a traditional small-farm crop and staple food in the rural lowland tropics, and it remains an important source of calories in northeast Brazil and Paraguay. Consumption tends to be lower in

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[5] Lowell S. Hardin, "CIAT: Mandate Objectives and Achievements," paper presented at the Tenth Anniversary Symposium, CIAT, Cali, 1983; and L. W. Roberts and Lowell S. Hardin, A Proposal for Creating an International Institute for Agricultural Research and Training to Serve the Lowland Tropical Regions of the Americas (New York: Rockefeller Foundation and Ford Foundation, 1966).

[6] Roberts and Hardin, A Proposal for Creating an International Institute.

urban areas, implying a need for technology for processing or storage. The protein contribution of cassava can probably best be increased by using it as animal feed. In Asia cassava is also an important source of calories, especially for the poor in Indonesia and Kerala, India.

Rice is important for both calories and protein in such countries as Brazil, Colombia, Costa Rica, Cuba, and Panama. Consumption of rice has risen dramatically throughout the region, from 29 kilograms per capita in 1960-62 to 41 kilograms per capita in 1978-80.[7] Rice is strongly preferred, moreover, and in some instances it is displacing such traditional food staples as maize and cassava.[8]

While the relative importance of individual commodities varies with income and region and between rural and urban areas, comprehensive data from Brazil show that the CIAT commodities consistently provide between 30 percent and 60 percent of total calories consumed and between 39 percent and 55 percent of total protein consumed, and they account for 20-48 percent of total food expenditures.[9]

To contribute to the definition of research priorities at CIAT, a study was begun at CIAT in 1970 to develop a methodology for appraising the nutritional effect of increasing the supply of a range of of foods as an instrument for setting priorities in agricultural research.[10] This study succeeded in demonstrating the viability of incorporating nutritional goals into the setting of priorities for agricultural research. The empirical results, based on a study of household food consumption in Cali, suggested that "rice, oil seed, cassava, and potatoes would provide the most effective means for improving calorie nutrition in the population studied and beef, beans and maize would be most effective in meeting protein nutrition goals."[11] Although there may appear to be a strong concurrence between CIAT's current commodity priorities and the commodities singled out in the study, it was certainly never the intention of the scientists who conducted this study to argue that patterns of food consumption in Cali should be relied upon to generate agricultural research priorities for the entire Latin American region. The

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7 Grant M. Scobie and Rafael Posada, The Impact of High Yielding Rice Varieties in Latin America, Series JE-01 (Cali: CIAT, 1977).

8 Douglas H. Pachico, N. R. de Londoño, and Myriam C. Duque, Economic Factors, Food Consumption Patterns, and Nutrition in Cali, SE-4-83 (Cali: CIAT, 1983).

9 Instituto Brasileiro de Geografía e Estatística (IBGE), Estudio Nacional de Despesa Familiar: Consumo Alimentar Antropometria (Rio de Janeiro: IBGE, 1978).

10 Per Pinstrup-Andersen, Norha Ruiz de Londoño, and Edward Hoover, "The Impact of Increasing Food Supply on Malnutrition: Implications for Commodity Priorities in Agricultural Research Policy," American Journal of Agricultural Economics 58 (No. 1, 1976): 132-142.

11 Ibid., p. 141.

difficulties of empirically estimating the parameters needed for the model, moreover, were recognized clearly.[12]

Besides being treated separately, nutritional goals have also been analyzed for planning purposes at CIAT as part of a multivariable objective function.[13] In order to assess allocation of resources between cassava and rice, the expected effects of new technologies on both rural and urban nutrition, import substitution, exports, incomes of landless laborers, small farmers, and large farmers were considered for cassava in Asia and Latin America and for rice in Latin America. Optimal strategies were not identified because both explicit policy weights to attach to different objectives and quantifiable data for many of the variables were lacking. Nevertheless, the analysis did succeed in alerting decisionmakers to the broad contours of the results of alternative research strategies in relation to a number of different policy objectives.

Several other research projects on individual commodities have been conducted at CIAT that have implications for the setting of research commodity priorities in order to achieve nutritional goals. Household expenditures for beef and milk, for example, were analyzed to determine the importance of these products for low-income urban consumers in Latin America.[14] This analysis, based on data from urban Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, and Venezuela, indicated that among low-income consumers beef accounts for between 9 percent and 25 percent of total expenditures for food, while milk accounts for between 8 percent and 18 percent. Income elasticities of demand for beef and milk were also estimated and were found to be higher among low-income consumers than among high-income consumers.

More recently time-series data from Brazil, Colombia, and Venezuela have been used to estimate income, price, and cross-price elasticities of demand for beef, pork, and poultry meat.[15] A high

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[12] J. A. Brandt and J. B. Goodman, "The Impact of Increasing Food Supply on Human Nutrition--Implications for Commodity Priorities in Agricultural Research and Policy: Comments," American Journal of Agricultural Economics 62 (No. 3, 1980): 588-591; and Per Pinstrup-Andersen, "The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy: Reply," American Journal of Agricultural Economics 62 (No. 3, 1980): 592-593.

[13] Gustavo A. Nores and John K. Lynam, An Evaluation of the Distribution of Potential Social Benefits of Rice and Cassava Research (Cali: CIAT, 1982).

[14] Eugenia Rubinstein and Gustavo A. Nores, "Gasto en Carne de Res y Productos Lacteos por Estrato en Doce Ciudades de America Latina," CIAT, Cali, 1980 (mimeographed).

[15] Luis R. Sanint, Libardo Rivas, and J. L. Cordeu, "Demanda de Carnes de Res, Cerdo y Aves en Brasil, Colombia y Venezuela: Un Análisis de Series Históricas," preliminary draft prepared for the workshop Trade in Cattle and Meats, Santiago, Chile, September 26-28, 1983.

degree of substitutability among these products was found, indicating that consumers are flexible in their meat-consumption patterns and adjust their purchases to changes in relative prices. The market shares of meats could therefore change substantially, for example, if cost-reducing technical change in either tropical pastures or cassava production were to reduce the relative price of beef or poultry. Market shares of products the prices of which are not reduced through technical change could erode rapidly. Although neither of the studies of beef consumption mentioned above addressed nutrition directly, the statistical parameters estimated in them are essential to a thorough study of nutritional implications of commodity priorities.

Similarly, an evaluation of the effects of new rice technology in Colombia revealed substantial economic benefits to low-income consumers because of both lower rice prices and increased consumption, but changes in nutrition per se were not treated.[16] It was found that the gains from new rice technology accrued principally to low-income consumers.

The effect on nutrition of new technology that reduced the price of farinha (cassava meal) in Brazil has been estimated,[17] using consumption functions obtained from data of the Estudo Nacional da Despensa Familiar (ENDEF) survey of some 45,000 households.[18] Without considering cross-price effects, this study estimated that the poorest 25 percent of the Brazilian population would increase its daily per capita calorie consumption by 45 calories as a result of improved cassava-production technology. In the rural northeast of Brazil, where it is estimated that up to 75 percent of the population suffers from calorie deficiencies,[19] among the poorest 25 percent it was estimated that cheaper farinha could supply as much as 20 percent of the average calorie shortfall for the region.

Although these studies of beef, milk, rice, and cassava all offer some evidence that can contribute to the setting of nutritionally based priorities for agricultural research, in none are cross-commodity comparisons attempted. The dominance of high-income groups in aggregate urban food expenditures, however, has been documented, and expenditure elasticities of demand for a broad range of commodities have been estimated.[20] This analysis indicated that food expenditures and the propensity to consume food remain sufficiently high in the upper-income quartile in Latin America and that growth in incomes,

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[16] Scobie and Posada, The Impact of High Yielding Rice Varieties.

[17] CIAT, Cassava Program Annual Report 1981 (Cali: CIAT, 1981).

[18] John K. Lynam and Douglas H. Pachico, "Cassava in Latin America: Current Status and Future Prospects," draft, CIAT, Cali, 1982.

[19] Getulio Vargas Foundation, Food Consumption in Brazil (Washington, D.C.: U. S. Department of Agriculture, 1970), p. 15.

[20] Douglas H. Pachico and J. K. Lynam, "Food Supply and Malnutrition in Latin America," in Latin American Agriculture (Cali: CIAT, 1981).

even if it occurred at a similar rate across income strata, would exert substantial upward pressure on food prices that would tend to cancel the effect of higher money incomes among the poor. Given the evidence that income growth in Latin America has been concentrated among the upper-income groups,[21] the urban poor may be caught in a malnutrition squeeze of slow growth or no growth in incomes and of rising prices caused by the demand of high-income groups for food. Since such a high proportion of the total expenditures of the poor are already for food, they have little scope for maintaining even present levels of nutrition by adjusting to rising food prices or by reallocating expenditures between food and nonfood items.

Through the normal working of market forces, moreover, technical change is likely to be induced in those commodities for which demand is strongest, price pressure greatest, and potential profits for producers highest. Without an explicit commitment of the research resources of the public sector to the contrary, growth in supply will tend to be biased toward commodities consumed primarily by high-income families and away from staples consumed primarily by the poor. To alleviate malnutrition in urban Latin America, then, the most rapid expansion of supply should occur in commodities for which expenditures are relatively high among the poor, or for which income elasticities of demand among the high-income consumers are low or negative.[22]

Those who administer the cassava and bean programs have recognized the importance of their commodities outside Latin America. A study of the demand for cassava in Asia has been undertaken in which the nutritional importance of cassava in India, Indonesia, Malaysia, the Philippines, and Thailand was considered in order to contribute to the setting of research priorities in the region.[23] Cassava was found to be a principal source of food in Indonesia, and in the Indian state of Kerala consumption of cassava is highest among the poor who cannot afford a diet of rice. It is thus a staple food in income groups most vulnerable to malnutrition. The use of cassava for animal feed or starch production was seen to be the principal future market potential for the crop in Malaysia, Thailand, and the Philippines. Varietal characteristics needed for these alternative markets were also discussed, as were characteristics of production systems. This study is to be used as a basis for setting research priorities among countries in the region, as well as for determining commodity characteristics.

The gravity of the nutritional situation in Africa, where population growth has been outstripping food production, is well known. After Latin America, Africa is the most important bean-producing region in the tropics, with a total annual production estimated at 1.5 million tons. Bean consumption per capita declined some 10 percent in Africa during the 1970s, and the region passed from being a net

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[21] J. Shail, Size Distribution of Income, A Compilation of Data (Washington, D.C.: World Bank, 1975).

[22] Pachico and Lynam, "Food Supply and Malnutrition."

[23] J. K. Lynam, "Cassava in Asia," in Trends in CIAT Commodities (Cali: CIAT, 1983).

exporter of food legumes to a net importer.[24] Nevertheless, beans remain critical in the diets of some of the peoples of Africa. Nowhere in the world do beans make a greater contribution to total national protein consumption than in Burundi and Rwanda, where beans provide a third of total protein, contributing more to total protein intake than all animal products combined. Beans are also known to be nutritionally important in Angola, Kenya, Tanzania, and Uganda, where 10-15 percent of total protein comes from beans.[25] Increasing attention has therefore been paid to Africa in the CIAT bean program for some years now, and a substantial research program is being developed there.[26]

COMMODITY CHARACTERISTICS AND NUTRITION: CASSAVA

After increasing the productivity of cassava and lowering its price, an original objective of the cassava program was to "explore the possibilities for improving the levels of high quality protein in cassava."[27] The importance of this objective is apparent from the known low levels of protein in cassava--typically 0.5-1.5 percent of weight--and the earlier assumption that protein shortage was the main nutrition problem in the low-income countries. The cassava program, though, was moved quickly to revise this priority, reporting only a year later that the "consensus is that the protein level is too low and cassava should be considered as an energy rather than as a protein source."[28]

A number of considerations lay behind this revision. First, there was little evidence of sufficient genetic variability to offer prospects of breeding varieties of cassava with higher protein content. Second, high-protein content was assumed to be associated with high levels of absorption of nitrogen and phosphorus from the soil, whereas the comparative advantage of cassava as a crop has come to be seen as its ability to produce carbohydrates in poor soils.

Third, there were no substantial populations in Asia and Latin America that were consuming cassava to the exclusion of other foods to the extent that they were dependent on cassava for protein. Consequently, the present philosophy underlying the cassava program is not to seek higher protein content through breeding, under the

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[24] Douglas H. Pachico and Walter Calderon, "Bean Consumption and Production in Sub-Saharan Africa: A Preliminary Review," in Trend Highlights in CIAT Commodities (Cali: CIAT, 1984).

[25] Food and Agriculture Organization of the United Nations (FAO), Food Balance Sheets (Rome: FAO, 1980).

[26] Pachico and Calderon, "Bean Consumption and Production in Sub-Saharan Africa."

[27] CIAT, A Proposal for the Improvement and Development of Cassava (Cali: CIAT, 1971), p. 11.

[28] CIAT, Cassava Program Review Conference (Cali: CIAT, 1972), p. 26.

assumption that adequate dietary protein will be obtained from other sources.

The presence of toxic hydrocyanic acids (HCN) has long been seen as a potential problem in long-term consumption of high levels of cassava,[29] and one response to this problem recently recommended is to select varieties of cassava that are low in cyanide.[30] Field studies in Africa, however, have shown that "chronic consumption of large quantities of cassava does not necessarily result in the development of endemic goitre."[31] Similarly, "although cassava is grown in countries such as India, Thailand, Indonesia and Malaysia, there is no evidence to show that cassava consumption plays any role in goitrogenesis in Asia."[32]

The onset of endemic goiter is dependent not only on the HCN content of certain varieties of fresh cassava and the amount of cassava consumed, but also on the level of iodine intake in the diet and the method of preparing cassava to be eaten.[33] Although high HCN content in fresh cassava does not necessarily lead either to short-term acute poisoning or to chronic problems of goiter or cretinism, consuming large quantities of varieties of cassava high in cyanide can nevertheless be a contributing factor in goitrogenesis. Breeding for acyanogenic cassava is a possible goal, but a costly massive inbreeding program might be needed, since this trait can be controlled by recessive genes.[34] Thus, the present strategy of CIAT is not to seek acyanogenesis in its cassava-breeding program. Instead, varieties are selected for low HCN content.

CIAT is also paying attention in its cassava program to several characteristics that influence the acceptability of cassava to consumers. Starch content has come to be seen as an important objective in the breeding program, at least for varieties destined for the fresh market. In research on the north coast of Colombia new varieties were found that, even if high yielding, would not be acceptable to farmers

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[29] Ibid.

[30] G. H. de Bruijn, "Towards Lower Levels of Cyanogenesis in Cassava," ed. F. Delange and R. Ahluwalia, Cassava Toxicity and Thyroid: Research and Public Health Issues (Ottawa: International Development Research Centre, 1983).

[31] F. Delange et al.,"Nutritional Factors Involved in the Goitrogenic Action of Cassava," ed. F. Delange and R. Ahluwalia, Cassava Toxicity, p. 23.

[32] N. Kochupillai and V. Ramalingaswami, "Public Health and Nutritional Aspects of Endemic Goitre and Cretinism in Africa," ed. F. Delange and R. Ahluwalia, Cassava Toxicity, p. 48.

[33] A. M. Ermans et al., "Role of Cassava in the Etiology of Endemic Goitre and Cretinism," ed. F. Delange and R. Ahluwalia, Cassava Toxicity.

[34] James Cock, "Comment: Animal and Genetic Research Trends in Cassava," ed. F. Delange and R. Ahluwalia, Cassava Toxicity.

selling to the fresh market in Colombia. Since high starch content is now perceived as a requirement for acceptance of fresh cassava by consumers, it is now as important a criterion as yield in the selection of fresh-market varieties.

The rapid postharvest physiological and bacterial deterioration of cassava is an important constraint to consumption of cassava. It has been observed that throughout urban Latin America, cassava consumption is lower than that of potatoes, even when cassava is the cheaper product.[35] While preferences may enter into the choice, the greater perishability of fresh cassava is also a factor. Consumers face the risk that the cassava they purchase may already be deteriorating or will have deteriorated by the time they use it. Frequent consumption of cassava requires the inconvenience of frequent shopping. Even if high-yielding varieties of cassava are developed, malnourished low-income consumers may not benefit greatly from them unless the constraints imposed by cassava's rapid postharvest rotting can be reduced. For that reason postharvest storage and handling of fresh cassava is the subject of a significant CIAT research effort.[36]

One method of enabling malnourished urban consumers to circumvent the limitations imposed on their consumption of cassava by its rapid postharvest deterioration is by processing it. Given the rapid rise in the consumption of wheat in Latin America, one potentially attractive form of delivering cassava to consumers is as a partial substitute for wheat in bakery products. It is recognized, however, that inclusion of cassava alone as a partial substitute for wheat will lower the nutritional quality of bread. Wheat, moreover, is one of the three main sources of protein in the diets of most Latin Americans. In order to promote the incorporation of cassava flour as a partial substitute for wheat without adversely affecting nutrition, funds are being sought to support research at CIAT on developing flour mixtures of cassava, wheat, and soy that are price competitive while maintaining good baking qualities and without reducing nutritional value.

The potential for using cassava as an ingredient in compound animal feeds is also being investigated at CIAT. This seems to be a promising market for cassava both because demand for poultry has always been strong throughout Latin America and because domestic production of feed grains has been insufficient to meet demand, leading to increases in imports of sorghum and maize in Latin America.[37] A pilot production program of cassava as an animal feed is now being launched by the Colombian government in its north coast departments. In this region, though, cassava has long been an important dietary staple.

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[35] Lynam and Pachico, "Cassava in Latin America."

[36] W. G. Janssen and C. C. Wheatley, "Urban Cassava Markets: The Impact of Fresh Root Storage," in Trend Highlights in CIAT Commodities (Cali: CIAT, 1984).

[37] Douglas H. Pachico, Willem Janssen, and John Lynam, "Ex Ante Analysis of New Technology: A Comparison of Cassava for the Feed and Fresh Markets in Colombia," Agricultural Systems 11 (No. 3, 1983): 131-142.

CIAT is therefore collaborating in an assessment of the effect of the promotion of cassava as an animal feed on the availability of cassava for human consumption.

COMMODITY CHARACTERISTICS AND NUTRITION: BEANS

The gravity of dietary protein deficiencies in low-income countries and the concern that the new rice and wheat technologies may even have exacerbated malnutrition as cheaper cereals have displaced high-protein food legumes were the principal problems cited in a proposal to initiate a field bean (*Phaseolus vulgaris* L.) research program at CIAT.[38] Not only was this focus on malnutrition the principal justification articulated for the program, but also several specific commodity characteristics were ranked high among proposed breeding priorities. These included improving the protein quality of beans by increasing the content of the sulphur-containing amino acids methionine and cystine and of tryptophan and by seeking to reduce the content of antimetabolates, hemagglutinating factors, trypsin inhibitors, linoleic acid, and flatus-producing factors.[39] These problems of quality and digestibility are of particular relevance for beans since compared to other important food legumes beans are very low in these factors.[40]

These various potential breeding objectives for beans can be conveniently grouped into improvements in protein quantity, protein quality, and digestibility. Although in some legumes it has been found that protein quantity is inversely correlated with yields,[41] present evidence for beans "indicates that it may be possible to select for high yield and high protein content."[42] Genetic variation has been observed in the protein content of beans, but an important environmental-genetic interaction appears to exist. Moreover, "in the pulses no major gene has been reported affecting protein quantity or quality.... The few studies to date ... have all indicated polygenic

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[38] CIAT, Field Beans and Soybeans: A Program Proposal for Research, Development and Training (Cali: CIAT, 1971).

[39] Ibid, pp. 2 and 4.

[40] R. A. Luse and K. O. Ratchie, "Seed Protein Improvement in Tropical Legumes," in Seed Protein Improvement in Cereals and Grain Legumes (Vienna: International Atomic Energy Agency, 1979).

[41] S. C. Litzenberger, "The Improvement of Food Legumes as a Contribution to Improved Human Nutrition," in Potential of Field Beans and Other Food Legumes in Latin America (Cali: CIAT, 1973).

[42] CIAT, Bean Program Annual Report 1982 (Cali: CIAT, 1982), p. 85.

control of these characters with additive genetic effects generally being the most important."[43]

Perhaps more important than the difficulties of breeding beans for a higher protein content is the lack of economic incentives offered by the market. Farmers will be little motivated to adopt high-protein bean varieties, all else being equal, unless they can expect a premium price after doing so. Yet there is no evidence to suggest that Latin American consumers would be prepared to pay more for high-protein varieties of bean.

The same lack of economic incentives stands in the way of increasing the protein content and digestibility of beans; screening for these factors, moreover, is very difficult. In part this is because the reasons for the poor digestibility of bean protein are understood only imperfectly. Even more problematic, though, is the present impossibility of identifying antinutrients and toxins or of measuring the biological availability of even the principal amino acids by purely chemical means. Biological trials--feeding food substances to experimental organisms--are presently the only methods available for assessing digestibility factors. This is not a very satisfactory method for screening a large number of breeding lines.[44] Moreover, there has "unfortunately ... been relatively little work done on the genetics of nutritional factors in pulses."[45] Work on breeding to improve protein quality and increase digestibility is therefore hampered by a lack of adequate screening techniques, a poor foundation in genetic knowledge, and a lack of economic incentives.

The objective of improving the protein quality of beans has also been called into question. It has been argued that since foods are never consumed alone, but always in mixed diets, the establishment of nutritional goals for a basic food such as beans must be seen in the context of the food-consumption system of which it is a part. In Central America, for example, beans are consumed as part of a maize-bean diet. Although beans are low in methionine and increasing their methionine content has been suggested as a breeding objective,[46] there is little to be gained in Central America from such an effort.

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[43] G. O. Hawtkin, K. O. Ratchie, and J. M. Green, "Breeding Strategy for Nutritional Improvement of Pulses," ed. J. M. Hulse, K. O. Ritchie, and L. W. Billingsley, Nutritional Standards and Methods of Evaluation for Food Legume Breeders (Ottawa: IDRC, 1977), p. 45.

[44] J. M. Hulse, K. O. Ratchie, and L. W. Billingsley, Nutritional Standards and Methods of Evaluation for Food Legume Breeders (Ottawa: IDRC, 1977).

[45] Hawtkin, Ratchie, and Green, "Breeding Strategy for Improvement," p. 44.

[46] Litzenberger, "Improvement of Food Legumes."

Nutritional goals can best be served in this context simply by increasing the rate of bean consumption in relation to that of maize.[47]

For all these reasons--poorly understood genetics, strong environmental interactions, weak market incentives to farmers, and lack of suitable screening techniques--improvement of protein content, quality, and digestibility are not now breeding objectives of the CIAT bean program. Instead, the aim is to evaluate advanced lines to ensure that the breeding program does not inadvertently select for beans of lower nutritional quality. This could happen if there were indeed an inverse correlation between high yield and protein content, or if, for example, resistance to some pests and diseases were related to the presence of polyphenols in the seed coat.[48] Preliminary evaluation studies of the protein content of advanced CIAT breeding lines suggest that neither selection for high potential yield nor selection for resistance to disease and insects appears to be reducing the protein content of seeds.[49]

Consumer preference and acceptance of beans can be as important a determinant of protein actually consumed as protein content or amino-acid balance. In the early stages of bean research at CIAT, relatively little weight was given to these factors. "At CIAT, work has been intensively conducted along the high productivity factor, without paying too much attention to the grain color factor.... National programs will be able to select from these high productivity materials ... then, back-cross them to their local varieties to recuperate the desirable grain characteristics."[50] This method has now been revised; in order to ensure the development of varieties acceptable to consumers, the present strategy is to send national programs only those new lines that satisfy local preferences concerning seed color and size.[51]

Studies are now being conducted in Colombia to refine methods of assessing consumer preferences toward beans. Estimated consumption functions have indicated that small red beans are an inferior good in Cali, while large reds are not.[52] Ethnic-regional background was also found to be a significant determinant of bean consumption.

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[47] L. G. Elias and A. Bressani, "Tentative Nutritional Objectives in the Major Food Crops for Plant Breeders," ed J. M. Hulse, K. O. Ritchie, and L. W. Billingsley, Nutritional Standards.

[48] Hawtkin, Ratchie, and Green, "Breeding Strategy for Improvement."

[49] CIAT, Bean Program Annual Report 1980 (Cali: CIAT, 1980).

[50] G. Hernandez Bravo, et al., "Bean Breeding," paper presented at the workshop on Genetic Improvement of Dry Beans, CIAT, Cali, 1975, p. 7.

[51] CIAT, Bean Program Research Strategies for Increasing Production (Cali: CIAT, 1981).

[52] Pachico, Londoño, and Duque, Economic Factors.

An attempt has also been made to relate bean characteristics to market price.[53] It was found that in Cali neither broth thickness nor cooking time, two factors that have received considerable emphasis in evaluation of bean quality at CIAT, was related to price or considered by consumers to be important.[54]

More detailed studies of the factors that influence consumer acceptance are now under way. Size, color, brilliance, shape, thickness and color of the broth, cooking time, and size and color after cooking are all factors that might influence consumer preferences; but it is being shown that for any particular market, only a subset of these traits may need to be considered, thereby relaxing somewhat the selection criteria by which breeders should be guided.[55] Complicating this effort, though, is a considerable variation, not only among countries but also among regions of a given country.

In sum, therefore, the CIAT bean program does not include improvement of protein content, amino-acid balance, or digestibility as objectives in varietal improvement; instead, its concern is to monitor the protein content of advanced lines. Improvements in nutrition are regarded as best coming from yield-increasing production technology that will reduce the price of beans, thereby permitting increased consumption. Consumer-acceptance factors, especially appearance, are, however, given high priority in varietal screening, and further studies of consumer preferences are being undertaken.

TECHNOLOGY CHARACTERISTICS, PRODUCTION SYSTEMS, AND NUTRITION

To discover the extent to which low-income small-farm families that are vulnerable to malnutrition gain from new technologies is a primary aim of both bean research and cassava research at CIAT. Both crops are produced principally by small farmers, and in the design and evaluation of technology considerable emphasis is placed on the development of technology appropriate for small farmers. Bean technology for small farmers can be developed by selecting varieties adapted to associated cropping systems, by selecting plant types that are difficult to mechanize, and through selection under the stresses of the environments in which small farmers with appropriate levels of input cultivate them.[56]

The central aim of the bean program has been to develop disease-resistant varieties that can be grown without the use of chemical

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[53] Ibid.

[54] CIAT, Bean Program Annual Report 1982; CIAT, Bean Program Annual Report 1980; CIAT, Bean Program Annual Report 1979 (Cali: CIAT, 1979).

[55] D. van Herpen, "Attitudes and Preferences Towards Beans in Cali: Development of a Methodology," CIAT, Cali, 1983 (mimeographed).

[56] Douglas H. Pachico, "Bean Technology for Small Farmers: Biological, Economic and Policy Issues," Agricultural Administration 15 (1984): 71-86.

inputs and in the farming system of the small farmer.[57] Furthermore, greater resistance to disease contributes to stability of production by reducing the risk of losses of yield. Food supplies thus become more dependable for consumers and the incomes of small-farm producers become more stable, thereby lowering the risk of reduced intake of nutrients for both low-income consumers and small farmers.

Small-farm systems are also the focus of the on-farm testing of new bean-production technologies. New varieties are tested within the farmers' present farming systems and at their present average levels of input. In three of the regions where new varieties are evaluated on the farm in Colombia, beans are grown in association or in relay with maize. In all these systems, beans are principally a cash crop for the farmer, while maize is grown for subsistence. New varieties that are adaptable to these existing systems are being sought.

In the high altitudes of the Andes, pop beans are cultivated in some areas. These are cooked like popcorn because the high altitude and shortage of fuel makes long boiling of beans an impractical cooking method. Although pop beans are not given a high priority, maintenance and some screening of pop bean germ plasm are being undertaken.

Since cassava is also a crop produced principally by small farmers, the emphasis of the cassava program is also on the development of technology appropriate for small-farm conditions. Consequently, varietal improvement is directed toward improving yields under marginal conditions, such as poor soil and frequent incidence of drought. Because of the long duration of the crop, reliance is placed on resistance to disease and pests rather than on chemical control. As in the bean program, on-farm trials of new technologies are conducted in the farmers' cropping systems. In some trials, therefore, cassava is grown in association with legumes, with cereals, and with other root crops.

Evidence from farm studies has shown that "contrary to what was observed in the Cerrado of Brazil and the Llanos of Colombia, extensive dairy ranching is practised in the Llanos of Venezuela."[58] Two-thirds of the ranches studied in Venezuela had dual-purpose herds, and an average of 34 percent of the income of these ranches came from sales of milk; the dual-purpose ranches also showed a higher rate of return on capital.[59] Similarly, it was found in a study of cattle farms in Panama that an average of 37 percent of the income came from milk.[60] These findings indicate that new pastures technology for the

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[57] CIAT, Bean Program Strategies.

[58] CIAT, Tropical Pastures Program Annual Report 1981 (Cali: CIAT, 1981), p. 251.

[59] C. Plessow, Un Estudio de Casos en la Región de los Llanos Nor-Orientales de Venezuela (Cali and Venezuela: CIAT and FONIAP-CIARNO, 1982), pp. 98 and 100.

[60] Carlos Seré, Ruprecht Schellenberg, and Ruben D. Estrada, Ganadería Doble Propósito: Diagnóstico de Sistemas de Las Provincias Centrales, Panamá (Panamá City and Cali: Banco Nacional de Panamá and CIAT, 1982), Table 68.

frontier can sometimes be usefully incorporated into dual-purpose herds when lack of infrastructure and distance from markets are not important constraints on the marketing of milk. Such dual-purpose production systems are especially attractive from the nutritional point of view, given the prominence of dairy products in the diets in Latin America. Dual-purpose herds also tend to be found more frequently among relatively small ranches.[61]

In the CIAT bean, cassava, and tropical pastures programs, considerable emphasis has been placed on the development of technologies adapted to high-stress, low-input environments so that resource-poor farmers can have access to the benefits of technical change. Neither low-input technologies nor high-stress conditions, however, are characteristic only of small, poor farmers. While in some instances the use of purchased inputs by small farmers is significantly limited by capital constraints or input-availability problems, in other situations the use of inputs is high among small farmers trying to maximize returns from their scarce land resources. Similarly, in some circumstances large farmers may be the principal beneficiaries of low-input technologies adapted to land-extensive production systems. Consequently, as CIAT seeks to slant the development of technology toward low-income producers, a balance is needed in technology design, with the features of new technology that make it appropriate to small farmers differing from country to country and from region to region within countries.[62]

This difficulty is illustrated by the use of herbicide by small farmers in Colombia. In one region the use of herbicide has increased dramatically among small bean farmers during the last few years as proximity to urban labor markets has made labor both scarce and expensive. This has occurred without the advice or encouragement of the extension system or the research system. In contrast, in another region of Colombia bean sharecroppers expressed the fear that trials of chemical weed control would lead to their loss of an important source of employment. Thus, there are often no general rules to guide the design of technology to the particular benefit of poor rural families that are vulnerable to malnutrition.

SUMMARY AND CONCLUSIONS

Nutritional factors have been important considerations both in the setting of commodity priorities at CIAT and in the determination of research strategies for individual programs. In common with the Consultative Group on International Agricultural Research system as a whole, concern with increasing food supplies, thereby improving nutrition, has been a fundamental motivation for the work of CIAT in general. Direct research on nutritional characteristics of new technologies, however, has been limited. As noted, the CIAT commodities in Latin America, like cassava in Asia and beans in Africa, form parts

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[61] Libardo Rivas and Gustavo A. Nores, La Evolución de la Ganadería Bovina en América Latina 1967/1977 (Cali: CIAT, 1979), p. 11.

[62] Pachico, "Bean Technology for Small Farmers."

of varied diets. In the Brazilian Northeast, for example, a diet containing large quantities of beans and cassava is typical, whereas in urban Brazil a diet built around rice and beef is often characteristic. Given these mixed diets, improvement in the protein content of cassava or rice, for example, has not been regarded as having a high priority because protein is supplied more efficiently through beans or beef. Increasing food consumption through the introduction of cost-reducing production technology is the principal means whereby nutrition is expected to be affected; and increased food consumption made possible by higher farm incomes is also seen as affecting nutrition.

Just as collaboration with national research and extension organizations is critical to the development of new technology for CIAT commodities, so also is collaboration with other institutes necessary in nutrition research. The CIAT bean program, for example, might benefit from advances in biochemical studies of protein digestibility that have led to more practical screening techniques. With limited resources and strong emphasis on applied research to improve bean-production technology, however, basic biochemical studies are considered to be outside the direct responsibility of CIAT, and CIAT depends on the work of others in the international scientific community.

Similarly, though the nutritional effects of technical change are recognized as important and have indeed been studied at CIAT, the costs of food-consumption surveys are so high and CIAT's areas of concern are so widely dispersed geographically that complete assessment of the potential nutritional effects of new technology cannot be conducted by CIAT alone. Collaboration with other institutions in the gathering of food-consumption data to estimate price and income elasticities of demand is essential for sound analysis of the nutritional effects of new technology. Lack of reliable estimates of these parameters greatly inhibits evaluation of the nutritional consequence of new technology, and a high priority must be given to collaborative research with other institutes to close this information gap.

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Nutrition in Agricultural Research at CIMMYT*

Robert Tripp

Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) has a global mandate to increase productivity in wheat and maize, the second and third most important staples in the developing world. Through collaboration with national programs--96 for wheat, 85 for maize--the research done by CIMMYT has had widespread effects. Since the inception of the CIMMYT wheat program, for example, national institutions have released more than 300 varieties of wheat, triticale, and barley that include CIMMYT germ plasm. Wheat grown on more than 35 million hectares in the developing world is derived in significant part from CIMMYT germ plasm. Similarly, during the last five years alone, 25 countries have released more than 100 varieties and hybrids of maize developed from CIMMYT materials.

The problem of malnutrition is also distributed globally. Various estimates put the number of inadequately fed people in the world between 500 and 800 million. But malnutrition is more difficult to characterize than trends in crop production or the release and distribution of improved varieties. Although the predominant form is calorie-protein malnutrition, other deficiencies are also widespread. And more variable even than the types of malnutrition is the range of factors responsible for its incidence; that is, although malnutrition is generally correlated with poverty, the specific causes vary from area to area. In some instances cash income is the primary factor; in others it is productive capacity; and often there are other biological and socioeconomic correlates. Although malnutrition is a global problem, the solutions must be location-specific.

How, then, can an institution such as CIMMYT, with a global mandate, ensure the applicability of its work to local problems of malnutrition? There are two principal approaches.

The first is to maximize flexibility and effectiveness by working through national programs. CIMMYT has long considered itself a producer of intermediate goods--germ plasm, procedures, and training--intended for national agricultural research programs. These national

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* This paper was prepared in consultation with the directors of the CIMMYT maize, wheat, and economics programs. The author wishes to thank the following colleagues for comments and contributions: Arnoldo Amaya, Chris Dowswell, Fritz Logan, Enrique Ortega, Surinder Vasal, and Evangelina Villegas.

institutions select from among the CIMMYT products those most suited to their own needs. Granted, the degree to which nutrition is a factor in this process varies among national programs, but most of CIMMYT's efforts at increasing the effectiveness of all its work, not only that concerned with nutrition, are directed toward strengthening national research capacities. This strategy underlies the description of CIMMYT work that follows and is prominent in the final section of this paper, which deals with suggestions for future work.

The second approach is to improve CIMMYT's own work in directing crop research toward specific target groups, the development of relevant crop characteristics, the consideration of production technologies, and the orientation of research on production systems. These are described in the sections that follow.

CIMMYT'S EFFECT ON HUMAN NUTRITION

The location-specific nature of malnutrition combined with the strategy of channeling the output of CIMMYT through national programs makes a precise assessment of the nutritional effects of CIMMYT's work particularly difficult. This is unfortunate, because a better grasp of these effects would give CIMMYT a valuable tool for evaluating its progress and, more important, for planning its future work. Some indications of CIMMYT's nutritional effects will, however, be discussed briefly here.

Because of the distribution of malnutrition, any assessment of the nutritional effects of agricultural research must be concerned with its effects on both producers and consumers. In some countries or areas it is resource-poor farmers who are the primary group at risk, while in others it is consumers--the urban poor and the rural landless--who form the bulk of the malnourished population.

To consider producers first, it is clear that the direction of technology toward those most in need is crucial for ensuring nutritional effectiveness. The importance of this is reflected in CIMMYT's allocation of research resources to the refining of techniques for identifying and reaching resource-poor farmers. More generally it is reflected in CIMMYT's efforts to develop germ plasm that can adapt to the various stresses that limit production in many environments. It is true that CIMMYT's success in the development of high-yielding wheats brought with it some criticism regarding possible bias toward the better-off farmers. It is also true that early successes with wheat tended to be in more favored areas, such as those with irrigation. Nevertheless, the charges of bias in favor of large farmers turn out to be based on impressionistic or anecdotal evidence. A careful examination of the available data shows that smaller farmers in such critical areas as the Punjab and northern Mexico who adopted the semidwarf wheats realized gains in productivity at least equal to those of larger farmers.[1] This finding is supported in an analysis of

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[1] Derek Byerlee and Larry Harrington, "New Wheat Varieties and the Small Farmer," paper presented at the Conference of the International Association of Agricultural Economists, Jakarta, Indonesia, August 24-September 4, 1982.

adoption behavior of both maize and wheat technology in a variety of settings.[2] Semidwarf wheats, moreover, have brought significant increases in productivity to small farmers in nonirrigated areas of countries as diverse as Turkey, China, and Bangladesh.

So there is undeniable evidence that large numbers of these resource-poor producers, who are among those who run the highest risk of malnourishment, have been reached by varieties that include CIMMYT germ plasm, with attendant increases in productivity, incomes and--probably--nutrition. The measurement of nutritional effect is still problematic, however, because the translation of increases in productivity to nutritional betterment is mediated by a host of location-specific biological and socioeconomic factors.

To assess nutritional effects on consumers accurately is more difficult still. An interesting analysis of the effect of advances in wheat production on the production of pulses and the availability of nutrients in India was done by Ryan and Asokan.[3] Their study showed that even with the attendant drop in pulse production, the increased wheat yields produced a substantial net gain in the availability of protein, energy, and essential amino acids. The problem in identifying actual effects, of course, is in disaggregating these results, as increases in production resting on CIMMYT-based germ plasm are subject to modification by policies that affect consumer price, imports and exports, distribution, and use. The task of separating these various components is challenging, but it has been attempted in only a few instances. To cite an important example, analysis of the effect on consumption of India's increased wheat production between 1961/62 and 1973/74 showed that consumption of wheat by the rural poor increased substantially.[4] In addition, wheat showed the smallest increase in price among the principal cereals marketed in urban areas, a fact that contributed to its availability to poor consumers.

In brief, then, varieties that incorporate CIMMYT germ plasm are widely used around the world and have contributed to substantial increases in production in developing countries. This suggests strongly that the nutrition of both producers and consumers has been improved. Even so, the evidence is not sufficient to establish the extent of CIMMYT's effect on nutrition precisely. To do that would require better measures, or at least effective proxies, for assessing this effect. Although CIMMYT itself does not have the expertise or the resources to develop such data, it recognizes the importance of

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[2] R. K. Perrin and D. L. Winkelmann,"Impediments to Technical Progress on Small Versus Large Farms," American Journal of Agricultural Economics 58 (December 1976): 888-894.

[3] J. G. Ryan and M. Asokan, Effect of Green Revolution in Wheat on Production of Pulses and Nutrients in India, Economics Program Occasional Paper No. 18 (Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 1977).

[4] P. S. George, "The Changing Pattern of Consumer Demand for Food Grains in India," Indian Journal of Agricultural Economics 35 (No. 1, 1980): 53-68.

generating relevant information and ensuring that national institutions and policymakers are able to make use of it.

PAST AND PRESENT CIMMYT NUTRITION-RELATED ACTIVITIES

Commodity Priorities

Wheat and maize, sources of food and income for millions of the world's poor, provide about a quarter of all food calories and proteins consumed in developing countries. Allocation of resources to the two crops by CIMMYT is roughly equal and will probably continue to be. CIMMYT is, however, vitally interested in the ways in which its mandated crops are used and how these patterns are changing. It has sponsored studies to look at these questions at the national level, and in a series of CIMMYT publications initiated in 1981 they are examined worldwide.[5]

The most recent analysis of maize consumption shows that it contributes about 13 percent of the cereal calories and protein consumed in the developing world. There are 51 developing countries with more than 100,000 hectares planted in maize. In 15 of these, maize represents an average of two-thirds of total cereal calories; in another 21 it represents about one-third. Of particular significance for future efforts of CIMMYT is the fact that those countries of Africa and Latin America whose dependence on maize for human food is greatest tend to realize the lowest yields per hectare.[6]

In the vast majority of countries that are heavily dependent on maize, the poor are the principal consumers, in both rural and urban areas. Yield increases benefit those farmers who grow maize as their staple; and if these increases lead to a reduction in the real price of maize, they can benefit lower-income consumer groups as well.

In spite of its importance to the poorer sectors, however, consumption of maize in developing countries is not increasing nearly as rapidly as consumption of other crops, such as wheat and rice. There are a number of reasons for this, but for the most part it represents the tendency of consumers to substitute the latter grains for maize as

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[5] See, for example, P. G. Ramachandran, "The Present and Future for Maize in India," lead paper at the International Workshop in Maize Utilization, Processing and Marketing, New Delhi, March 19-22, 1979; Centro International de Mejoramiento de Maiz y Trigo (CIMMYT), "Analysis of Changes in Production, Consumption, Trade, and Prices Over the Last Two Decades," in World Maize Facts and Trends, Report One (Mexico City: CIMMYT, 1981); CIMMYT, "Analysis of Changes in Production, Consumption, Trade, and Prices Over the Last Two Decades," in World Wheat Facts and Trends, Report One (Mexico City: CIMMYT, 1981); CIMMYT, "An Analysis of Rapidly Rising Third World Consumption and Imports of Wheat," in World Wheat Facts and Trends, Report Two (Mexico City: CIMMYT, 1983).

[6] David Rohrbach, "Maize Consumption in the Developing Countries," draft, Economics Program, CIMMYT, Mexico City, 1983.

their incomes rise. Another significant trend is the increasing use of maize as animal feed, but a corresponding decline in the importance of maize as a direct source of food has not been identified. Increased demand for maize as feed will mean greater pressure on supplies.[7]

The importance of wheat in the diets of developing countries continues to grow.[8] In less than 15 years it has moved from providing 20 percent of cereal calories to 27 percent and now provides about 33 percent of the protein. Wheat consumption per capita in developing countries has increased at a rate of 2.3 percent a year since 1961, the most rapid increase shown by any major food crop. Four of the principal producers--China, India, Pakistan, and Turkey--produce almost two-thirds of all the wheat consumed in developing countries. In these countries, where wheat is a staple for the poor, increases in production are keeping pace with increases in consumption. In other regions where wheat is traditionally consumed--North Africa and the Middle East--wheat consumption is growing slowly, but production is not keeping pace. The highest growth rates in wheat consumption are found in areas that have traditionally neither consumed nor produced wheat, such as West Africa and Southeast Asia. It is here that CIMMYT is making exploratory efforts to develop wheats for the cooler seasons of the tropical areas in the hope that local farmers can help to meet the growing demand.

CIMMYT works on other crops of value to poor people. These are barley, durum wheat (included in the statistics on wheat in the foregoing discussion), and triticale. Barley is consumed by relatively few people, but these are among the poorest, often living on marginally productive lands. The circumstances in which durum wheat is produced are more varied than those of barley, but its producers include very poor farmers in countries such as Peru, Ethiopia, and India. Triticale can be grown on land that is marginal for wheat, and therein lies one of its principal advantages. There are countries in which barley, durum, and triticale are used by relatively small, well-defined populations, and some of these present opportunities for more refined studies of nutritional effects.

Consumption of bread wheat and maize, however, is so high and variations in their use are subject to so many factors that it is difficult to imagine any CIMMYT-initiated study of their consumption that would be of much use for realigning priorities for the two crops. Resources are considered to be better spent in encouraging countries to formulate and articulate development policies that would help them guide their own crop research. Such policies would make it possible for them to frame their demands on CIMMYT more effectively.

Commodity Characteristics

CIMMYT endeavors to improve the nutritional quality of its commodities and to make them more acceptable to consumers. The outstand-

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[7] Ibid.

[8] CIMMYT, "An Analysis of Third World Consumption and Imports of Wheat."

ing example of improvement in nutritional quality is the work on quality protein maize (QPM).

Research into the nutritional quality of maize had its origins in the discovery of the biochemical effect of the opaque-2 gene in maize in 1963.[9] By reducing the proportion of zein in maize endosperm protein, the gene has the effect of increasing the content of lysine and tryptophan, the first two limiting amino acids in maize. Early on, the opaque maizes were shown to be much superior to normal maizes as feed for nonruminant animals and in human nutrition.[10]

CIMMYT's work on the nutritional quality of maize began in the late 1960s; since 1970 it has been funded largely by a research grant from the United Nations Development Programme (UNDP). The project is now in its fourth phase. Although other researchers had converted a number of normal materials to opaque-2 or to other high-lysine mutants, acceptance was limited. Not only was the soft, chalky texture of the kernel itself unacceptable to consumers, but it also contributed to other undesirable qualities, including lower grain density, higher susceptibility to storage insects and ear rots, and slower drying. Early work at CIMMYT was concentrated on the development of QPM that would suffer less from the defects of the original opaque-2 materials.

The focus of this early work was on a wide range of modifier genes that would be able to convert the soft, starchy materials to hard vitreous types of grain.[11] The first materials with these modifiers proved to be unstable in different environments, but as work continued and expanded, more stable modifiers began to be identified.[12]

The expansion of this breeding effort was supported by CIMMYT's Protein Quality Laboratory, in which techniques for rapid and reliable

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9 E. T. Mertz, L. S. Bates, and O. E. Nelson, "Mutant Gene That Changes Protein Composition and Increases Lysine Content of Maize Endosperm," Science 145 (1969): 279-280.

10 G. L. Cromwell, R. A. Pickett, and W. M. Beeson, "Nutritional Value of Opaque-2 Corn for Swine," Journal of Animal Science 26 (1967): 1325-1329; Ricardo Bressani, J. Alvarado, and Fernando E. Viteri, "Evaluación en Niños de la Calidad de la Proteina del Maíz Opaco-2," Archivo de Latinoamericana Nutrición 19 (1969): 129-140.

11 S. K. Vasal, "Use of Genetic Modifiers to Obtain Normal Type Kernels with the Opaque-2 Gene," in High Quality Protein Maize (Stroudsburg, Pa.: Dowden, Hutchinson, and Ross, 1975).

12 Magni Bjarnason and S. K. Vasal, "High Quality Protein Maize: Its Role and Future Prospects in Developing Countries," in Improvement of Quality Traits of Maize for Grain and Silage Use, ed. W. G. Pollmer and R. H. Phipps (The Hague: Martinus Nijhoff, 1980), pp. 15-27; S. K. Vasal, Evangelina Villegas, and C. Y. Tang, "Recent Advances in the Development of Quality Protein Maize Germ plasm at CIMMYT," paper presented at the Research Coordination Meeting on the Use of Nuclear Techniques for Cereal Grain Protein Improvement, Vienna, December 6-10, 1982.

protein quality evaluations were developed.[13] This allowed for the analysis of a large number of samples each breeding cycle; 20,000 samples a year can be analyzed in the laboratory. More than 50 scientists from developing countries have been trained in these methods at CIMMYT, and protein quality laboratories have been established in a number of national programs in order to support local breeding efforts.

By 1979 advanced hard endosperm QPM materials were producing mean yields equal to normal checks across selected test locations. In addition the appearance of the kernels was stable across environments in their regions of adaptation. There are now five QPM populations in CIMMYT's international testing program; three of these are adapted to the lowland tropics and two to subtropical regions. These populations include both white and yellow varieties of normal appearance that are equal or superior in yield potential to many normal maize varieties under cultivation in the environments to which they are adapted.

Five additional QPM populations are now being improved and are expected to enter the international testing system within the next few years. The aims of future research will include further improvement of yield and kernel weight and development of greater resistance to ear rot. In addition a strong effort is being made to include QPM varieties in more extensive farm-level verification trials.

The most extensive adoption work on QPM so far has taken place in Guatemala. The Institute of Nutrition for Central America and Panama (INCAP) has recently completed a study on the production, storage, acceptance, and effect on nutrition of QPM.[14] The study included the production of large quantities of QPM, its testing under local storage conditions and with local food-preparation methods, and its use in an intervention study among the families of coffee plantation workers in eastern Guatemala in which QPM was substituted for normal maize during a period of 17 months. Among the conclusions were the following:

1. Varieties of QPM grown locally maintain their nutritional quality.
2. The varieties tested sustained no more losses during storage than local varieties.
3. The acceptance of QPM in local maize preparations was equal to or greater than that of local varieties.
4. No problems were encountered in production of the QPM varieties.
5. There was evidence of improvement in the nutritional status of children under two years of age when QPM was substituted for normal maize in their diet.

In addition the Guatemalan National Agricultural Research Institute (ICTA) has recently released a variety of QPM that has been tested in on-farm verification trials and has been shown to yield as

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[13] Evangelina Villegas, Enrique Ortega, and Reynald Bauer, Métodos Químicos Usados en el CIMMYT Para Determinar la Calidad de Proteína de los Cereales (Mexico City: CIMMYT, 1982).

[14] Victor Valverde et al., "The Patulul Project: Production, Storage, Acceptance, and Nutritional Impact of Opaque-2 Corns in Guatemala," working document, Institute of Nutrition for Central America and Panama, Guatemala City, 1983.

well as the best improved normal variety now under cultivation. ICTA is promoting this material and the Guatemalan Ministry of Agriculture is studying the possibility of using QPM in orphanages, schools, and other institutions.

Other countries are also developing QPM materials. China, for example, is interested in QPM for both food and feed and is using CIMMYT materials for the production of hybrids. Panama, Argentina, and the Dominican Republic are using CIMMYT materials to produce QPM hybrids, varieties, or both for animal feed. Brazil is exploring the possibility of producing QPM materials that could be used both for feed and for composite bread flours. Venezuela has had excellent results with a CIMMYT variety of QPM, and the national seed company has begun distributing this variety for planting. The possibility of using this material in arepas, one of the commonest forms of maize preparation in Venezuela, is now being examined. Members of the CIMMYT staff are investigating the prospects for QPM in a number of other countries in Asia and Africa.

In conjunction with this work and with more general concerns, CIMMYT, with funds from UNDP, established a panel of five distinguished nutritionists to advise it on nutritional strategies. The panel has met three times--in 1979, 1980, and 1982. The development of QPM has been a primary concern of the panel, which has considered a number of pertinent issues. With respect to breeding objectives for lysine content, for example, the panel judged that the present level of about 40 milligrams per gram of maize protein is acceptable. Although the panel has identified those most likely to benefit from QPM--young children, for whom maize is the predominant source of protein and whose energy intakes are not too inadequate--it feels that specific targeting of QPM at this time is inadvisable. Rather, it recommends the introduction of varieties of QPM wherever agronomic and economic circumstances permit. The panel also endorses CIMMYT's efforts at exploring the possibilities of QPM as a feed for swine and poultry.

The panel approves CIMMYT's current efforts to involve nutritionists from the various countries in which QPM is being tested. This involvement will be helpful in identifying particular nutritional problems and describing dietary practices and methods of maize preparation into which QPM might be introduced.

Another topic discussed during meetings of the panel was the need for increasing the energy density of foods for the poor, especially those for young children. The maize program has initiated an exploratory breeding effort on oil content in two QPM populations. The object is to see whether modest increases in oil content--up to 7 percent--are feasible, without sacrificing yield. Interactions between yield and oil content, however, may well limit the usefulness of this approach as may storage problems and agronomic and organoleptic factors.

Other work at CIMMYT has also been focused on the nutritional characteristics of its crops. In both the wheat and maize programs, for instance, the protein content of advanced-generation materials sent to national programs is assessed to ensure that acceptable levels are maintained in newly emerging lines.

In the wheat program, efforts are also devoted to improving protein quality and content in crops. The development of high-lysine wheats was eventually abandoned, however, with the realization that

improvement of the protein quality of wheat has not been nearly so high a priority as similar work with maize. Work on identifying lines of wheat and triticale with higher-than-average protein content was also done, but there is little evidence that the higher protein levels can be combined with high yields. A limited amount of evaluation of the higher protein lines is still under way, but the tendency is to discontinue this type of work. In barley the high-lysine, high-protein gene from the variety Hyproly was used to develop a number of advanced lines. The relatively low priority given to improvement of barley protein for human nutrition, however, combined with difficulty in finding lines with suitable agronomic characteristics, has led to a de-emphasis of this work.

Similarly a great deal of research has been done on developing hull-less barleys. A hull-less barley would require less preparation time, and tend to have a higher proportion of edible dry matter and greater vitamin and mineral content than normal barley. Unfortunately, hull-less materials with acceptable yield characteristics have not yet been found, and less research effort is now being given to the attempt.

Acceptability to consumers is also important for ensuring that improved varieties reach their targets. CIMMYT maintains a milling and baking laboratory to ensure that new wheat lines are adequate for bread, chapatti, and other wheat products. The laboratory has tried mixing maize or other flours with wheat in bread production in a search for appropriate substitutes for wheat. The laboratory also gives its trainees from developing countries experience in testing barleys and durum wheats according to some of the preparation methods used in their countries for these grains.

Technology Characteristics

Widespread malnutrition exists among resource-poor farmers in Asia, Africa, and Latin America. CIMMYT helps alleviate this situation through its contribution to technologies that increase the food-production capacities or incomes of these farmers. It must be emphasized, however, that CIMMYT itself does not develop technologies. That is the function of national programs. CIMMYT supplies inputs that facilitate the efforts made in these programs. CIMMYT's work, then, is a reflection of its sense of the composite demand of its clients, the national programs. CIMMYT also recognizes that in order for this contribution to be effective, technologies--varieties and management practices--must be developed with an understanding of the conditions under which these farmers work.

CIMMYT's breeding efforts are aimed at a wide range of agroclimatic and socioeconomic circumstances. In general the idea is to develop germ plasm that adapts well under various stresses, so as to make yields greater and more dependable. This work is carried out in cooperation with national programs as they shape results to fit their special needs.[15]

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[15] R. L. Paliwal and E. W. Sprague, Improving Adaptation and Yield Dependability in Maize in the Developing World (Mexico City: CIMMYT, 1981).

Resource-poor farmers--those at nutritional risk--are especially well served by these efforts to limit the effects of various stresses on yields and by their contribution to dependability in production. Disease- and insect-resistant materials are examples. In the strategy of CIMMYT's maize and wheat programs, with their emphasis on resistance to disease, yield stability has been given a very high priority. Although the maize program emphasizes reduced plant height, with its implications for reduced lodging and increased efficiency in grain production, dependability is also an important goal.

Another threat to production is drought, and workers in both the maize and wheat programs are aware of the seriousness of this threat. One selection program is being carried out to identify families of maize that give better-than-average yields under moisture stress without sacrificing yield under normal conditions. Through the international testing activity of the maize program--a multinational effort--good progress has been made in developing materials that adapt well to moisture stress. Varieties of wheat derived from spring x winter crosses that appear to have superior drought tolerance have been identified, and work on them continues.

Production may also be limited by particular soil conditions. In cooperative work between CIMMYT's wheat program and several Brazilian institutions, materials with promising tolerance for otherwise toxic levels of free aluminum ions in the soil have been identified for use in Brazil and in such areas as the Andes, the Himalayan hills, and East Africa. Work on maize shows similar possibilities for these difficult soils.

In breeding work at CIMMYT the challenge of intensifying the production patterns of farmers is also addressed. A prime example of this effort is work on early-maturing varieties, which can be used in accommodating an extra crop in rotation or making better use of a restricted pattern of moisture availability. Since 1975 various research strategies for developing earlier-maturing maizes have been examined in the maize program. One result has been the formation of new populations of early-maturing material.

The introduction of wheat as a winter crop in Bangladesh is a significant example of CIMMYT's contributions to intensification of cropping systems. In less than a decade after the introduction of short-season wheats, fostered by collaborative work between CIMMYT and Bangladesh wheat researchers and drawing upon earlier results achieved in India, Bangladesh experienced a tenfold increase in wheat production. Surveys have shown that half these new wheat farmers own less than one hectare, and 60 percent keep all their wheat for home use.[16] In current research on subtropical wheats the possibility of extending wheat to farmers in new areas of Asia and Africa is being explored. Similarly winter maize in India, made possible through the development of new subtropical germ plasm, has brought more productive cropping systems for farmers.

The CIMMYT breeding strategies and goals described above offer great advantages to farmers, especially to resource-poor farmers, who frequently cannot afford costly plant-protection materials or soil amendments. All of CIMMYT's germ plasm reaches farmers through

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[16] CIMMYT, "Wheat in Bangladesh," CIMMYT Today, no. 15, 1982.

national programs; CIMMYT itself releases no varieties. The effects on nutrition of the varieties released thus depend in large part on the abilities and interests of those who run the national programs. CIMMYT's function is to provide a wide range of materials, methods, and training.

This is also true of CIMMYT's work in agronomy. The vast majority of CIMMYT-assisted agronomic research is carried on outside Mexico, in location-specific, on-farm research projects with colleagues from national programs. CIMMYT's production training emphasizes the importance of diagnosing local production problems and designing experimental programs to solve them. The focus of this training is on identification of target groups of farmers and designation of technologies for them, rather than attempts at generation and diffusion of specific technological innovations from the top down.

The nutritional effect of agricultural technology is, like that of agronomy, location-specific. Issues such as the relation between allocation of household resources to technological change cannot be studied on an international level. What such an institution as CIMMYT can do is train agricultural scientists to participate in the diagnosis of particular situations and the design of specific solutions. Many of the skills appropriate to such a task are incorporated into the CIMMYT approach to on-farm research, which will be described in the following section.

Production Systems

Production systems like problems of malnutrition arise out of the complex interaction of a number of factors that vary from area to area, and the design of improvements require location-specific studies. The complexity and range of production systems is now universally acknowledged, and this consensus has given rise to a number of different research approaches generally included under the heading of farming-systems research.

CIMMYT, in its approach to production-systems research, takes a farming-systems perspective. The CIMMYT strategy, known as on-farm research, involves a distinctive and well-integrated approach to diagnosis, planning, experimentation, and analysis.[17] This is not the place to review these procedures; in a recent paper CIMMYT's on-farm research is set forth and distinguished in the context of the farming-systems research movement.

Two points are to be made about the possibility of using the on-farm research approach as one method of attacking problems of rural

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[17] Derek Byerlee et al., Planning Technologies Appropriate to Farmers (Mexico City: CIMMYT, 1980); Alejandro Violic, Federico Kocher, and A. F. E. Palmer, "Research and Technology Transfer," paper presented at the Instituto Interamericano de Cooperación para la Agricultura/Banco Interamericano de Desarrollo/Instituto Nacional de Investigaciones Agropecuarias Seminar on Generation of Information and Transfer of Technology, Viña del Mar, Chile, November 23-27, 1981; R. K. Perrin et al., From Agronomic Data to Farmer Recommendations (Mexico City: CIMMYT, 1976).

malnutrition. First, a research approach must be feasible for national programs, with their limited resources, before it can be considered as a vehicle for any sort of development effort, including applied nutrition. The CIMMYT on-farm research approach was designed specifically with the needs and resources of national programs in mind and with an eye toward institutionalization. The success of this approach is indicated by its increasingly wide adoption: the on-farm research procedures developed by CIMMYT now form the basis of production research in a number of national programs.[18]

The second point is more direct. The philosophy and methods of the on-farm research approach permit the inclusion of nutritional concerns at various stages in the process and in varying intensities, depending on the situation. Some of these points will be outlined below. Further detail is provided elsewhere.[19]

The on-farm research promoted by CIMMYT places heavy emphasis on the selection and identification of target populations for agricultural research. Through the concept of the recommendation domain, researchers delineate groups of farmers in similar circumstances and with similar potential for the adoption of given recommendations.[20] Probably the greatest single failure to realize the full potential of nutrition in agricultural development projects has been the inadequate attention paid to identification of target farmers. In the hands of various national research programs, however, the concept of recommendation domain has guided researchers in designing technologies appropriate to specific groups of farmers. Although nutritional need has not been used as a specific criterion for identifying target groups, the potential is certainly there because, through its systems perspective, on-farm research offers the opportunity to include dietary and nutritional concerns in the design of new technologies. With its incrementalist nature, moreover, on-farm research is unlikely to lead to the deleterious changes in diet that are sometimes encountered when production systems are changed radically.[21]

Furthermore, in CIMMYT's on-farm research, the dietary practices and preferences of farmers can be considered explicitly. In East

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[18] Edgardo Moscardi et al., Creating an On-Farm Research Program in Ecuador, Economics Program Working Paper (Mexico City: CIMMYT, 1983); J. R. Arauz and J. C. Martinez, Desarrollando Tecnologia Apropriada Para el Agricultor (Panama City: Departamento de Publicaciones, Instituto de Investigación Agropecuaria de Panama, 1983).

[19] Robert Tripp, "On-Farm Research and Applied Nutrition," draft, Economics Program, CIMMYT, Mexico City, 1983.

[20] Larry Harrington and Robert Tripp, Recommendation Domains: A Framework for On-Farm Research, Economics Program Working Paper (Mexico City: CIMMYT, forthcoming).

[21] Per Pinstrup-Andersen, Nutritional Consequences of Agricultural Projects: Conceptual Relationships and Assessment Approaches, World Bank Staff Working Paper 456 (Washington, D.C.: World Bank, 1981).

Africa, for example, where the supply of staple foods is the primary concern of most farmers, diagnostic procedures involve analysis of farmers' preferences for certain staples, seasonality of diet, and uses of secondary crops.[22] In Haiti on-farm experimentation with improved varieties of maize included panels of consumers to judge the acceptability of new varieties under local techniques of preparation.[23]

On-farm research is an iterative system of data collection, analysis, and experimentation. Dietary issues can be included in exploratory surveys, formal questionnaires, conversations with farm families, and observations during experimentation or in special studies. This strategy was, for instance, part of an on-farm research program in northern Ecuador.[24] Diagnostic surveys helped identify crops that were particularly important to poor producers. Once experimental work on important research opportunities (in this case, early-maturing maize) was under way, researchers obtained increasingly precise information on the acceptability of the new varieties. And when an early-maturing variety had been tested and recommended, a short qualitative dietary survey helped direct further research toward other crops, to be grown in rotation with the new maize, that were particularly important to the diets of these farmers. Thus, with its emphasis on the circumstances of well-defined groups of farmers, on-farm research can contribute to a fuller understanding and resolution of the location-specific problem of malnutrition.

Suggestions for Further Work

There are several activities that could be undertaken, either by CIMMYT or by other institutions, that would help to sharpen the nutritional focus on maize and wheat.

1. CIMMYT has benefited considerably from its nutrition panel. Their counsel helped both in reaffirming guidelines for work on QPM and in sorting out issues of concern in work on bread wheats and durums. CIMMYT believes that easy access to specialists in nutrition is important for the international agricultural research centers (IARCs) and feels that one group could probably serve all the centers. Such a group could inform the centers about and assess the consequences of new developments in

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22 CIMMYT, Demonstrations of an Interdisciplinary Approach to Planning Adaptive Agricultural Research Programmes: Part of Serenje District, Central Province, Zambia (Nairobi: CIMMYT East Africa Economics Program, 1978).

23 Service de Recherches Agricoles/Departement de l'Agriculture, Des Ressources Naturelles Et Du Developpement Rural, "Results of a SERA/CIMMYT Farmer Survey in the Cayes Plain," draft, Les Cayes, Haiti, 1982.

24 Robert Tripp, Including Dietary Concerns in On-Farm Research: An Example from Imbabura, Ecuador, Economics Program Working Paper (Mexico City: CIMMYT, 1982).

nutrition. The centers, in turn, could then apply that information and insight to their own work.

CIMMYT, in particular, would find such guidance useful, especially in making decisions regarding breeding projects on the nutritional characteristics of its crops. That is, CIMMYT would want access to evidence regarding the severity and distribution of particular nutritional deficiencies and the economic attractiveness of particular breeding approaches among alternatives intended to counter such deficiencies before embarking on an exploratory research program. Such research might in some instances best be done by CIMMYT; in others a basic research institution would be more appropriate. The choice would be made by considering both the facilities and the breeding techniques required for the initial research.

2. CIMMYT believes that a significant opportunity for increasing the nutritional emphasis of agricultural development exists in the work of national institutes of nutrition. These are important but underused sources of skill and experience. CIMMYT would therefore encourage closer collaboration between these institutes and their national counterparts in agricultural research.

   One possibility for collaboration would be the participation of national nutrition institutes in the on-farm research activities of national agricultural research institutes. Besides providing an opportunity for communication between workers in applied nutrition and those in agricultural research, participation in on-farm research could lead to improvements in nutrition research methods, which should include methods of conducting dietary surveys to provide relevant information to agricultural researchers, better techniques for analyzing the food preferences and consumption patterns of the poor, and better identification of important areas for studying the etiology of rural malnutrition, in order to understand when and under what conditions agricultural interventions are possible solutions to problems of malnutrition.

   CIMMYT would thus be interested in seeing an international organization approach national nutrition institutes on the issue of increased coordination with agricultural research. If it were agreed that on-farm research offered an opportunity for this type of collaboration, CIMMYT would be prepared to suggest appropriate national settings and to offer its advice.

3. CIMMYT will continue to analyze trends in the use of its crops in order to help set priorities for future work, but CIMMYT also recognizes the need for more precise information. Analyses so far have been based, by and large, on country-level data, and, as consumption studies show, there is certainly a need for more disaggregation. It would thus seem worthwhile for an appropriate institution to identify and organize those studies already completed, as well as to help direct future work toward areas and themes that should be given high priority. This would be a formidable task, but some sort of consumption-studies clearing house would be of great help to agencies concerned about nutrition.

   The function of such a clearing house should be to generate better data for national policymakers and for international agencies and to develop local capacities for carrying out such studies. This effort would include giving attention to the types of

dietary and nutritional surveys carried out routinely in many countries in an effort to determine ways of making such surveys more useful to agricultural policymakers. This effort would also involve coordinating studies of issues such as the effects of pricing and subsidy policies or of various rural-development strategies on human nutrition.

6
The Incorporation of Nutritional Goals into the Research Design of CIP*

José Valle-Riestra

The International Potato Center (CIP), working on only one commodity, the potato, does not suffer, as do other centers, from the complexities of balancing priorities within its commodity portfolio. Fortunately, the excellent nutritional quality of the potato has been widely documented: it is an important source of carbohydrates and of high-quality protein, ascorbic acid, and minerals. The protein-to-carbohydrate ratio is highly favorable, and the amino-acid balance--the lysine content is relatively high--is of a high standard for human nutrition. It is thus not surprising that the potato is recognized as being among the staple foods with the highest overall nutritive value. Furthermore, this high nutritive value is consistent throughout the range of varieties currently being cultivated in the world's traditional production zones.

CIP is conscious of the need to maintain the potato's high nutritive value as efforts are made to increase production and consumption of potatoes by extending the use of germ plasm and making the best use of production environments. The policy of CIP is to make sure that quality is maintained as other desirable traits are built into advanced breeding populations. The aim of CIP, in cooperation with national potato-improvement efforts, is to develop potatoes that will meet the requirements and preferences of consumers.

Since its inception CIP has incorporated nutritional goals into its research strategy. Different areas of emphasis have been developed and will be discussed in more detail later. They can be grouped in the following categories:

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* This paper is essentially an edited compilation of documents prepared by various CIP scientists. Particular credit should be given to Susan Poats, whose paper "Potato Nutrition and Consumption Research at the International Potato Center" (August 1982), with minor editing and deletions, has been used as the basis of the historical overview. I would also like to thank Douglas Horton for his contribution to the sections on nutritional research conducted by the social science department and the effectiveness of CIP research activities and Peter Keane for the summary of potato processing.

1. Increasing the availability of potatoes to nutritionally vulnerable groups by increasing production and productivity.
2. Increasing the nutrient content of potato tubers through breeding efforts.
3. Keeping the natural component of toxic elements, such as glycoalcaloids, at the lowest levels.
4. Increasing the use of potatoes by developing adequate storage facilities and by means of processing.
5. Monitoring consumer preferences and patterns of demand.
6. Monitoring farming systems that include the potato. Points 5 and 6 are fed back into the CIP research program in order to define characteristics of the product and technology.

HISTORICAL OVERVIEW

Research activities at CIP concerning the nutritional value and consumption of potatoes have had a long and varied history. They began in early 1973, one year after the center was founded, with the hiring of a nutritional breeder. His initial efforts were focused on protein quality and biological value, and he established procedures for rapid determination of protein quality, using knowledge of the limiting sulphur-containing amino acids and their effect on the growth of streptoccocus zymogenes.[1] Laboratory technicians were employed and instructed in the replication of these techniques.

From the beginning CIP established a tradition of conducting planning conferences, using outside expertise in specific research areas, to make recommendations for the guidance of future research programs. The fourth of these was the Protein Quality Planning Conference held in November 1973.[2] It was strongly recommended at the conference "that data derived from chemical and biological evaluation of nutritional quality are to provide the basis for selecting parental materials."[3] This recommendation and subsequent project-specific recommendations set the stage for nutrition activities for the following five years. Two other points stressed repeatedly during the conference, however, were ultimately linked to a later decision to discontinue analysis of nutritional quality:

1. Resistance to diseases and insects should be given preference over other properties in making crosses and selection.
2. High dry-matter content should be given priority over high protein content.

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[1] Robert Luescher, "Evaluation of Methods to Determine the Sulphur-Containing Amino Acids in Potatoes" (M.S. Thesis, Michigan State University, 1972); Robert Luescher, "Genetic Variability of Available Methionine, Total Protein, Specific Gravity, and Other Traits and Tetraploid Potatoes" (Ph.D. dissertation, Michigan State University, 1972).

[2] International Potato Center (CIP), Potato Protein Quality, Report of the International Potato Center's Planning Conference on Potato Quality (Lima, Peru: CIP, 1973).

[3] Ibid.

One of the participants, who was then head of the UN Protein Advisory Group, stimulated a great deal of discussion with his comment that carbohydrates, not protein, was the issue. He claimed that if the need for carbohydrates could be met, the need for protein would be met automatically. Since protein quality had already been selected as the conference topic, however, his observation was overruled and the conference proceeded to plan largely for future research on protein.

Although the emphasis of the conference was on protein quantity and methods of evaluating quality, the following other recommendations were made:

1. That a minimum cutoff for protein be established at 10 percent crude protein (dry basis).
2. That vitamin A content could be improved.
3. That breeding materials with antinutritional factors, primarily glycoalcaloids, beyond accepted tolerance limits should not be released to countries that do not possess adequate facilities to assess them.
4. That suitable analytical methods for evaluating the protein content of potatoes be identified and put to use.
5. That work on processing techniques for developing countries, initiated at the National Agrarian University in Peru, be promoted.
6. That evaluation of potatoes and potato products by human and rat assays and assessment of cultural food preferences in developing countries be obtained through collaboration with other institutions.
7. That, since the quality of storage facilities is directly linked to maintenance of the nutritive status of potatoes, work on innovative design of potato storages for developing countries should be undertaken.

These recommendations, with a few adjustments, were followed in the course of the following years. A nutrition laboratory was established in the physiology department and a phase of screening, analysis, and investigation for nutritional quality was begun. The laboratory functioned for five years, primarily in service to other departments, sometimes to outside institutes, that needed nutritional analyses of certain research or breeding materials. This function reached a peak in 1977, by which time seven analysis procedures had been fully implemented: crude and true protein, total sugars, reducing sugars, starch determination, total glycoalcaloids, and dry matter.

Apart from the service functions of the laboratory, a number of research projects on specific nutritional features of potatoes were conducted through contractual arrangements with U.S. universities; one concerning nitrogen metabolism in potatoes was conducted by Paul Li for the University of Minnesota research.[4] Visiting scientists on sabbatical added to the nutrition-related projects and perspective

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[4] Paul Li and K. D. Sayre, "The Protein, Non-Protein, and Total Nitrogen in Solanum Tuberosum ssp. Andigena Potatoes," American Potato Journal 52 (No. 11, 1975): 341-350.

during this period.[5] A number of graduate students from the National Agrarian University in Lima, Peru, were supported by CIP scholarships in conducting nutritional research in conjunction with the nutritional laboratory.[6] One of these was subsequently hired as a technician in the nutrition laboratory. Two Ph.D. research projects having to do with glycoalcaloids in native Andean tubers were also supported during this period.[7]

One important joint research effort with a local institution was initiated during this time. The Instituto de Investigaciones Nutritionales (IIN) initiated studies of the value of the potato in infant nutrition. In conjunction with CIP, the IIN concentrated initially on protein quality and digestibility. In subsequent studies the ways in which potatoes can best be used in the recuperation of severely malnourished children and the dietary treatment of better-nourished children recovering from an acute episode of diarrhea were evaluated. The input of CIP into this research continues, and plans are now under way to evaluate new processed potato-based feeding supplements.

Though most of the nutrition activities of CIP during this period were concentrated in the laboratory, a gradual shift from the laboratory to the consumer began. Within the physiology department intermediate research in the technology of processing was geared toward improvement of the processing techniques for traditional Andean potato products. Storage research, though concentrated on seed stores, began to encompass the need for improvement in rural storage of potatoes for home consumption. The social science department took a growing interest in potato consumers. Statistical compilations of national average consumption of potatoes per capita were initiated, as was a thesis investigation of consumer demand for potatoes and meat in the northern region of Peru.[8] Considerations of demand for and use of

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[5] N. R. Thompson, R. T. Wurster, and K. D. Sayre, "Utilization of Potatoes in the Tropics," proceedings of the Fourth Symposium of the International Society for Root Crops, Cali, Colombia, August 1-7, 1976, pp. 203-206.

[6] A. M. Muñoz de Maguiña, "Evaluación química, bromatológica, y nutricional de las combinaciones de papa, tarhui, y cebada" (M.S. thesis, Universidad Nacional Agraria La Molina, Lima, Peru, 1979); N. Espinola Carranza de Fong, "Análisis químico y evaluación de calidad protéica de algunes variedades de papa" (Thesis, Universidad Nacional Agraria, Lima, Peru, 1979).

[7] P. E. Schmiediche, "Biosystematic Studies on the Cultivated Frost Resistant Potato Species Solanum X Juzepeczukii Buk. and Solanum Cortilobum Juz. et Buk." (Ph.D. dissertation, University of Birmingham, 1977); Jorge Christiansen, "The Utilization of Bitter Potatoes to Improve Food Production in the High Altitudes of the Andes" (Ph.D. thesis, Cornell University, 1977).

[8] Doug Horton, "A Plea for the Potato," Ceres 14 (No. 1, 1981): 28-32; Luis Quintanilla, "Estudio econometrico de funciones de consumo de papa y carnes de la zona norte del Peru" (Thesis, Universidad Nacional Agraria, Lima, Peru, 1979).

potatoes were included in a number of country studies of potato production that were supported through the social science department during this period.[9] Interest in potato consumers grew, and a decision was made to support a three-year postdoctorate study of potato consumption, beginning in mid 1979.

Toward the end of 1978, a significant shift in CIP's nutrition-related research activities began. The physiology department took responsibility for an important research program involving production of potatoes from true seed--instead of tuber seed. New staff were brought in, including a new department head. The new program also required both space and technical personnel who were at that time assigned to other programs. This shift in priorities sparked an evaluation of the ongoing physiology programs, and one that came under scrutiny was the nutrition laboratory. Questions were raised about the effectiveness of the laboratory and whether the results were actually useful to breeders in the evaluation of new potato clones. It was concluded that the breeders were not making effective use of the voluminous nutritional information and that a significant portion of the work was being done in response to requests from outside CIP.

More significant, the breeding department staff and others agreed that the research in recent years had revealed a negative correlation between protein content and yield. Since high yield was the primary objective, it was decided that the effort to increase protein content could not be given a high priority.

The nutrition laboratory was closed in February 1979 and the research technicians who had been associated with it were shifted to other projects. Though a small number of nutritional analyses continued to be made, primarily using the facilities of other local institutions, most of the further research of this sort was related solely to potato consumption and, except for work done in collaboration with IIN, located almost entirely within the social science department.

The social science department has conducted research in three areas related to potato consumption and nutrition.

1. Anthropological case studies of potato consumption in developing countries.
2. Economic research on the demand for and marketing of potatoes.
3. An extensive review of the literature on the potato in the human diet.

Potato Consumption Studies

During a three-year period anthropologist Susan Poats conducted case studies of potato consumption in Peru, Rwanda, Guatemala, the Philippines, Indonesia, Bangladesh, and Bhutan. These studies provide some preliminary estimates of potato consumption levels, information

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[9] Georg Durr and George Lorenz, Potato Production and Utilization in Kenya (Lima, Peru: CIP, 1980); G. Fu Alvarez, Producción y utilización de papa en Chile (Lima, Peru: CIP, 1979); M. Valderrama and H. Luzuriaga, Producción utilización de la papa en el Ecuador (Lima, Peru: CIP, 1980).

on how and by whom potatoes are consumed, and insight into consumer preferences. The results show how national average estimates of potato consumption may be misleading for policymakers: they substantially underestimate actual levels of consumption and they mask significant differences in consumption across ecological zones and socioeconomic groups. In Peru, for example, annual consumption per capita was found to range from 200 kilograms in some highland villages to less than 1 kilogram in the selva (jungle area). In the Philippines and Indonesia, surveys indicated that potato consumption may be two or three times the official estimate. In Bhutan, where government officials assumed that nearly all potatoes were exported and that local consumption was nil, actual consumption may average around 40 kilograms per capita. In light of the present food deficit in Bhutan and the acceptance of potatoes by consumers there, this finding should have some bearing on nutritional policy. The consumption studies illustrated the variety of functions of the potato in the human diet, ranging from its use as a low-cost staple food to that as a high-cost luxury vegetable. Price is important, but it is not the only factor that influences potato consumption. This leads to the second subject of investigation by the CIP social science group, marketing and demand.

Marketing and Demand Studies

The marketing of potatoes is frequently assumed to be extremely inefficient, with high retail prices that are primarily the result of marketing problems and traders' monopoly profits. In 1979 CIP initiated a research project on potato marketing in Peru, the results of which are being published this year in a book entitled, Markets, Myths, and Middlemen: A Study of Potato Marketing in Central Peru. An important finding of this detailed study is that, given the difficult and hazardous environment in which potato traders operate in Peru, marketing is surprisingly efficient. The instability of the market and the periodically high prices are caused, not by extreme inefficiency or by collusion on the part of traders, but primarily by the instability of production and the bulk and perishability of the product.

These and other studies of the marketing of and demand for potatoes are generating the data needed to reframe policies in ways that are conducive to expansion of the production and use of potatoes.

Demand analysis conducted in Peru and elsewhere indicates that, in sharp contrast to the situation in Western Europe, consumers in developing countries are highly responsive to potato prices, and that levels of consumption are, in general, correlated positively with income.[10] These findings suggest that growth in income will stimulate greater consumption of potatoes in poor countries. They also highlight the importance of generating new potato technologies that will reduce unit costs of production, and thereby, consumer prices.

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[10] D. E. Vander Zaag and Doug Horton, Potato Production and Utilization in World Perspective, with Special Reference to the Tropics and Sub-Tropics, Potato Research No. 29 (Lima, Peru: CIP, 1983).

Potatoes in the Human Diet

No comprehensive study of the use of potatoes analogous to the Food and Agriculture Organization of the United Nations (FAO) series on other important crops has been published so far. For this reason, and because the popular literature on potatoes contains many fallacious assumptions, CIP engaged a nutritionist, Jennifer Woolfe, to compile a comprehensive review of the literature on potatoes in the human diet. Her findings are being published in journal articles and in a book with chapters on the structure and composition of tubers, their nutritional value, their nitrogenous constituents, the effects of cooking, processing, and storing them, their toxic components, and their dietary uses. This book should be a valuable resource for researchers and policymakers for many years to come.

NUTRITIONAL IMPLICATIONS OF CURRENT RESEARCH AT CIP

Nutrition is obviously the object of all research at CIP, since in the developing world the potato is primarily consumed as a human food in contrast to other roots and tubers that are used primarily as feedstuffs or for industrial purposes.

Commodity Characteristics

The potato qualities preferred by consumers and the nutritional characteristics of the potato are many and varied. As a consequence, several quality factors are considered in the core research program of CIP, in contract and student thesis research, and through the regional research network with national potato-development programs.

As a result of early studies and discussions at CIP on the protein content of potatoes, the effort to increase the amount of protein to be obtained from potatoes was approached through an attempt to increase total yields rather than by breeding for greater protein content per se. This approach requires that the protein content of CIP breeding materials be checked periodically. Before 1978 this task was performed in the CIP laboratories. During 1978, partly because of the pressure of other research priorities, this service function was contracted to national institutions that have analytical capabilities and greater comparative advantages for conducting these laboratory tests. Similarly, glycoalcaloid testing in those populations into which species known to have a high content of glycoalcaloids--*Solanum chacoense*, *S. curtilobum*, and *S. juzepczukii*, for example--had been introduced, was performed at CIP. Now this service is being performed under contract.

An important aspect of potato quality is dry-matter content. Dry matter, also measured as specific gravity, is monitored in several CIP research projects. In addition to information on the specific gravity of advanced selections made both by CIP and in national programs, information is being accumulated on the stability of dry matter across environments and agronomic practices and on the potential use of species that contain a high level of dry matter in breeding programs.

To make use of the sources of high dry-matter content present in many primitive Andean cultivars from the world potato collection, a

research project has been initiated. Among other cultivated species, Solanum goniocalyx (2n = 2x = 24) is characterized by an extremely high dry-matter content in addition to outstanding culinary attributes, such as flavor and texture. Because of ploidy barriers, it has not been possible to use this source of tuber quality in breeding commercial tetraploid cultivars.

The number of chromosomes in samples of various genotypes of S. goniocalyx is being doubled, either by tissue culture or by colchicine treatment. The objectives of this research are

1. To compare the effect of chromosome doubling on both the dry-matter content and other culinary attributes.
2. To increase the frequency of occurrence of genes that control these attributes.
3. To select from the experimentally obtained tetraploids those clones having a high content of dry matter and other attributes related to tuber quality and use them in breeding high-quality commercial tetraploid cultivars.

Selection for phenotypic quality or tuber appearance--shape, color, eye depth, and so on--is carried out at an early stage in the selection of promising materials from within advanced populations. These selections are made both at CIP stations and in regional and national programs to which tuber families have been distributed.

Culinary quality and processing quality are quite important in the final selection of varieties. CIP recognizes this and through its regional research network and training courses on germ plasm management encourages national scientists to evaluate materials according to the specific needs of their consumers. The results of these evaluations constitute an important feedback to the potato-improvement efforts of CIP.

Additionally, when those responsible for national programs express their need to breed for specific quality traits in order to satisfy the preferences of consumers in their countries, arrangements are made for national scientists to search and evaluate the world potato collection at CIP for these specifics.

As progress is made at CIP in the seed-production and agronomic research requirements for producing potatoes from true seed, greater attention is being given to the question of quality. Considerable progress has already been made in breeding for phenotypic uniformity of tubers. The problem of variability in dry matter and culinary characteristics may need more intensive research in collaboration with national programs in those countries where such considerations are important.

Technology Characteristics

Nutritional goals are characteristically present in the design of potato technology at CIP. This is well illustrated by CIP's efforts to develop a low input technology and by its research on true potato seed.

Low-Input Technology. By low-input technology I refer to the efforts of CIP in controlling insects and diseases by incorporating genes that resist them. The obvious results are greater productivity and less

dependence on pesticides. Other advantages are that

1. Farmers save money on the cost of pesticides and their application.
2. Farmers are less exposed to toxic substances during the application and as residues in crops.

In developing resistance to pests and diseases, germ plasm not previously used is employed, which often confers nutritional benefits. Clone BR 63.65, released as a variety in several countries--as Molinera in Peru--contains 12.9-15.9 percent protein, about 3-6 percent more than standard varieties. Both its high protein content and its resistance to bacterial wilt were derived from a Solanum phureja diploid parent. Other diploid clones have dry-matter contents as high as 36 percent, nearly twice that of common varieties. A great potential thus remains to be exploited.

True Potato Seed. A significant portion of the potato harvest that could otherwise be used as food is used as seed. If the area annually cultivated in potatoes throughout the world is about 20 million hectares, 40 million tons of potatoes a year that could be used as food are used for planting.

In most traditional potato-growing areas characterized by favorable ecological conditions for seed-tuber production, true seed may not offer a distinct advantage. In many other regions, however, where potato production is constrained by the high cost of tuber seed, true potato seed has a high potential. This happens when tuber seed cannot be produced or stored locally, usually in those climates in which the activity of virus vectors causes the quality of normally expensive imported seed tubers to deteriorate rapidly. In these areas true potato seed could be produced locally or imported from favorable growing areas at relatively low prices. This would make available for human consumption the tubers traditionally lost as seed and would, in addition, permit the local cultivation of the potato as a new alternative contributing to a general increase in the available food, the income of farmers, or both. In many of these areas there is demand for potatoes, but their consumption is restricted because of their high cost.

In many areas in the tropics and subtropics the potato could fit perfectly into the existing cropping system in well-defined periods, either as a sole crop using the short period between the main staples or as an associate crop. True potato seedlings could be grown in seedbeds simultaneously with the final stages of the first crop, for example, then transplanted to the field as another relay crop within the system. Using proper true seed progenies, potato production under these conditions is feasible within 90 days after transplanting and therefore fits well into the existing farming systems. Also, seed tubers that originate from true seed produced in an off-season can be advantageously used in conditions under which transplanting might be difficult. The production of either one, potato seedlings from transplanting or seed tubers from true seed, gives a tremendous flexibility and potential for expanding this crop into many areas of the tropics. The possibility of maximizing the use of scarce land resources by growing a high-nutrient-density crop such as the potato during these periods will undoubtedly have significant implications for nutrition.

Processing. Proper processing is an effective means of increasing consumption of the potato and of improving its nutritive value. For many years CIP has been involved with the development of low-cost technologies for processing potatoes for low-income groups. A low-cost processing system has been established for the production of papa seca--basically a dried potato produced for centuries in the Andean region by the same traditional means and consumed in a special Peruvian dish called Carapulcra--demonstrating that a traditional process can be improved and kept in operation on a village scale. A simple plant with a capacity for processing 1 metric ton of fresh potatoes daily will yield approximately 200 kilograms of papa seca. A full account of the process was published in a CIP circular in June 1980 and in a more complete publication in 1982.[11] There has been a high level of both national and international interest; the CIP pilot plant has been mentioned in several international newsletters, such as AVRDC Comments and the newsletters of the League for International Food Education. During 1982 CIP received more than 60 written inquiries, originating from 30 countries, about the potato-processing plant.

CIP is now involved in the production of simple potato-based mixtures, blending dry cereals, legumes, and potatoes, combined in proportions that acknowledge the economic need for low-priced foods. More than 20 different potato-based mixes have been developed using nationally available ingredients. Two are now being processed for market-acceptance trials. The mixes are all in dry-powder form and are reconstituted to a thick souplike consistency with the addition of 1 liter of water to 8 grams of the mix. The products are boiled for 25 minutes, after which the taste is neutral or bland and as such forms an excellent base for breakfast foods, savory foods, and desserts. Sugar, cocoa, and cinnamon can be added to the cooked product to produce an acceptable porridge-like meal; alternatively, a stock cube, chicken or beef, can be added to the cooked product to produce an acceptable savory soup. More water can be added if the consistency is too thick. Likewise, the addition of sugar and fruit flavors makes a pleasant dessert.

The process, which can be adapted to any scale of operation, is simple, requiring little capital and little processing expertise. Potatoes are cooked and mashed. Flours from various cereals and legumes are then mixed with the mashed wet potato. This mixing spreads the moisture content of the potato throughout the mix, facilitating drying, which is accomplished by means of solar energy; artificial means can of course be used as well, though at a higher cost. Preliminary findings among several poor neighborhoods in Lima and Huancayo indicate a high level of interest in this type of product, which, because of its low cost and high nutritive value, is expected to improve the nutritional status of poor households. CIP is now coordinating its efforts with those of national institutions for the further development and evolution of this type of product.

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[11] R. L. Shaw and R. H. Booth, Simple Processing of Dehydrated Potatoes and Potato Starch (Lima, Peru: CIP, 1982).

THE EFFECTIVENESS OF CIP RESEARCH ACTIVITIES

Weakness of the Data

Present knowledge of the production and consumption of root crops in general and potatoes in particular in developing countries is poor, certainly much poorer than knowledge of the production and consumption of cereal grains.[12] For several reasons, consumption of root crops, particularly potatoes, in relation to consumption of cereals is underestimated.

In most developing countries potatoes are considered to be of secondary or tertiary importance, after the cereals and other root crops. In traditional household surveys the consumption of potatoes is generally underestimated. Potatoes are often consumed in small amounts as side dishes or at certain times of the year. Respondents in a survey are likely to forget them, as they recall the components of yesterday's, last week's, or last year's diet. Equally important, potatoes may be consciously or unconsciously overlooked by some researchers, who regard them as "unimportant or inferior foods."

Reliance on national production statistics and food-balance-sheet equations to estimate potato consumption is also problematic. Measurement of potato production is difficult because potatoes are generally grown in small, discontinuous plots in isolated areas, often as multicrops or intercrops, or in backyard gardens. Some plots are harvested several times in a single season, while potatoes are left in other plots in in-ground storage against future hard times. In official statistics potatoes are often confused with sweet potatoes or other root crops, and in some instances root-crop production is stated in confusing cereal-grain-equivalent units.

The following are three examples of the way potato production may be severely underestimated: first, for years the CIP regional staff in Africa suspected that FAO underestimated potato production in Zaire. Early in 1984 this was confirmed by statistics published for three potato-producing districts of the country, which reported a production level three times that estimated earlier for the entire country. Second, in the Baguio area of the Philippines the official yield estimate is less than 10 tons per hectare, but on-farm estimates consistently average around 20 tons per hectare, indicating an underestimate of production, and hence of consumption, of 50 percent.[13] Third, FAO estimate of potato production in China is 15 million tons. In sharp contrast, Bruce Stone of IFPRI, having made a detailed analysis of Chinese documents, estimates Chinese potato production to be nearly 50 million tons.[14] FAO is now contemplating a revision of its Chinese figures.

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[12] Horton, "Plea for the Potato."

[13] Michael Potts, Potato Technology Transfer in the Philippines: The Development of the Optimizing Potato Productivity Approach, Benguet and Mountain Provinces (Lima, Peru: CIP, 1983).

[14] Bruce Stone, "Notes on Interpreting PRC Root and Tuber Crop Data," China Quarterly, forthcoming.

Even more difficult to estimate than production is the use of potatoes--as seed, as feed, in processing, and as fresh food--and the amount wasted. Seed rates are often overestimated, and waste estimates are usually guesses with no empirical basis whatever. The use of potatoes for feeding livestock and for processing is so difficult to determine that published estimates have little or no value. As an example, FAO Food Balance Sheets indicate no processing of potatoes in such countries as Peru and Bolivia, where household production of chuño and papa seca is widespread and well documented. Conclusions drawn from FAO Food Balance Sheets can therefore be extremely misleading.

In the food-balance equation human consumption is the residual estimate after estimates of other uses have been subtracted from the total quantity available. Given the many weaknesses of these estimates, it is easy to see how poor are the consumption figures derived from food balance sheets. An additional shortcoming is that such an equation does not provide disaggregated information on socioeconomic, regional, and seasonal variations in consumption. Other methods must be used to obtain this information so that potato consumption and nutrition can be understood and sound policies concerning potatoes can be made. A series of anthropological case studies conducted by the CIP social science department represent a first step in this direction.[15] These studies illustrate the way potato consumption can be underestimated by a substantial margin and the fact that disaggregated data are essential to an understanding of the function of potatoes in food consumption and nutrition.

Contribution of Research

Given the approach of CIP to improvement of the potato and its policy of involvement with national programs, it would be impossible--indeed undesirable--for CIP to distinguish sharply between the effects of its own research on human nutrition and that of other institutions, both in industrial and developing countries. If CIP can measure specifically what it has done in any country, the job has been done incorrectly. But what can be said is that a number of country programs, through involvement with CIP, both direct and indirect, have stimlated potato production and that their efforts have had a significant, beneficial effect on human nutrition. Some specific cases follow.

Rwanda. Rwanda, one of the world's poorest and most densely populated countries, has increased its potato production by approximately 75 percent during the last decade. In the process, the potato has become both an important cash crop and a staple food for many people in the northern volcanic region. During the past five years a National Potato Program--Programme National de l'Amelioration de la Pomme de Terre (PNAP)--has been established with financial support from the

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[15] CIP, Annual Report 1980 (Lima, Peru: CIP, 1981); CIP, Annual Report 1981 (Lima, Peru: CIP, 1982); CIP, Annual Report 1982 (Lima, Peru: CIP, 1983).

Belgian government and technical support from CIP. A range of new varieties and potential varieties was screened for resistance to disease, agronomic characters, and acceptability to consumers, and two of these--Montzama and Sangema, of Mexican origin--were selected for multiplication and distribution to farmers. In widespread on-farm trials, improved seed of these varieties outyielded common farmers' varieties by 50 percent.[16] An evaluation of the program indicated that during the next ten years the use of these two varieties by farmers could be expected to increase total production by 30 percent, with no use of complementary inputs whatever and no future introduction of other varieties. In fact, several superior new varieties have been identified and are now being multiplied, and other technological improvements, such as in storage, are being made. Since additional production of potatoes is going principally to human consumption, these increases in production are clearly contributing to nutritional well-being in Rwanda. Since the potato is commonly used as a weaning food, the increased production is particularly beneficial to the country's nutritionally vulnerable infants.[17]

Bangladesh. Bangladesh presents the important case of a poor country in which the potato is changing its dietary function from that of a costly vegetable to that of a low-cost staple food accessible to nutritionally vulnerable low-income groups. The production of potatoes has increased substantially during the last decade; and, as a result of the recent expansion of cold-storage capacity and the establishment of a basic seed program, even more dramatic increases in production and consumption are projected for future years.

CURRENT NUTRITIONAL POLICY

Throughout its efforts to increase the production and use of the potato, CIP will continue working to maintain the well-documented high quality and nutritive value of the potato. To this end, either directly or through contracts, CIP will monitor the quality, nutritional composition, and glycoalcaloid content of new lines produced. Furthermore, CIP will continue to explore cost-effective ways of increasing the nutritive value of potato tubers and of promoting their use by nutritionally vulnerable groups by developing appropriate storage and processing technologies. CIP, through its regional research and training program, is committed to the transfer of this philosophy to national potato programs.

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[16] Anibal Monares, "Economic Evaluation of the Rwanda National Potato Program," draft, 1983.

[17] Susan Poats, Potato Nutrition and Consumption Research at the International Potato Center (Lima, Peru: CIP, 1982).

7
The Function of Plant Genetic Resources in the Improvement of Nutritional Quality, with Emphasis on Activities Undertaken by IBPGR

Gurubasavappa Shivashankar

The International Board for Plant Genetic Resources (IBPGR) was established in 1974 as an autonomous international scientific organization under the aegis of the Consultative Group on International Agricultural Research (CGIAR); it has a global mandate to promote an international network of genetic resources for furtherance of the collection, conservation, documentation, evaluation, and use of germ plasm through its free exchange, thereby helping to raise the standard of living and the welfare of people throughout the world.

In the nine years since its inception, the IBPGR has been instrumental in making both the scientific and lay communities aware of the importance of crop genetic resources. In particular, there have been marked increases in the collection of germ plasm and in the establishment of storage facilities to hold the material. The IBPGR works in close collaboration with national, regional, and international institutes, including other IARCs that make up the IBPGR global network.

The IBPGR is primarily concerned with endangered material, including traditional cultivars, land races, and wild relatives of cultivated plants.

The best scientific advice is obtained through crop advisory committees and ad hoc working groups established by the IBPGR that have helped to select from the vast array of plants in need of attention those that merit priority. Initially, the board focused its attention on the important cereals--wheat, maize, rice, sorghum, and millets--and pulses. It then phased in root, tuber, and vegetable crops, minor cereals and minor pulses, fruit crops, and some others.

MOBILIZATION OF THE GERM PLASM OF NUTRITIONALLY IMPORTANT CROPS

The efforts made by the IBPGR in mobilization of the germ plasm resources in the three main groups of crops that contribute significantly to human nutrition--namely, cereals and millets, grain legumes and oilseeds, and vegetables--will be discussed here in more detail.

Cereals and Millets

Ever since its inception the IBPGR has given priority to the collection and conservation of germ plasm of rice, and it has

organized 31 exploratory missions so far. In this endeavor the IBPGR has close links with the International Rice Research Institute (IRRI), the International Institute of Tropical Agriculture (IITA), the West African Rice Development Association (WARDA), and several other regional and national institutions.

Rice. A directory compiled by the IBPGR gives the number of accessions and other details of collections held in 38 different countries. This wealth of variability has been made available to the geneticist for manipulation and substantial work has been done in evaluating the collections, especially by IRRI, which holds 26,000 of the approximately 70,000 accessions in the world rice germ plasm collection. These have been screened for protein content, and the samples showed a wide range, from 4.3 to a little over 13 percent. Although this variability is high, rice breeders cannot make much progress in solving such problems as the following: protein content is greatly influenced by the environment and the heritability is low; the assimilation of protein has not been clearly understood; an increase in yield is proportional to an increase in protein only up to a certain point, after which the yield begins to decrease; there is no direct relation between overall protein content and lysine content--that is, with an increase in protein content there is no concurrent increase in lysine content; and the low protein content is dominant.

Maize. In maize the germ plasm has been exhaustively collected in most priority areas. Almost all the 45 or so maize-growing countries maintain their own collections, which contain about 300,000 accessions.[1] The IBPGR has sponsored missions to many different priority regions and has assisted in collecting more than 10,000 genotypes.

Good progress has been made toward improvement of nutritional quality of maize. In time it may be possible to sort out the problems of high-yielding, nutritious maize. The basic variability has been collected and kept at the disposal of the breeder. The discovery in the early 1960s of two endosperm mutants, opaque-2 and floury-2, from among the collections and the demonstration of genetic control of protein composition revealed the possibility of improving the quality of the protein in rice.

ICTA, in collaboration with INCAP and CIMMYT, recently developed a new variety called Nutrica, a maize of high protein quality.

Because maize is a highly cross-pollinated crop and because the high gene content opaque-2 is recessive, governing the endosperm character, the maintenance of any cultivar with opaque-2 still remains a problem unless only Nutrica is permitted to grow in the entire country.

Sorghum. The existence of a large number of samples of sorghum in collection and their subsequent evaluation for nutritional content has led to the discovery of nutritionally valuable genotypes. After the

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[1] International Board for Plant Genetic Resources, Directory of Germplasm Collections of Maize (Rome: IBPGR, 1980).

evaluation of more than 9,000 samples during the early 1970s, two lines from Ethiopia with high lysine and protein content were discovered. The character was found to be inherited, controlled by a single recessive gene. As is true of the opaque-2 mutant of maize, these lines were linked with many undesirable traits; the grains were partially dented and floury, the seed weight was low, and the lines had low yield potential. Other researchers have shown that lysine content can also be induced by mutation, which can be crossed with high-yielding lines from the world collection of germ plasm maintained at Purdue University and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to obtain a high-yielding variety that is favored by consumers. Several elite lines have been developed and are reported to be performing well in Africa.

The IBPGR has given high priority to sorghum, has organized several missions, and has acquired nearly 5,000 samples from 25 different countries. Sorghum is now collected throughout the world, and more than 80,000 collections are being maintained in 20 sorghum-growing countries. ICRISAT and the United States have the largest germ plasm collections, each possessing more than 15,000 accessions.[2]

Millet. There is much room for improvement of the nutritional quality of pearl millet. The protein content varies from 8 percent to 23 percent, lysine content from 0.9 percent to 3.8 percent, oil content from 2.8 percent to 8.0 percent, and carbohydrate content from 59.7 percent to 74.5 percent. As is true of wheat there is a possibility that the protein content can be increased without affecting the yield, although the environment seems to have a greater influence. Several composites have shown a range of protein content from 8 percent to 15 percent, and nutritious composites from the germ-plasm collections can be used as parents in developing high-protein millets.

The IBPGR has emphasized Pennisetum in its collecting program, and nearly 2,000 samples have been collected from those regions in which diversity has been shown in the crop. Work on evaluation and use is being done at various centers.

Wheat. It has been observed that genes that control protein content are independent of genes that contribute to yield enhancement; to increase the nutritional quality of wheat is less of a problem than it is with other cereal crops. Lines with high protein content have been developed in which the standard yield or a slightly higher yield has been maintained.

A slight increase in the protein content and quality of wheat would clearly have a considerable effect on the nutritional status of peoples throughout the world since wheat is a staple food of 35 percent of the world population and provides 20 percent of the food calories consumed. The IBPGR has accorded a high priority to the collection of wheat and related species, listing 38 countries in which

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[2] These collections are listed in International Board for Plant Genetic Resources, Directory of Germplasm Collections of Sorghum and Millets (Rome: IBPGR, 1981).

more than 330,000 wheat accessions are maintained. About half of these appear to be duplicates, which the IBPGR is now helping to identify.

Barley. The value of indigenous genetic resources is clearly evident in the case of barley. Many of the Ethiopian barleys, for example, are immensely valuable sources of genetic resistance to a wide range of plant diseases. Many also have high protein content. The high-lysine barley found in Ethiopia is poor in agronomic characteristics, yielding only a third as much as contemporary cultivars. By crossing and backcrossing, lines have been developed with yields 90-95 percent as large as those of recurrent parents with high protein and lysine content.

Food Legumes and Oilseeds

After cereals and millets the food legumes constitute the next largest source of protein in the diet in many developing countries. The most important of these are dry beans, pigeon peas, cowpeas, chick-peas, broad beans, peas, and the two leguminous oilseeds, peanuts and soybeans. These have been seriously neglected, and research is needed both to increase yield and to improve nutritional quality. The latter will entail increasing the concentration of protein, producing higher levels of methionine and cystine--sulphur-containing amino acids that are usually the main limiting acids in legume proteins--augmenting with higher levels of lysine whenever feasible, and increasing the digestibility of the protein. Legumes are invariably associated with toxic constituents such as trypsin inhibitors, hemagglutinins, antivitamins, goitrogens, cynogens, alkaloids, lathyrogens, and factors that lead to favism, a debilitating illness due to consumption of faba beans, and flatulence.

As is true of cereals and millets, considerable variation in the protein content has been observed.

Pigeon Peas. In pigeon peas it is reported that there is a wide range of variability in methionine and cystine content, 0.7 grams to 1.58 grams and 0.7 grams to 1.3 grams, respectively, which points to the possibility of genetic improvement. The transfer of the genes from samples with high protein content would have a tangible effect because pigeon peas are the principal source of pulse protein for 30-40 percent of the peoples of Southeast Asia.

Chick-peas. Chick-peas are another important grain legume that is a mandate crop of ICRISAT, which maintains more than 12,000 accessions. The range of variability in protein content is reported to be 12.4 percent to 28.1 percent. At present, there is no specific program for genetic improvement for nutritional quality.

French Beans. The French bean, *Phaseolus vulgaris*, is an important source of protein in Latin American countries. CIAT in Colombia maintains more than 35,000 accessions. Although the complete collection has not been systematically analyzed, a preliminary analysis showed a high coefficient of variability with a good prospect for genetic advancement. Such a wide range of variability--19.25 to 28.29

percent--has also been observed in the mung bean. When the entire germ plasm has been analyzed, the range may well prove to be higher. A similar range of variability has been noted in other legumes, such as cowpeas, lentils, rice beans, and *Vicia faba*.

Soybeans. A more systematic collection and evaluation of soybeans has been made in addition to genetic improvement for nutritional quality. The range of protein and oil content is quite high and is negatively correlated. At the same time, selection for either of these has been found to reduce the yield.

Oil Content. Nutritional improvement has been made by increasing the oil content in many crops through the use of their genetic variability. Russian breeders have increased the oil content of sunflower seed from 30 percent to almost 50 percent in 50 years by using modified recurrent selection. The oil content of safflower has been increased from 37 percent to 50 percent by reducing the hull content. In the same way that changes in the amino-acid spectrum reflect the nutritional quality of the protein, the fatty-acid composition determines the nutritional quality of the oil. Oils with more unsaturated fatty acid are more digestible, are easily assimilated, and do not lead to accumulation of cholesterol. A large amount of variation in fatty-acid composition has been observed among the different accessions.

Vegetables and Other Relevant Crops

Although vegetables form a relatively small part of the diet, they are nutritionally important in that they supply vitamins and minerals. A high degree of progress has been made in the collection and use of germ plasm for nutritional quality in the tomato, potato, carrot, and sweet potato.

Tomatoes. The tomato is a good source of vitamin A; it is said that one average-size tomato can supply a fourth of the daily requirement of vitamin A. Much of the carotene in tomato is lycopene, which does not contain much vitamin A. The vitamin-A content can be augmented by increasing the B-carotene content, which can be transferred from related species of *Lycopersicon pimpinellifolium* and *L. peruvianum*. These lines have never become popular, however, because the yellow color of the fruit has not found favor with consumers. A red cultivar with high B-carotene content has yet to be developed.

Potatoes. A still more important crop is the potato, which has several attributes that make it an important target for improvement: it is eaten in substantial quantities in many parts of the world; the protein content varies from 6 percent to 8 percent; the yield per unit of cultivated area is 1.5 to 2 times that of wheat; the amino-acid content is well balanced; it shows a wide range of genetic variability in protein concentration and the limiting amino acids; the nonprotein nitrogen in the potato, 75 percent of which is free amino acids, is also nutritious.

Cassava. The protein content of cassava is generally no more than 1.5 to 2 percent; it is, on the other hand, a staple food in African countries. A collection with protein content as high as 6 percent has been reported, so improvement may be possible.

Amaranth. The amaranth, both grain and leaves of which are consumed, is a crop of great nutritional potential. The amino-acid composition of amaranth is unique in that the plant contains both lysine and sulphur-bearing amino acids. A wide array of germ plasm has been collected and analyzed for protein content and the amino-acid spectrum, but the task of synthesizing a genotype with all the desirable nutritional qualities and other useful economic characteristics as well has been left to the plant breeder.

STRATEGIES OF COLLECTION, EVALUATION, AND GENETIC MANIPULATION

Unlike breeding for high yield, resistance to pests and diseases, adaptability, and other economic characteristics, attempts to improve the nutritional quality of several food crops have been met with only limited success. The constraints have to do with the availability of adequate genetic resources and the means of combining nutritional quality with other economic traits, such as yield, adaptability, and consumer preference.

While the task of the geneticists and plant breeders is to reconstitute the genotypes by transferring useful genes from various sources, it is the job of the germ-plasm botanist to supply the necessary variability. It is more difficult to identify those plants whose seeds, fruits, tubers, or other vegetative parts possess high nutritional quality than to identify morphological characteristics, yield and yield attributes, and so on. Cooperation between biochemist and nutritionist is necessary, because the procedures are complicated, expensive, and time-consuming. The frequency with which a genotype of nutritional importance occurs, moreover, may be quite low.

Unlike the other characteristics of natural fitness, the traits for high nutritional quality in a genotype may not survive readily under the stress of evolutionary forces. Genotypes possessing such nutritional quality that have evolved through mutation or by segregation and recombination would have been lost in the evolutionary process had they not been linked with traits of high survival value and adaptability.

While biological evolution may have caused the selection of plants that produce fruits, seeds, and other vegetative parts of high nutritive value, both wild and domesticated animals have also been instrumental. Plants and animals coexist in a symbiotic way and continue to evolve. Many birds and herbivorous animals have identified plants with nutritious seeds and fruits and dispersed them, leading to new populations, new ecotypes, new species, or even new genera.

In plants having highly nutritious substances in their seeds and other vegetative parts, many will have built up toxic substances and other antinutritional factors as a means of survival. Such plants may be overlooked on the assumption that they are not edible, while it may be possible to develop edible plants from them by a simple mutation-breeding procedure. Development of sweet lupine from bitter, non-edible but highly nutritious lupine is an outstanding example.

Man has also been a factor in evolution in this direction while domesticating plants. It was probably not possible to select plants having high protein and vitamin content and other nutritional qualities. With respect to sugar content, Saccharum officinarum derived its high sucrose content from S. robastum through a series of mutations and selection was made by the people of the Polynesian islands. Similarly, selection for greater sweetness or higher sucrose content in fruits or for higher oil content in oilseed crops may have been made in the primary or secondary centers of diversity where these plants were domesticated.

Many food habits, medicines, and taboos may have influenced evolution and may also hold important clues in the search for plants of nutritional importance. The reason for the cultivation and consumption of low-yielding dent sorghum by Ethiopians of the Wallo Province is that its lysine content is high. Similarly, the reason for the preponderant use of green gram soup for the old, the sick, and children in India is that it contains protein of relatively high digestibility.

Evaluation for nutritional quality is tedious, time-consuming, and expensive, and the results depend heavily upon environmental conditions. Obtaining reliable results may require growing the available collections of the crop in replication, and the plants should be analyzed for the desired quality by one of the standard methods, preferably in the same laboratory, by the same group of technicians and scientists. At the same time the geneticist will have to acquire all the basic information about gene action if progress in genetic improvement is to be made. There are many possible approaches and many problems in meeting nutritional requirements through crop-improvement programs.

Collections of germ plasm can only furnish genetic moiety to the plant breeder, who then manipulates the different forms and encounters various degrees of complexity in using them. The first thing to consider is the plant itself. There are many plants listed by the U.S. National Academy of Sciences that are known for their high nutritional value. Notable examples are marama beans, lupine, and winged beans. These contain 32-38 percent protein and 12-18 percent oil. Breeding efforts must be made to give them high harvest index and wide adaptability. The lysine content of the grain amaranthus is reported to be 8-12 percent; considerable work is being done in India and the United States to develop high-yielding varieties.

Other plants that are of potential nutritional value have the disadvantage of possessing antinutritional factors, such as alkaloids in canary grass, saponins in alfalfa and clovers, coumarin in sweet clover, and mimosin in ku-babul, that prevent their consumption. Achievements in reducing toxins or anti-nutritional factors in canary grass, tescue, sorghum, and alfalfa are promising; rape with no erucic acid has been developed; and sweet lupine selected from toxic wild lupine is being harnessed for use as fodder. This gives hope to germ-plasm geneticists searching for plants of nutritional value, although acceptance of the results by animal and man is not always assured.

There are other plants in which genetic moiety of nutrition is present in related wild species, although transferring the trait would be time-consuming. Recurrent backcrossing must be done to eliminate all the undesirable traits of the wild species. Occasionally the

genes governing nutritional qualities may be present in related genera. A related genus of the pigeon pea, atolosia, is found to contain 32-36 percent protein. It has been crossed with pigeon pea, and at ICRISAT, many backcrosses have also been made in an effort to eliminate undesirable genes. Species related to cultivated species of tomato and oat that are more valuable nutritionally have been found and are being used in breeding. It goes without saying that the mobilization of resources must be extended to the collection of all the related species--and to the collection of all related genera in some instances.

A successful example of nutritional improvement by intergeneric crosses is triticale, a cross between wheat and rye. Triticale is finding an ecological niche and the area of cultivation is increasing.

A less complicated procedure is the transfer of genes in genotypes in cultivated species that possess high nutritional value. The nutritional value can be controlled by a polygenic system, as was the protein content of rice, or by primary genes, as in maize and sorghum. Self-pollinated crops such as rice allow the characteristics to be fixed easily, and the prospect of increasing their protein content remains to be exploited further.

While inheritance is complicated in rice, a much simpler genetic system for improvement of protein quality was found in maize and sorghum. In maize, increases were found in the concentrations of lysine, tryptophan, and methionine, which are essential for monogastric animals. This discovery gave impetus to all nutritionists and geneticists to work toward the development of maize with high-quality protein. Unfortunately, these characters were associated with low yield and soft endosperm quality. The latter makes the maize susceptible to insects and pests and gives it poor keeping quality. After a decade of innovative and intensive work, maize breeders were able to obtain hard-endosperm types by incorporating many modifier genes. Maintenance of this character has become difficult, however, because maize is a cross-pollinated crop and the high lysine content is controlled by recessive genes in a homozygous condition. Nonetheless, the newly synthesized maize has been accepted by consumers in many places. Since both maize and sorghum are open-pollinated, maintenance of a variety is difficult, unless only one variety is allowed to be grown.

Production of hybrids (F_1S) combining yield and nutritional quality, as is done in grasses, is a good strategy that can well be applied to food crops.

Much is expected from manipulation through genetic engineering, but so far no comprehensive project for nutritional improvement of an important food crop has been undertaken.

SUMMARY

Breeding crops for better nutritional quality is one of the cheapest and most reliable means of addressing the world nutritional gap. Other means, such as using a combination of different foods in the diet or fortifying the staple foods with supplementary nutrients, have been found to be expensive and have generally not been very well

accepted. Genetic improvement as a means of filling this gap appears to be the best possibility.

Little advancement has been made so far in this direction for the task is difficult and requires a multidisciplinary approach involving the germ-plasm geneticist, the biochemist, the nutritionist, and the plant breeder, who must work together in harmony. A multitude of problems must be solved in each discipline before success can be achieved. For the germ-plasm geneticist the task of identifying the genotype that possesses high nutritional quality involves an intimate knowledge of the evolutionary background of the cultivated species, its center of diversity, and the food habits of animals and man. These data can only serve as a guide for the initial collection of crop germ plasm. The nutritional quality will be assessed by later evaluation, which is an expensive and time-consuming procedure. So far such analyses have been made of relatively few samples--by no means of all the material held in collections.

Nine years ago, when the IBPGR was formed, first priority was given to the collection of rapidly disappearing variations in species of food crops. Now that the IBPGR is directing more attention toward evaluation of this material, a necessary prerequisite is the building up of accurate information on the accessions held in gene banks. The information available at the present time is fragmentary; in many gene banks there is a wide range of variability, however, a situation that holds promise for genetic manipulation and improvement.

Improvement of nutritional quality is limited by the fact that in many instances the mode of inheritance is not well understood. When the inheritance has been worked out, it has been found to be complicated. The polygenic inheritance often associated with modifying factors makes the transfer of traits difficult. Low heritability, undesirable linkages, and correlated responses--such as an increase in lysine content concomitant with a decrease in protein content or an increase in protein content that causes a lessening of yield--has made genetic manipulation a slow and complex task. Various methods, both conventional and unconventional, such as mutation breeding and polyploidy breeding preceded by interspecific and intergeneric crosses, are now being used. On the other hand, there appears to be strong potential in breeding to remove toxic substances and agronomic deficiencies from crops that are otherwise nutritionally valuable. Sophisticated techniques of genetic engineering are being developed, such as those used to transfer genes in bacteria, although at present it is uncertain whether these expensive techniques will be available for crop-improvement programs.

Whatever means are used by genetic resources workers, the basic genetic variability remains the bulwark upon which improvement in nutritional qualities will be based. The variable genes of the principal crops will continue to be scrutinized for nutritional traits by the scientific institutions with which the IBPGR works, with the possible result that the kind of breakthrough that has boosted yield in wheat and rice will be achieved.

The IBPGR is giving its support and expertise for the collection, maintenance, and evaluation of crop germ plasm for training at various levels, particularly with a view to increasing the capabilities of national institutes and programs in developing countries and for the most effective and beneficial use of this germ plasm. In short, it is an integral part of the effort to meet world nutritional needs.

8
Nutritional Dimensions of Agricultural Research at ICARDA

Kutlu Somel

The International Center for Agricultural Research for the Dry Areas (ICARDA) is located in Syria. Its headquarters are in Tel Hadya, a 948-hectare farm 30 kilometers south of Aleppo.

ICARDA was founded in 1977, and its administrative headquarters were in Beirut until 1981 when all offices were moved to Tel Hadya. Aleppo province was chosen as the center of research activities because it is possible to observe a variety of environmental conditions within the limits of an area covered by a radius of 100 kilometers. Average rainfall, for example, varies from 477 millimeters in the northwest at Jindiress, near the Turkish border, to 219 millimeters at Khanasser, 100 kilometers to the southeast. The average at Tel Hadya, more or less in the center, is 389 millimeters. Similar variation can be observed in soils, social conditions, and so on, but climatic variability is a crucial constraint to rainfed agricultural production in the Middle East and North Africa. Aleppo province thus provides a suitable environment in which to conduct agricultural research for diverse rainfed conditions.

Within CGIAR, ICARDA has a regional mandate covering the Middle East and North Africa. This region extends from Pakistan to Morocco and from Turkey to the Sudan. It has the world mandate to coordinate research on barley, lentils, and faba beans. On a regional basis it conducts research on chick-peas in collaboration with ICRISAT and in wheat--bread wheat and durum--in collaboration with CIMMYT. ICARDA also conducts research in pasture and forage improvement and in livestock management.[1]

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* Assistance from Mirella Mokbel is gratefully acknowledged. The views expressed in this paper are those of the author only and do not necessarily reflect official ICARDA policy.

[1] Livestock research activities are primarily concerned with management of the local fat-tail Awassi sheep and do not involve breeding activities.

A list of ICARDA publications utilized has not been provided as it would have been too long. Those interested can write for a list of publications to Larry Chambers, ICARDA Communications and Documentation, P. O. Box 5466, Aleppo, Syria.

The salient characteristic of ICARDA is its emphasis on farming systems in agricultural research. The Farming Systems Program is quite active in research in Syria and internationally. It is involved in interdisciplinary research and, with a multidisciplinary team of scientists, in such diverse fields as economics, agronomy, soil physics, soil chemistry, weed science, agroclimatology, microbiology, sociology, livestock science, and plant physiology.

These research activities at ICARDA are organized around four programs:

1. Farming Systems Program.
2. Cereals Improvement Program.
3. Food Legume Improvement Program.
4. Pasture and Forage Improvement Program.[2]

In addition to these, there are a Genetic Resources Unit (GRU), a computer center, a training center, a communications unit, and various laboratories and workshops.

The primary concern of research at ICARDA is production. It regards the rural population principally as producers, and it seeks to improve their welfare and that of populations in general by contributing to increases in agricultural production. For this reason ICARDA emphasizes crops that are important in its mandate region:

1. Wheat is the basic staple crop in the Middle East and North Africa. It is consumed primarily in the form of various types of bread--flat, sheet, and leavened, for example. Durum wheat is an important source of nutrition in typical regional dishes such as burghul and couscous, but it is also widely used in making the local flat breads.
2. Barley is the basic feed crop of the region. Because it is adapted to the drier zones, it is an important crop for the farmers of these poorer areas, who exploit the limited potential of the areas to the full--sometimes to excess--by integrating barley production with livestock production on the farming unit. Grazing, or rather overgrazing, of the pastures in the steppes is also typical of the livestock-driven activities of the drier zones of the region. ICARDA's research in the PFIP includes efforts to rehabilitate pastures and to develop and promote forage crops that may slow the degradation of the steppe that will come about if current stocking rates are maintained.
3. Food legumes are quite important in the region nutritionally. The traditional food legumes are lentils, chick-peas, and faba beans. They figure as important sources of protein in the traditional dishes of the region such as lentil soup, hommos bi-tahine (a chick-pea paste containing sesame oil), and ful (a faba-bean dish). Labor-intensive production, especially harvesting processes, mainly for lentils and chick-peas, poses problems in the face of scarce agricultural labor and associated high labor costs. Efforts are being made at ICARDA to develop mechanized

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[2] The Pasture and Forage Improvement Program and livestock research in the Farming Systems Program have engaged in many cooperative activities. Integration of livestock research into the Pasture Program was suggested in the First Quinquennial Review of ICARDA and was put into effect in 1984.

harvesting for these crops, so that they will still figure in production and nutrition.

ICARDA operates in a region in which, with the exception of one country, there are chronic food deficits that are met in part by imports. Invariably these imports are directed to the urban areas, while rural consumers are expected to make do with what they can produce themselves. These producers, when they have deficits in food, may not be able to benefit from the subsidized food sales that are directed to urban consumers. They are thus doubly penalized, first as producers, by inadequate incentives because of subsidized food prices while most food is imported, and second as consumers, by being expected to bear the full costs of the food they have produced. It would not be too difficult to imagine that the poor have more than their share of these deficits. Because of the existence of global food deficits, however, policymakers seem to give priority to assuring adequate food supplies in the aggregate; the problems of the poor, the malnourished, and the nutritionally vulnerable appear to have lower priority. Food security through increased food production, for example, is a common theme of policy in the region. It is not clear, however, whether the problem has been adequately analyzed, especially with respect to comparative advantage, on a national basis or on the basis of groups of countries such as the Islamic Conference.

ICARDA does not seem to have identified target groups whose nutritional needs are specifically considered and incorporated into its research activities. On the other hand, its efforts are concentrated on staple commodities that are consumed widely and, at least theoretically, by the poor.[3] We can therefore easily claim to be addressing the nutritional problems of the poor in general.

The principal reason for ICARDA's concentration on barley and livestock is the crop-livestock systems that are observed primarily in the resource-poor areas of the Middle East and North Africa. The symbiotic relation between sheep raising, barley production, and the steppe as the grazing area exemplifies a time-tested way of exploiting the scarce resources of the drier regions efficiently. Sheep raising, moreover, is not a purely specialized meat-production activity; dairy products and wool are also important. In certain instances, dairy products may even be the most important activity. It is also possible to hypothesize a banking function in livestock production: herds are thinned in times of financial need but rebuilt when finances improve.

In the Middle East and North Africa in general, but more in rural areas, two dairy products besides butter are almost staples. These are yogurt (lebneh) and white cheese, items that are widely consumed and can be considered to constitute the primary source of high-quality animal protein, especially for the rural populations. According to the results of a rural expenditure survey conducted in Turkey in 1973-74, real and imputed expenditures for dairy products were three to four times as great as expenditures for meat. It can thus be claimed that research on livestock, barley, and forages, apart from the possibility of generating increases in incomes, will cause

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[3] This characteristic is not unique to ICARDA: all the centers in the CGIAR that are primarily concerned with production are essentially involved in staple commodities.

increases in dairy production, which will have positive nutritional effects.

Another characteristic of research at ICARDA is the development of technologies in components rather than in complete packages, an approach taken in various outreach activities in Jordan, the Sudan, Egypt, and Syria. For various reasons that have been adequately discussed in the literature, farmers are reluctant to adopt complete packages. ICARDA therefore attempts to produce components of research with clear assessment of their marginal benefits and costs, whether individually or in groups. In this way it is possible to project a more realistic picture of potential adoption and diffusion processes and produce research results more appropriate to the particular conditions under which farmers work.

NUTRITION-RELATED RESEARCH AT ICARDA

Despite its emphasis on production and its not having tangible target groups for its nutritional objectives, ICARDA has nonetheless exhibited consciousness of nutritional issues, even at this early stage of its development. In this respect three sets of activities can be discussed:

Product Quality Research

These research activities are an integral part of the commodity-improvement programs. Although there are routine analyses of nutrient content, especially of protein content, the emphasis in product quality research is on acceptability. The quality laboratories use advanced equipment and process large numbers of samples. Tests for acceptability, however, involve approaches that vary according to the nature of the product. Some examples may illustrate this point:

1. Important quality factors for chick-peas and faba beans are taste and cooking time. Quite simple tests, such as 90 percent cooking time and manual checks for softness are conducted, along with such tests as the crude-fiber digestion system. Panels are used to evaluate taste factors. Protein content is tested for routinely. In addition, serious problems, such as favism, a debilitating illness that arises, particularly in children, due to consumption of faba beans, are given special attention.
2. In cereals routine quality tests are for protein content, thousand-kernel weight, vitreous-kernel percentage, hardness, and wheat-meal fermentation time. Two other activities are worth noting, however. The first is the Cereal Quality Nursery, a series of advanced lines of cereals grown in several locations in the ICARDA region under rainfed and irrigated conditions. The objectives of the Cereal Quality Nursery are to determine the stability of quality-parameter ranks under varying environmental conditions and to determine the extent to which environment rather than genotype determines individual quality factors. Preliminary results seem to indicate that genotype has a greater effect on quality than environment.

   The second activity involves testing the bread-making quality of flour from different cultivars and genotypes. For

this an oven for baking a traditional local flat bread, khobz, was built at Tel Hadya along with a small milling facility. Although this oven is typical of local ovens, selected flours are also tested in traditional and modern commercial ovens. In this manner an effort is made to conform quality tests as far as possible to local taste patterns. As a consequence it was determined that weaker wheats make the best khobz, flours with 10-11.5 percent protein are most satisfactory, and pure durum flours are unsuitable for khobz and need to be blended with at least 50 percent bread-wheat flour.

3. In addition to routine tests for such factors as protein content and fiber content, barley and other forage crops are subjected to studies of their digestibility by sheep in the livestock unit. Plans are being made to subject barley straw, which is important as feed, to similar tests.
4. Research on resistance to disease and insects and tolerance for stress are particularly important as special aspects of product characteristics. Drought-tolerance research has important implications for assuring the availability of food during climatically adverse seasons.

The ICARDA/UNU Workshop on Interfaces Between Agriculture, Food Science, and Human Nutrition in the Middle East, Aleppo, February 21-25, 1982

This international workshop, organized and financed by the United Nations University and ICARDA, increased the sensitivity of both ICARDA and regional scientists to nutritional issues. The participation of scientists of diverse disciplines from many national and international research organizations produced a fruitful exchange of ideas. The proceedings of the workshop have been edited by David F. Nygaard and Peter L. Pellett and will soon be published.

One of the recommendations of the workshop was that similar workshops be held at the regional and national levels. As a consequence the workshop in the Sudan, which will be discussed below, was organized.

The Workshop on Interfaces Between Agriculture, Food Science, and Nutrition in the Sudan, Khartoum, December 10-15, 1983

This workshop, sponsored by ICARDA and supported jointly by the Ford Foundation and UNICEF, had as its primary objective bringing together national scientists who conduct disciplinary research on agricultural and nutritional problems. It was held at the Food Research Center, Shambat. Thirty national scientists, representing such diverse disciplines as food science and technology, nutrition, medicine, agronomy, agricultural economics, and community health care, participated, as did planners and policymakers from the Sudanese ministries of health, commerce, industry, and agriculture.

During the workshop, current research was reviewed and the present state of food and nutrition in the Sudan was assessed.

Subsequently, subjects that needed further research, multidisciplinary approaches, and constraints to research were discussed.

The workshop concluded with several recommendations bearing on policies, research, and action to increase production and consumption of food and to improve nutritional status. The principal recommendations were the following:

1. That a National Food and Nutrition Council be organized to coordinate the activities of agencies involved in food production, food science, and nutrition.
2. That in order to increase food production, more financial resources be allocated to agriculture, principally for the production of food crops, for production in rainfed areas, and for the improvement of marketing and storage facilities.
3. That the local food industry be protected and that adequate export and import policies be developed, taking into consideration consumer demand and national interest.
4. That present nutrition education programs be evaluated and developed, with emphasis on the mass media and community involvement.
5. That infant nutrition be supported, breast-feeding encouraged, and weaning foods developed from locally available ingredients.
6. That protein-energy malnutrition be detected early by means of simple anthropometric criteria and the development of simple rehabilitation activities that can be conducted by the existing health services.
7. That diets be fortified, especially with vitamin A, iron, and iodine.
8. That international agencies that can provide technical and financial assistance cooperate with one another.

Two Specific Nutrition-related Activities Supported by ICARDA and the Farming Systems Program

1. A nutrition survey of rural and urban Irbid, an important wheat-producing province of Jordan, was carried out as part of a collaborative research activity with the University of Jordan. Preliminary results from this survey were presented and conveyed to regional scientists at the First ICARDA Regional FSR Workshop, held in Aleppo, May 24-26, 1983. The purpose of the survey was to assess nutritional status with respect to age, sex--including the nutritional status of pregnant and lactating women--family size, income, and rural or urban residence and to determine the significance of wheat in nutrition. Preliminary indications are that

   - differences related to family size, residence, and three income groups do not appear to be discernible;
   - nutritional conditions in general appear to be below average recommended daily allowances but well within the range of recommended daily allowances;
   - only children, grouped as less than 1, 1-3, 4-6, and 7-9, appear to be deficient in energy requirements. Average protein intake in the same groups exceeds requirements by as much as 100 percent, except for infants less than 1 in the low- and moderate-income groups. Because of the energy deficit, the

use of protein may not be excessive to the degree that it appears to be.

Bread is the dominant element of nutrition in rural and urban areas. Most rural families produce their own wheat, however, and in times of deficit purchase wheat from rural markets. They therefore cannot benefit from the subsidized sales of flour and bread in urban areas. In Jordan, this finding has interesting policy implications.

2. With similar objectives but also with the objective of identifying the problems of vulnerable groups, a small-scale survey will be conducted in the villages of Aleppo Province by a Ph.D. student from the University of Massachusetts at Amherst. ICARDA will give her scientific and logistical support.

It is expected that the results of these studies will familiarize scientists with nutritional issues and gradually increase consideration of incorporating nutritional concerns into agricultural research. It must be admitted, however, that such efforts are in very early stages.

AGRICULTURAL PRODUCTION RESEARCH AND NUTRITION ISSUES

Without fear of oversimplification it can be said that nutritional problems emanate from the following causes:[4]

1. Inadequate production and availability of food.
2. Inadequate systems for the distribution of food.
3. Inadequate income and inequalities in the distribution of income.
4. Inadequate nutritional information and education.
5. General health problems.

Similarly, the solutions lie on many planes:

1. Research on production.
2. Improvement of health conditions and education.
3. Policies concerning subsidies for food, products, and inputs.
4. Investment in storage and distribution.
5. Macroeconomic policies to alleviate problems in the distribution of income.

These lists are by no means exhaustive; they cover only the dominant aspects of nutritional problems.

Within such a framework, IARCs that emphasize production can make some contribution to the solution of nutritional problems. It is clear that as a matter of comparative advantage their contribution will be disproportionately on the plane of research on production.

The issues for production research in contributing to the solution of nutritional problems are the following:

1. First of all, IARCs do not always have an adequate picture of the demand and the increase in demand for the products they are working on. While projections of aggregate food demand do exist, if the possibilities for substitution among food items are the

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[4] A more thorough discussion of these issues can be found in Eileen T. Kennedy and Per Pinstrup-Andersen, Nutrition-Related Policies and Programs: Past Performances and Research Needs (Washington, D.C.: IFPRI, February 1983), pp. 7-20.

subject of consideration, disaggregated commodity-based projections, of which there are very few, are required. We are working primarily on staples and with the conception of limitless increases in demand. The principal effort, therefore, is to increase yields and production.

We can gauge our production targets more realistically if we have adequate projections of demand. We could also give adequate consideration to trade-offs between yield and production targets and other objectives, such as nutrition.

2. Production research can contribute to improvement of the nutritional condition of the poorer elements of populations involved in production. It must be said here that concepts such as "resource-poor farmers" and "poor agricultural laborers" are relative. Poverty need not always be associated with nutritional problems. It is necessary to identify target groups and their needs, which can best be done by national research organizations, and the IARCs can be most effective in collaboration with such organizations.
3. The claim that IARCs can increase production, thereby improving the welfare of producers, is based on an assumption that may not hold under all circumstances. This is the assumption that producers can capture most or all of the benefits of increased production. It is neither inconceivable nor unexpected that producers will share the benefits of increased production with landlords, intermediaries, tax officials, and consumers, but the effectiveness of production research will be diluted by this distributional aspect. Some of the sharing of benefits--with consumers, for example--may be desirable while others probably will not. The distributional issue can be resolved only through national policies. The IARCs should not be prevented from maintaining their research perspectives, provided the distributional issues do not prevent the implementation of the results of production research. It would be still better for them to be conscious of the issues and adjust their research accordingly, but such a recommendation is more easily made than followed.
4. It is claimed that one way of assuring that the poorer farmers will benefit from agricultural research is to develop technologies that will reduce unit costs of production. This puts an unfair burden on agricultural research for the following reasons:
   - The general approach in IARCs is to develop technologies appropriate to conditions that do not increase risks and that provide sufficient net benefits to justify their adoption. Adding the aim of reducing unit production costs imposes the extra burden of ensuring that yields grow faster than costs. This argument also assumes stable--or even decreasing--output prices, a point of importance to consumers. In practice it is possible, by subsidizing both consumers and producers, to increase farm-gate prices. We are not necessarily advocating such distortions, however.
   - Unless significant untapped indigenous resources are discovered and used, improved technologies invariably require increases in costs. As research moves away from areas in which large increases in yields can be expected, the possibility that yields will grow faster than costs decreases. Unfortunately, resource-poor farmers usually work in the areas

where relatively large increases in yields are not likely to be realized.

- Policies concerning water management tend to favor the areas where large gains in yields can be realized. Charges for water in areas that are irrigated through large irrigation networks run by state agencies usually do not reflect costs. In other words, the water costs of farmers in these advantaged areas are subsidized.

  In drier areas, if there is irrigation, it is accomplished by simpler means such as tube wells and pumps, which are generally privately owned. The farmers in these disadvantaged areas usually have to pay actual costs that more nearly reflect opportunity costs.

  There is then the possibility that farmers in areas in which the potential yield is lower may pay higher costs because of discriminatory policies.

- One way of achieving growth in costs lower than growth in yields is to subsidize input prices. This is a matter of policy. Economists are generally not in favor of using input subsidies as production incentives, however. Inputs such as fertilizer can be used on many crops, and a staple crop selected for subsidization may not benefit fully from the input subsidy. An output-price subsidy is a more efficient instrument of policy to provide incentives to production.

  In conclusion, to reduce unit costs of production is not easy, and it is especially difficult in the poorer areas.

5. One of the intended beneficiaries of nutritional research is agricultural labor. It is clearly possible for this group, especially women and children who are agricultural workers, to have serious nutritional problems. However, the concern for this group is conditioned by the preoccupation with labor-intensive agricultural production processes and labor surplus areas. ICARDA operates in a region in which the agricultural sector can be characterized by scarce and expensive labor. The identification of target groups for improvement of nutrition or nutritionally vulnerable groups must therefore be based on location-specific or national research rather than on general preconceptions.

6. Intrahousehold decisions about the allocation of such resources as labor are of interest to the IARCs. The connections with expenditures in general and expenditures for food specifically can lead to a better understanding of the farm-household enterprise.

   For long periods the myth of the ignorant and inefficient peasant was perpetuated, but the evidence has done much to eradicate it. Yet doubts have arisen that the farm-household enterprise that is capable of allocating resources efficiently on the farm is not capable of a similarly efficient allocation of food and income among its members. This may or may not be true. The analytical tools for studying intrahousehold decisionmaking processes must be sharpened, and considerable concrete evidence must be gathered.

CONCLUSIONS

The contribution of IARCs that are primarily concerned with production to the solution of nutritional problems is limited to the plane of increasing food production. At the same time, it is necessary to be conscious of the issues and incorporate nutritional concerns into agricultural research.

It would be realistic to expect that the success of the IARCs in influencing nutrition through increases in production will be tempered by other factors that are primarily matters of policy. This indicates that nutritional problems are best approached at the national level. The multiplicity of factors that impinge on nutritional problems requires an integrated approach if it is to be effective, and the contributions of IARCs in collaborative research will enhance the effectiveness of research at the national level. IARCs can assist national organizations by offering their expertise in analysis and interpretation of the policy implications of research results.

The continuation of the present work of the IARCs on quality tests, workshops, and the like would enable the scientists of IARCs to maintain a high degree of awareness of nutritional issues.

9
ICRISAT Research and Human Nutrition*

N. S. Jodha

This paper highlights the nutritional aspects and implications of research done by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The research activities of ICRISAT that have to do with nutrition can be grouped in two categories:

1. Those directed toward understanding and documentation of the nutritional status of people, factors that affect nutrition status, and the desirable components of technologies for addressing nutrition problems.
2. Those designed to affect the determinants of human nutrition.

The first category is largely reflected in the work of social scientists and biochemists, who highlight the nutritional problems and analyze the determinants of nutrition to help define and plan research policies. Biochemists analyze the nutrient components of various crops and cultivars, thereby assisting plant breeders in the selection and incorporation of valuable crop characteristics and in understanding the nutritional quality of the newly developed material.

The activities in the second category include research by agrobiological and physical scientists that is directed toward development of crop-centered and resource-centered technologies for semiarid tropical areas--technologies that will ultimately influence the quantity, quality, and composition of food production, income, and employment and finally of consumption. These activities have to do with commodity priorities, commodity characteristics, technology characteristics and production-systems research as suggested by Pinstrup-Andersen.[1] For want of space, however, the present discussion will be confined to the first two aspects.

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[1] Per Pinstrup-Andersen, Incorporating Nutritional Goals into the Design of International Agricultural Research (Washington, D.C.: International Food Policy Research Institute, 1983).

RESEARCH TO UNDERSTAND NUTRITIONAL ISSUES AND PROBLEMS

An understanding of human nutritional status and the factors affecting it is an essential step toward a sharpening of the nutritional focus of prospective technologies. This involves research activities in the following two categories:

1. Research directed toward understanding the current nutritional status of people in semiarid tropical areas;
2. Research directed toward understanding the food quality of ICRISAT mandate crops.

On Current Nutritional Status

The ICRISAT research directed toward understanding the current nutritional status of rural populations in semiarid tropical areas has been largely confined to India.[2] Its objectives are to arrive at an understanding of the factors that influence the nutritional status of people and to derive useful inferences to help agrobiological scientists to attune their research strategies to nutritional issues. In some instances nutrition per se is the goal of research, while in others nutrition emerges as a component of the complex of issues studied. These studies have been conducted largely by economists in collaboration with nutritionists, biochemists, physiologists, and medical scientists.

Determinants of Individual Diet and Nutritional Status of People in Semiarid Tropical Villages in India. A detailed collaborative study was conducted by ICRISAT, the National Institute of Nutrition, and the Home Science College of Andhra Pradesh Agricultural University between 1976 and 1978 to determine the nutritional and health status of residents of semiarid tropical villages in Southern India. The study covered 1,200 people from a panel of 240 households in six villages of three agroclimatic zones throughout four seasons. The principal nutrient deficiencies found were energy, calcium, and vitamins A, B

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[2] Most of the attempts to understand the nutritional problems of Africa have been made by reviewing past investigations; see D. W. Norman et al., Farm and Village Production Systems in the Semi-Arid Tropics of West Africa: An Interpretative Review of Research, Research Bulletin No. 4 (Patancheru, Andhra Pradesh, India: ICRISAT, 1981), and Barbara Harris, The Marketing of Foodgrains in the Sudano-Sahelian States: An Interpretative Review of the Literature, Economics Program Progress Report 31 (Patancheru, Andhra Pradesh, India: ICRISAT, 1982). The village-level studies being conducted by ICRISAT in West Africa will also throw some light on the nutritional problems of the people; see P. J. Matlon, Profile of Farm Units in Two Villages of Central Upper Volta, West Africa Economics Program Progress Report 1 (Kamboinse, Upper Volta: ICRISAT, 1980), and John McIntire, Reconnaissance Socioeconomic Surveys in North and West Upper Volta, West Africa Economics Program Progress Report 3 (Kamboinse, Upper Volta: ICRISAT, 1982).

complex, and C. Protein was generally not limiting. Villages whose diets consisted largely of sorghum and pearl millet had better vitamin and mineral intake than the largely rice-consuming villages. The nutritional status was found to be determined primarily by agroclimatic and socioeconomic characteristics of villages rather than by the level of net household income. There was little seasonal variation in intakes of nutrients other than vitamin B complex, the consumption of which increased during the season of surplus foodgrains. In view of the importance of vitamin and mineral deficiencies found in the study villages, programs to increase the production of vegetables, dairy products, and fruits that contain significant quantities of these nutrients would seem appropriate. The role of common property resources (CPRs), such as village forests, pastures, ponds, and rivulets, from which people gather a variety of food and fodder freely, thus assumes greater significance. The calorie deficit should be overcome largely by increasing the availability of foodgrains, especially cereals. Crop-breeding programs can make a significant contribution to this effort by focusing on increasing and stabilizing crop yield.[3]

A further analysis of the data highlighted some aspects of intrahousehold allocation of nutrients. In the surplus season nutrients are allocated among children in households in the village-level study with some concern about distribution and not just about productivity--that is, parental inequality aversion. But in the lean season when food is scarcer there is much less concern about equality and the expected health outcome of boys and older children is favored over that of girls and younger children. Furthermore, in the lean season households that hold land favor older children less than those who do not. And households with more educated heads favor boys less in the surplus season, but more in the lean season.[4]

Nutritional Imbalances Induced by the Green Revolution. The spread of high-yielding varieties of wheat at the cost of acreage--and production--of pulses, a principal source of protein, became a matter of serious concern during the early 1970s. Its possible implications in the appearance of nutritional imbalances was examined by means of secondary data from important wheat-growing states in India. The study revealed that significant improvement in wheat production--caused by a plant-breeding strategy to increase yields--overcompensated for the possible decline in nutritional well-being of the people from the decline of pulse production in India. One reason that wheat could displace pulses to such a large extent, however, was that increases in wheat yields occurred at a time when yields of pulses were stagnant. This indicates the need for improving yields of pulses to

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[3] J. G. Ryan et al., The Determinants of Individual Diets and Nutritional Status in Six Villages of South India, Research Bulletin No. 7 (Patancheru, Andhra Pradesh, India: ICRISAT, 1984).

[4] J. R. Behrman, Intra-household Allocation of Nutrients in Rural India: Are Boys Favoured? Do Parents Exhibit Inequality Aversion?, Economics Program Progress Report 67 (Patancheru, Andhra Pradesh, India: ICRISAT, 1984).

prevent their prices from reaching a level that would take them out of reach of the nutritionally vulnerable and economically poor. The need for a breeding strategy for increasing the yield of pulses also became apparent.[5]

Human Nutrition and Crop-Breeding Objectives. Review of dietary surveys and related literature on the semiarid tropics showed that diets were deficient in calories, vitamin A, vitamin B complex, and some minerals, although deficiencies in proteins and amino acids were not as great as they were believed to be in the 1960s.[6] This suggests that higher priority should be given in the ICRISAT crop-improvement programs to breeding for increased yields and therefore more calories than to breeding for greater protein content and higher protein quality. Screening for high protein content may be confined to the elite progenies in a breeding program to ensure that the lines released have satisfactory nutrient profiles after other priorities have been met.[7] A review of this research by the governing board of ICRISAT was partly responsible for changes in breeding priorities in favor of higher and more stable yields, particularly in sorghum.

Nutrition and Traditional Farming Systems. Comprehensive village-level studies in semiarid tropical areas in India and in parts of West Africa have revealed several ways in which good nutrition and food management can be achieved through traditional farming systems. Mixed cropping or intercropping, involving a combination of crops with different food values, maturity periods, capacity to withstand hazards, and salvage possibilities, represents one of the most important practices that characterize traditional farming systems.[8] Intercropping and crop diversification can minimize crop fluctuations and the number of total crop failures, thereby helping to stabilize income

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[5] J. G. Ryan and Muthiah Asokan, "The Effects of the Green Revolution in Wheat on the Production of Pulses and Nutrients in India," Indian Journal of Agricultural Economics 32 (July-September, 1977): 8-15.

[6] J. G. Ryan et al., Human Nutritional Needs and Crop Breeding Objectives in the Semi-Arid Tropics, Economics Program Occasional Paper 4 (Patancheru, Andhra Pradesh, India: ICRISAT, 1974).

[7] Ibid.; and J. G. Ryan et al., Human Nutritional Needs and Crop Breeding Objectives in the Semi-Arid Tropics: A Further Note, Economics Program Occasional Paper 8 (Patancheru, Andhra Pradesh, India: ICRISAT, 1975).

[8] N. S. Jodha, "Intercropping in Traditional Farming Systems," Journal of Development Studies 16 (July 1980): 427-442; P. D. Bidinger and Bhavani Nag, "The Role of Pigeonpeas in Village Diets in the Semi-Arid Tropics of South India," in Proceedings of the International Workshop on Pigeonpeas, vol. 1 (Patancheru, Andhra Pradesh, India: ICRISAT, 1981), pp. 257-264; McIntire, Reconnaissance Socioeconomic Surveys.

and food supply.[9] The traditional integration of crops, livestock, grass, bushes, and trees into a total farming system underscores the importance of self-provisioning and food security.[10]

Drought-Induced Instability of Food Intakes and Nutritional Levels. A substantial decline in the consumption of food, particularly "protective" foods such as milk, vegetables, fruit, and meat, and in expenditures by farmers for food was observed in drought-affected areas of India. Curtailment of consumption, partly because of reduced supplies and partly because of the need to reduce current commitments, suggested the need for technological and institutional means of increasing and stabilizing crop production to protect people's nutritional status.[11] The quest for short-term food security also influenced the decisionmaking of farmers. Shortages in their own food supplies and lack of purchasing power encouraged such practices as agreements to working as attached labor, insistence on wages in kind, seasonal migration, tenancy, and the linking of various factor markets and product markets in villages.[12]

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9 R. P. Singh and T. S. Walker, Determinants and Implications of Crop Failure in the Semi-Arid Tropics of India, Economics Program Progress Report 40 (Patancheru, Andhra Pradesh, India: ICRISAT, 1983); T.S. Walker et al., Dimensions of Farm Level Diversification in Semi-Arid Tropics of Rural South India, Economics Program Progress Report 51 (Patancheru, Andhra Pradesh, India: ICRISAT, 1983).

10 Helga Vierich, "Anthropology in the Context of ICRISAT's Objectives in West Africa: Progress to Date and Plans for 1983," report prepared for ICRISAT in-house review, 1983; N. S. Jodha, "Market Forces and Erosion of Common Property Resources," paper presented at the International Workshop on Agricultural Markets in the Semi-Arid Tropics, ICRISAT, Patancheru, Andhra Pradesh, India, October 24-28, 1983.

11 N. S. Jodha, "Famine and Famine Policies: Some Empirical Evidence," Economic and Political Weekly, October 1975, pp. 1609-1623; N. S. Jodha, "Effectiveness of Farmers' Adjustment to Risk," Economic and Political Weekly, June 1978, pp. A.38-A.48; N. S. Jodha and A. C. Mascarenhas, "Adjustment to Climatic Variability in Self-Provisioning Societies: Some Evidence from India and Tanzania," ICRISAT Conference Paper No. 129, presented at the meeting of the Scientific Committee on Problems of Environment (SCOPE), Canadian Climate Centre, Toronto, Canada, September 27-October 7, 1981.

12 H. P. Binswanger et al., "Common Features and Contrasts in Labor Relations in the Semi-Arid Tropics of India," in Contractual Arrangements, Employment, and Wages in Rural Labor Markets in Asia, ed. H. P. Binswanger and M. R. Rosenzweig (New Haven: Yale University Press, 1984), pp. 143-168; N. S. Jodha, "Agricultural Tenancy in Semi-Arid Tropical India," in Contractual Arrangements, Employment, and Wages in Rural Labor Markets in Asia, ed. H. P. Binswanger and M. R. Rosenzweig (New Haven: Yale University Press, 1984), pp. 96-113.

Nutrition as a Determinant of Labor Wages and Participation Rate. ICRISAT research has indicated the adverse effects of tractorization and of herbicide-based weed management on employment.[13] Women, who are often at risk nutritionally and who are the principal source of labor for weeding, are the ones who suffer the most from the introduction of herbicides.[14]

Analysis of data on village labor markets--participation rates, wage rates, composition of wages, the provision of meals along with wages, cash, and payment in kind--indicated that a better nutritional status conferred a significant positive effect on the daily wages of men but not on those of women.[15] The effect on participation was the opposite, however. Women who were better nourished participated more actively in the daily market for casual agricultural labor, while the nutritional status of men was not significantly associated with their participation in the labor market. This explains in part why men are given priority in the allotment of food supplies in low-income households in rural areas. It also explains to some extent the tendency for a diversion of food away from nutritionally vulnerable members to the male adults in a family under the nutrition intervention programs for vulnerable groups.[16]

An econometric analysis of agricultural wages and farm productivity further demonstrated the importance of health in the short-term in influencing the marginal productivity of labor. For every percentage point increase in the standardized weight-for-height of a worker, ceteris paribus, his daily agricultural wage rate as well as the marginal productivity of his labor on the family farm increase by Rs 0.03 (the daily agricultural wage rate at the sample mean is Rs 2.45). This is a rather large effect, which suggests that investments in nutrition to increase the weight-for-height of individuals would have high returns in agriculture. So would other policy interventions that allow more weight-for-height to be 'produced' from given nutritional intakes by improving the general health environment and reducing the incidence of diseases.[17]

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[13] H. P. Binswanger, The Economics of Tractors in South Asia: An Analytical Review, ADC-ICRISAT Monograph (Patancheru, Andhra Pradesh, India: ICRISAT, 1977).

[14] H. P. Binswanger and S. V. R. Shetty, Economic Aspects of Weed Control in Semi-Arid Tropical Areas in India, Economics Program Occasional Paper 13 (Patancheru, Andhra Pradesh, India: ICRISAT, 1977).

[15] J. G. Ryan, Wage Functions for Daily Labor Market Participants in Rural South India, Economics Program Progress Report 38 (Patancheru, Andhra Pradesh, India: ICRISAT, 1982).

[16] Ibid.

[17] A. B. Deolalikar, Are There Pecuniary Returns to Health in Agricultural Work? An Econometric Analysis of Agricultural Wages and Farm Productivity in Rural South India, Economics Program Progress Report 66 (Patancheru, India: ICRISAT, 1984).

Elasticities of Demand for Protein and Calories. Income and price elasticities of demand for protein and calories were derived through an analysis of data on consumption collected in the National Sample Survey in India. Income and price elasticities of demand for both calories and protein are highest among the poorest consumers, particularly in rural areas. Sorghum and millet are significant components of the diets of very poor people, indicating that a breakthrough in the technology of production of these crops will bring about substantial nutritional gains for the poor.[18]

Analysis of Consumer Preference for Sorghum and Pearl Millet. Assuming that market prices reflect the preferences of consumers, relating these to characteristics of preferred foods revealed that protein content, cooking quality, and absence of glumes and molds in grain are important determinants of consumer preference for certain varieties of sorghum and millet.[19] The influence of nutrient content was confirmed by consumer panel studies.[20] These findings offer useful information for crop breeders in their efforts to make new cultivars acceptable to consumers. On the basis of the estimation coefficient for the relevant quality characteristics, a selection index can be derived to predict the preference of consumers for any new variety.

Common Property Resources and Human Nutrition. The initial results of a study of rural CPRs--resources used by the whole community without any exclusive right of individual ownership--revealed their significant contribution to human nutrition, particularly of the rural poor. The latter gathered fruit, leaves, flowers, honey, game, fish, wild cereals and legumes, and off-season vegetable crops from various CPRs, such as forests, pastures, wastelands, ponds, and rivulets, in the villages. The nutrients that are often unavailable from field crops

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[18] K. N. Murty and Matthias von Oppen, "Nutrient Distribution and Consumer Preference in India, with Policy Implications," paper presented at the International Workshop on Agricultural Markets in Semi-Arid Tropics, ICRISAT, Patancheru, Andhra Pradesh, India, October 24-28, 1983.

[19] Matthias von Oppen and P. P. Rao, "A Market Derived Selection Index for Consumer Preference of Evident and Cryptic Quality Characteristics of Sorghum," proceedings of the International Symposium on Sorghum Grain Quality, ICRISAT, Patancheru, Andhra Pradesh, India, 1982; Matthias von Oppen and Ramamurthi Jambunathan, "Consumer Preference for Cryptic and Evident Quality Characteristics of Sorghum and Millet," paper presented at the Diamond Jubilee Scientific Session of the National Institute of Nutrition, Hyderabad, India, October 23-27, 1978.

[20] P. P. Rao and Matthias von Oppen, Village Consumer Preference for Sorghum Varieties and Its Relationship to Sorghum Preference Index, Economics Program Progress Report 50 (Patancheru, Andhra Pradesh, India: ICRISAT, 1983).

and that are too costly or of too low a priority to be bought were gathered free from CPRs. In village households in semiarid tropical regions, these products comprised 9 percent of the diets of small farmers but only 4 percent of the diets of large farmers.[21]

Nutritional Considerations in the Allocation of Research Resources. In response to specific requests from ICRISAT policymakers, some exercises using different criteria were done to evaluate the present priority of nutrition in the allocation of resources. The relative contributions of mandate crops to total nutrient production in various regions was one criterion that indicated the need for a shift in allocation of research resources in favor of Sub-Saharan Africa.[22] Details of this work will form part of the section on commodity priorities.

These studies are summarized in Table 9.1.

Nutritional Quality Dimensions of Mandate Crops

The nutritional profiles of mandate crops are determined through chemical and biochemical analyses by the department of grain quality and biochemistry. This work covers the nutritional composition of grain, the effects of processing methods and techniques on nutritional composition, and antinutritional factors and their removal in processing. In the past these separate aspects have not been given equal emphasis.

Nutrient Profile of Mandate Crops. The main emphasis in the past has been on the analysis of mandate crops for their chemical composition, particularly proteins, carbohydrates, amino acids, minerals, and trace elements. Of late, processing methods have received fairly high priority. The department of grain quality and biochemistry analyzes thousands of samples of mandate crops from germ plasm accessions as well as from breeding material. The following are among its findings.

Improvement of Protein Quality Through Breeding. Genetic variability for protein content has been explored for improvement of

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[21] N. S. Jodha, "Market Forces and Erosion of Common Property Resources," paper presented at the International Workshop on Agricultural Markets in the Semi-Arid Tropics, ICRISAT, Patancheru, Andhra Pradesh, India, October 24-28, 1983.

[22] J. G. Ryan, "Agriculture and Research in the Semi-Arid Tropics," paper prepared by the Economics Program for the Quinquennial Review of ICRISAT, Patancheru, Andhra Pradesh, India, 1978; Matthias von Oppen and J. G. Ryan, Determining Regional Research Resource Allocation Priorities at an International Agricultural Research Center, ICRISAT Journal Article No. 293 (Patancheru, Andhra Pradesh, India: ICRISAT, 1984).

Table 9.1--Summary of ICRISAT research directed toward understanding of issues and problems related to human nutrition

Subject or Study	Principal Findings and Recommendations	Potential Users of Results	Relevant Area of Research Policy
1. Determinants of diets and nutrition status of people in semiarid tropical villages (Ryan et al. 1983, Behrman 1984)	Diets are deficient in energy, calcium, and vitamins A, B complex, and C, rather than in protein. Villages that consume sorghum and millet have better vitamin and mineral intake than those that are dependent on rice. Village-specific agroclimatic and socioeconomic factors have a greater bearing on intake of nutrients than does annual net income. Nutrient allocation to children is governed by concern for equity during the surplus season and productivity during the lean season.	Nutrition policymakers, research policymakers	Commodity characteristics, production systems
2. Nutritional imbalances induced by the green revolution (Ryan and Ashokan, 1977)	Improvement in wheat yields overcompensated for possible decline in nutrition on account of decline in yields from low-yielding pulse crops.	Nutrition policymakers, research policymakers, breeders	Commodity priorities, commodity characteristics, production systems
3. Human nutrition and crop-breeding objectives (Ryan et al. 1974, 1975)	Yield improvement should be given priority over protein-quality improvement.	Research policymakers, plant breeders	Commodity characteristics

Table 9.1 (Continued)

Subject or Study	Principal Findings and Recommendations	Potential Users of Results	Relevant Area of Research Policy
4. Nutrition and traditional farming systems (Jodha 1980, Singh et al. 1983, Walker et al. 1983, Bidinger and Nag 1981, McIntire 1983, Vierich, 1983)	Better food mix, self-provisioning, and food stability through reduced crop failure can be achieved by means of intercropping and crop diversification.	Research policymakers, nutrition policymakers	Production systems, technology characteristics
5. Drought and food intake instability (Jodha 1975, Jodha and Mascarenhas 1983, Binswanger et al. 1984)	Decline in food intake as a first step in adjustment to drought; other decisions with long-term implications for nutrition concern attached labor, tenancy, factor-market linkages, and migration.	Development and relief policymakers and planners	Production systems, commodity characteristics
6. Common property resources and human nutrition (Jodha 1983)	Poor derive significant quantities of free goods with nutritional value from common property resources.	Planners and policymakers, research policymakers	Production systems, commodity characteristics
7. Nutrition as a determinant of labor wages (Ryan 1982, Deolalikar 1984)	Better nutritional status has significant positive effect on wages of adult males, which has intrahousehold implications for food distribution. Short-term health factor (proxied by weight-for-height) positively influences wage rate as well as marginal productivity of farmers' labor.	Nutrition policymakers, planners	Production systems

Table 9.1 (Continued)

Subject or Study	Principal Findings and Recommendations	Potential Users of Results	Relevant Area of Research Policy
8. Elasticities of demand for nutrients derived from elasticity of demand for commodities Murty and von Oppen 1983)	Price and income elasticity of demand are highest among the rural poor. Sorghum and pearl millet contribute significantly to their intake of calories and protein.	Research policy-makers, breeders	Commodity priorities, production systems
9. Consumer preference for certain qualities in sorghum and millet (von Oppen et al. 1982, Rao et al. 1983)	Protein content, cooking quality, and cleanliness are important determinants of consumer preference, as revealed by market price indexes and consumer panels.	Plant breeders	Commodity characteristics
10. Nutrition and allocation of research resources (Ryan 1978, von Oppen et al. 1983)	Priorities in allocation of regional research resources need to be changed.	Research policy-makers	Commodity priorities

protein quality through breeding.[23] The range in the protein content of the samples analyzed was 4.4-21.1 percent in sorghum, 5.8-20.9 percent in pearl millet, 10.6-31.1 percent in chick-pea (whole seed), and 13.2-26.5 percent in pigeon pea. Protein content was highest in wild relatives of chick-pea and pigeon pea, ranging from 25.6 percent to 31.7 percent and from 28.3 percent to 30.5 percent, respectively. These pulses could be sources for development of high-protein lines.[24]

The results of a study using the two high-protein, high-lysine sorghums as parents suggested that the high-lysine gene may not be stable.[25] It may vary in different environments and with different agronomic practices. This has led to a lessening of emphasis on breeding for high-protein sorghum. Similarly, the instability of chick-pea protein under varying field conditions in different years has meant less progress in the protein-improvement program.[26]

The analysis of a diverse range of germ plasm of pearl millet revealed the possibility of selecting for greater content of protein and basic amino acids--of which lysine is the most important--by monitoring the levels of lysine and protein, respectively, without detriment to grain yield or grain weight. Grain yield was not found to be significantly correlated in pearl millet to either protein content or basic amino acids.[27]

Antinutritional Factors. The levels of various antinutritional factors, principally in chick-pea and pigeon pea, have been studied. Large differences have been found among protease inhibitors in

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[23] Ramamurthi Jambunathan et al., "Grain Quality of Sorghum, Pearl Millet, Pigeon Pea and Chickpea," paper presented at the Workshop on Interfaces Between Agriculture, Nutrition, and Food Science, ICRISAT, Patancheru, Andhra Pradesh, India, November 10-12, 1981.

[24] Umaid Singh et al., "Seed Protein Fractions and Amino Acid Composition of Some Wild Species of Pigeonpea," Journal of Food Science and Technology 18 (May-June 1981): 83-85; L. J. Reddy et al., "Seed Protein Studies on *Cajanus*, *Atylosia* spp. and Some Hybrid Derivatives," paper presented at the International Symposium on Seed Protein Improvement in Cereal and Grain Legumes, sponsored by International Atomic Energy Agency and the Food and Agriculture Organization of the United Nations, Munich, West Germany, 1978.

[25] K. W. Riley, "Inheritance of Lysine Content and Environmental Responses of High and Normal Lysine Lines of *Sorghum bicolor* (L) Moench in Semi-Arid Tropics of India" (Ph.D. dissertation, University of Manitoba, Canada, 1980).

[26] Umaid Singh et al., "The Protein Content of Chickpea (*Cicer arietinum* L.) Grown at Different Locations," Qualital Plantarum - Plant Foods for Human Nutrition 32 (No. 2, 1983): 179-184.

[27] K. A. Kumar et al., "Relationship Between Nutritional Quality Characteristics and Grain Yield in Pearl Millet," Crop Science 23 (March-April 1983): 232-235.

cultivated and wild species of pigeon peas.[28] Considerable variation seems to exist among the chick-pea cultivars with respect to trypsin and chymotrypsin inhibitors and amylase inhibitors.[29]

Polyphenolic compounds, commonly referred to as tannins, act as nutritional inhibitors in coarse grains. They have been reported to reduce the bioavailability of protein and other nutrients, but at the same time polyphenols, particularly in sorghum, have been shown to contribute some degree of resistance to or tolerance of depredation by birds, preharvest germination, and withering.[30] Polyphenols in chick-pea and pigeon pea inhibit the activity of digestive enzymes.[31] Considerable differences were found in the levels of these inhibitors in different cultivars of these pulses. The level of most of these nutrition inhibitors is low, and they are found principally in seed coats. They are reduced or destroyed in processing and cooking.

Effects on Breeding Programs. While useful information about the chemical composition of grains and antinutritional factors present in them is available to breeders, its use is very much restricted because of the variability and instability of some of the characteristics according to the environment and the agronomic background of the material. Protein improvement and, to some extent, work on food quality are therefore confined to the criterion that the newly developed material, while giving larger, more stable yields, should not prove inferior to existing cultivars in protein and food quality--essential condition for the adoption of new cultivars. Chemical analysis also helps in cautioning the breeders about the possible toxicity of the wild relatives of cultivars used for crossing.

Nutritional Quality and Food-Processing Methods. Because the final availability of nutrients is affected not only by the nutrient content of the grain but also by the method of its processing before consump-

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[28] Umaid Singh and Ramamurthi Jambunathan, "Protease Inhibitors and in Vitro Protein Digestibility of Pigeonpea [Cajanus cajan (L.) Mill sp.] and Its Wild Relatives," Journal of Food Science and Technology 18 (November-December 1981): 246-247.

[29] Umaid Singh and Ramamurthi Jambunathan, "Studies on Desi and Kabuli Chickpea (Cicer arietinum L.) Cultivars: Levels of Protease Inhibitors, Levels of Polyphenolic Compounds, and in Vitro Protein Digestibility," Journal of Food Science 46 (September-October 1981): 1364-1367; Umaid Singh et al., "Studies on Desi and Kabuli Chickpea (Cicer arietinum L.) Cultivars: The Levels of Amylase Inhibitors, Levels of Oligo Saccharides, and in Vitro Starch Digestibility," Journal of Food Science 47 (March-April 1982): 510-512.

[30] J. H. Hulse et al., Sorghum and the Millets: Their Composition and Nutritive Value (New York: Academic Press, 1980).

[31] Umaid Singh, "The Inhibition of Digestive Enzymes by Polyphenols of Chickpea (Cicer arietinum L.) and Pigeonpea (Cajanus cajan L.)," Nutrition Reports International 29 (March 1984): 745-753.

tion, food processing is an important determinant of nutrition. Furthermore, the preference of consumers for a product or its quality is guided by its taste and its suitability to preferred processing practices. Food quality, consumer preference, and food technology are therefore integral parts of ICRISAT research in nutrition. At ICRISAT, emphasis on food quality has recently increased, and special attention is being given to food forms and food-processing techniques, qualities preferred by consumers, and food-processing technology.

The effect of the processing method--soaking, milling, cooking, and so on--on the final availability of nutrients and on the reduction of antinutritional factors is being studied. In addition information is being collected on traditional food forms and household processing practices in various semiarid tropical areas. Most research on household processing practices has been focused on sorghum.[32] International sorghum food quality trials were carried out in collaboration with various scientists in Africa and in Latin America. Grain samples from 25 cultivars were evaluated for food quality across an array of foods to learn the possibilities of breeding sorghum with properties that would permit its use for almost all sorghum foods. Correspondence and field evaluation visits by various scientists in Asia, Africa, and Latin America have revealed that most sorghum produced for human consumption is consumed in eight basic forms. Various sorghum cultivars, including roti, have been evaluated in these forms.[33] As mentioned earlier, the work on consumer quality preferences through both market-determined indexes and consumer panels has been done by the economics group.

Promotion of Nutritional Awareness. An important activity of ICRISAT is promotion of awareness of nutrition problems and of possible solutions. Through periodic seminars and workshops it encourages interaction among workers in the field of nutrition, including scientists, policymakers, and field workers in various parts of the world. The biochemistry group takes an important part in such activities. Nutrition and food quality have been integral parts of the themes--in some instances the sole themes--of international seminars conducted periodically by ICRISAT. Two important ones were the International Symposium on Sorghum Grain Quality, sponsored jointly by USAID Title XII Collaborative Research Support Program on Sorghum and Pearl Millet (INTSORMIL), ICRISAT, and the Indian Council of Agricultural Research (ICAR) during 1981, and the Workshop on Interfaces between Agriculture, Nutrition, and Food Science, sponsored jointly by ICRISAT, the

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[32] Vaidhyanathan Subramanian and Ramamurthi Jambunathan, "Traditional Methods of Processing of Sorghum (Sorghum bicolor) and Pearl Millet (Pennisetum americanum) Grains in India," Reports of the International Association of Cereal Chemistry 10 (June 1980): 115-118.

[33] D. S. Murty et al., Sorghum Roti: Genotypic and Environmental Variations for Roti Quality Parameters, Proceedings of the International Symposium on Sorghum Grain Quality held at ICRISAT, Patancheru, Andhra Pradesh, India, October 28-31, 1981.

National Institute of Nutrition, Hyderabad, and the United Nations University, Tokyo, during 1981. Such meetings are valuable, not only for exchanging the results of past work, but also as opportunities for collective thinking on the future direction of work relating to nutritional issues. Some of the research findings about the nutritional profiles of mandate crops are summarized in Table 9.2.

RESEARCH DIRECTED TOWARD INFLUENCING NUTRITION

Besides research for the purpose of understanding nutrition problems and related issues discussed in the preceding section, several ICRISAT research activities are designed to influence the nutritional position of its clients. This is done through the development of technologies to increase and stabilize the production and availability of food in semiarid tropical areas. Two processes through which ICRISAT attempts to influence nutrition status are the establishment of commodity priorities or research priorities and the specification of desired changes in commodity characteristics.

Commodity Priorities

Commodity priorities were established by ICRISAT as a part of its research mandate. Accordingly, sorghum, pearl millet, chick-pea, and pigeon pea--staple foods of most people in semiarid tropical areas--were included in its crop-improvement program from the beginning. Groundnut was added later as the fifth mandate crop of ICRISAT. The effectiveness of research on these crops in increasing agricultural production in semiarid tropical areas is revealed by their predominance in these areas. The share of semiarid tropical countries in the total area given to these crops and in total world production of them, respectively, is as follows: sorghum, more than 80 percent and 55 percent; millets, including pearl millet, more than 50 percent and 39 percent; chick-pea, more than 90 percent and 90 percent; pigeon pea, more than 90 percent and 96 percent; groundnut, 77 percent and 65 percent.[34] The share of semiarid tropical countries in world production of these crops is less than their share of the area planted in them because their yields are lower. Their average yields range from about 500 kilograms per hectare for millet to 840 kilograms per hectare for sorghum.[35] Furthermore, yields are highly unstable, principally because of the variability of rainfall and the periodically high incidence of diseases, pests, and insects. Most of the producers are poor; their annual per capita income is less than U.S. $100. Those who rely on sorghum and millet as their staple cereals consume up to 700 grams a day per capita.[36] This description applies to 48 of

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[34] Ryan, "Agriculture and Research in the Semi-Arid Tropics."

[35] Ibid.

[36] J. G. Ryan and Matthias von Oppen, "Global Production and Demand for Sorghum and Millet to the Year 2000," paper prepared as a background document for the CGIAR Impact Study, FAO, Rome, 1983.

Table 9.2--Summary of ICRISAT research directed toward understanding the nutritional quality of mandate crops

Subject	Principal Findings
Protein quality	1. High-lysine gene in sorghum is too unstable in varying environments to be helpful in breeding high-protein sorghum (Riley 1980).
	2. Protein content of cultivated chick-pea fluctuates according to field conditions, obstructing work to improve the protein quality (Singh et al. 1983).
	3. Wild species of pigeon pea, the protein content of which is higher, are a potential source for developing high protein lines (Reddy et al.1979).
	4. Yield, grain weight, and protein content of pearl millet are not significantly correlated, indicating the possibility of breeding simultaneously for higher calorie content and higher quality protein (Kumar et al. 1983).
Antinutritional factors	1. Greater trypsin and chymotrypsin activity was observed in wild factors species of pigeon peas. Clear-cut difference in chymotrypsin inhibitors was observed between wild and cultivated species of pigeon pea (Singh et al. 1981).
	2. Chick-pea and pigeon pea contained high level of polyphenolic components, which affected activities of digestive enzymes adversely and had implications for assimilation of nutrients (Singh 1983).
	3. Variation in tannin content was much higher than the variation in other constituents of 18 *sorghum* genotypes studied (Subramanian 1983).
Food quality	1. Cooking quality of early pigeon pea appeared to be better than that of peas requiring medium and long maturity periods (Singh et al. 1983).
	2. Sorghum roti: significant effects for crop season, year, and genotype-year interaction for grain, dough, and roti quality parameters. Effect of nutrition, fertility level on roti quality was insignificant (Murty et al. 1981).

the 49 semiarid tropical countries that could be described as developing countries.

In keeping with its research mandate, ICRISAT has decided upon its research priorities and the allocation of its resources. Table 9.3 summarizes the pattern of allocation of resources during the period 1980-82. The crop-improvement programs received about 70 percent of the funds, while about 20 percent was allocated to research on farming systems and about 10 percent to economics. Among the crop-improvement programs, that for sorghum received the largest allocation in direct cost and man-years of scientists. Table 9.3 reveals further that the cereals--sorghum and pearl millet together, the staple foods in semiarid tropical areas--received around half the total resources devoted to crop improvement or a third of ICRISAT's research funds. A comparison of the distribution of ICRISAT's resources to mandate crops with the respective importance of these crops as determined by the area given to them and the value of their production in the semiarid tropical world reveals certain imbalances. According to a more detailed analysis by Ryan, pulses are allotted a proportionately larger share of ICRISAT research resources than cereals.[37] If the area devoted to crops rather than the value of production is considered, this imbalance becomes sharper. To a certain extent, however, the effect of this imbalance is reduced once it is realized that national research programs, while devoting considerable resources to sorghum and millet, have usually neglected pulses. It may also be noted that the area sown with pulses and the value of their production are underreported in several countries. An important but subsidiary component of traditional intercropping systems, they are often not fully reported in crop statistics.

Expressed in its aggregate form and unrelated to regional differences in the importance of these crops, the foregoing picture of resource allocation does not tell much about its underlying logic in relation to the nutritional problems of people in the semiarid tropical areas. Increased and stabilized food production, larger incomes, and fuller employment will surely help the poor and inadequately fed people in the semiarid tropical areas. The semiarid tropical countries are not homogenous in the distribution of factors that affect nutrition, however. They differ in per capita income and its growth; in demographic pressures and trends; in current standards of food consumption; in levels, stability, and trends of crop production; in the importance of crops to which research by ICRISAT is devoted; and in the mix of production and consumption. The allocation of the research resources of ICRISAT needs therefore to be evaluated with reference to these variables in the several zones. Such an exercise has been attempted by von Oppen and Ryan.[38] They divided the 49 semiarid tropical countries, which are spread over five continents, into seven groups: India, Eastern Africa, West Africa, Southern Africa, the Near East, Other Asia, and North, Central, and South America. Through the use of data on the aforementioned variables and the

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[37] Ryan, "Agriculture and Research in the Semi-Arid Tropics."

[38] von Oppen and Ryan, "Determining Regional Research Allocation Priorities."

Table 9.3--Allocation of resources to various research programs at ICRISAT, 1980-82[a]

Research Programs	Share of the Programs in Resources Allocated: All Research Programs: Direct Cost	All Research Programs: Man-Years of Scientists: Principal	All Research Programs: Man-Years of Scientists: Others[b]	Crop-Improvement Programs: Direct Cost	Crop-Improvement Programs: Man-Years of Scientists: Principal	Crop-Improvement Programs: Man-Years of Scientists: Others[b]	Share of Crops in Semi-Arid Tropical Total of 5 Crops[c]: Area	Share of Crops in Semi-Arid Tropical Total of 5 Crops[c]: Production Value
	(percent)							
Sorghum	19.9	19.5	18.1	28.5	27.7	24.7	39.2	35.4
Pearl millet[d]	15.4	15.8	16.0	22.2	25.3	23.9	30.8	15.4
Chick-pea and Pigeon pea	21.7	19.0	22.9	31.2	28.2	32.6	13.8	18.3
Groundnut	12.6	11.8	13.3	18.1	18.8	18.8	16.2	30.9
Farming systems	19.7	21.0	23.9	...	...	...	...	...
Economics	10.7	12.9	6.1	...	...	...	...	...

[a] Prepared from budget documents. Only direct cost of programs considered.

[b] Includes support staff working in each program.

[c] Area and production value (from Food and Agriculture Organization data) indicate average of 1974-78 in semiarid tropical countries.

[d] Also includes other millets in semiarid tropical countries other than India.

development of a weighting system involving considerations of efficiency and equity, they developed several priority indexes for these regions. Some of the indexes placed greater emphasis on considerations of equity--that is, helping first those who suffer more because of lesser production, consumption, poverty, demographic pressure, and agricultural stagnation--others gave more emphasis to considerations of efficiency. Actual allocation of resources to different crops in different regions was compared with these priority indexes. Resource allocation suggested by one index broadly matched the actual pattern of allocation of research resources to crops and regions by ICRISAT.

This index showed an implicit preference for considerations of efficiency--on the assumption that the effectiveness of research will be greater if the regional contribution of the crop is greater--weighted by ad hoc equity criteria based on such factors as population and food status. ICRISAT plant breeders tend to support this view.

According to the study, in the case of sorghum this index more closely reflects the actual allocation of resources by ICRISAT expressed in principal-scientist equivalents, although in actual terms West Africa is given slightly higher priority and North, Central, and South America slightly lower priorities than those assigned by the index. In the case of pearl millet, actual allocation of resources is almost exactly congruent with the index. For pigeon pea the analysis shows the predominance of efficiency criteria in the allocation of research resources. Since pigeon pea is predominantly an Indian crop, India accounting for about 95 percent of the area devoted to it and of its production in semiarid tropical regions, efficiency criteria favor this pattern of allocation. On the basis of equity concerns, however, regions such as Southern Africa, Eastern Africa, and Southeast Asia seem good candidates for allocation of additional resources to research on pigeon peas. Similarly, on an equity basis there appears to be an overinvestment in chick-pea research in India and the Near East at present, whereas on efficiency grounds there is not. It would seem that there is some case for allotting additional resources to chick-pea research in other semiarid tropical Asian countries, Southern Africa, and the Americas at the cost of India. A similar picture emerges with regard to groundnut. Only equity criteria suggest that there is an overinvestment in groundnut research in India; the use of efficiency criteria presents a picture of congruence between actual allocation of resources and priority indexes.

An important point to be added is that allocation of resources to India by ICRISAT is not directed to India alone. Certain technologies and methodologies that emanate from the ICRISAT Center in India have spillover effects for other regions. This is revealed by prolonged work and visits to other regions by scientists based in India, the transfer of methodologies developed at ICRISAT headquarters to other outreach stations through training, and the distribution of seed material to all regions. Using all these considerations, Swindale developed a more realistic weighting system and found that the actual allocation of resources by ICRISAT to different geographical zones matched quite well with the pattern of resource allocation revealed by their weighting scheme.[39]

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[39] L. D. Swindale, "Centers Week Presentation," internal document, ICRISAT, Patancheru, Andhra Pradesh, India, 1983.

Commodity Characteristics

One way to understand the assignment of priorities to specific crop characteristics is to examine the objectives of research projects. An analysis of the objectives of ICRISAT research projects is presented in Table 9.4, which shows the distribution of all research projects that involve mandate crops undertaken during the period 1975-82 according to their main objectives. These projects are grouped into four categories, which may involve some degree of overlapping. Projects in farming-systems research, even when they involve the mandate crops, are not included. Finally, a significant limitation of Table 9.4 is that it deals with the number of projects, irrespective of their size.

Table 9.4--Distribution of ICRISAT research projects among various crops, by principal objectives, 1975-82[a]

Research Objective	Crop				
	Sorghum	Pearl Millet	Chick-pea	Pigeon Pea	Groundnut
	(percent)				
Resistance to yield reducers					
Physiological constraints	21	13	10	8	17
Disease, insects, and pests[b]	49	38	24	36	58
Yield increase per se	5	15	18	8	4
Grain quality improvement					
Nutritional quality	9	10	9	8	-
Consumer preference	5	5	3	2	-
Miscellaneous					
Cross-location, adaptation, etc.	11	19	42	38	21
Total (Number)	100 (38)	100 (40)	100 (45)	100 (51)	100 (42)

a Based on documents prepared for ICRISAT In-House Review 1981.
b Includes research projects on striga weed also.

An important finding is that through its research ICRISAT attempts to improve nutrition more by increasing the availability of food than by improving its nutritional quality, particularly the quantity and quality of the protein in its mandate crops. Accordingly, nutrition improvement, primarily improvement of protein quality, constitutes the principal objective of only 8-10 percent of the research projects on various mandate crops. This proportion declines further when the projects undertaken before 1979 are excluded. During that period, increasing the protein content and improving its quality were important considerations, particularly in the case of sorghum. The gradual change took place following the increased emphasis on the need for breeding for high yields rather than for high protein content and the realization by breeders of the instability of the protein-promoting gene in different environments and with different agronomic practices.[40] In all mandate crops other than pearl millet, protein improvement has a low priority; in pearl millet it is still emphasized because there is no significant trade-off between research for yield improvement and that for protein improvement.[41] In all crops the important consideration is that protein levels in newly developed materials should not be lower than those in the existing cultivars.

Of late, emphasis has slowly shifted simultaneously to development of the qualities preferred by consumers in grains because it is these qualities, rather than nutritional quality, that determine the acceptance of new material by farmers. The proportion of projects with such objectives, however, hardly exceeds 5 percent of total research projects on any of the crops.

Another fact revealed in Table 9.4 is that development of resistance to biotic and abiotic hazards constitutes a primary goal of a large proportion of the crop-improvement research projects of ICRISAT. Building resistance to diseases and insect pests on the one hand and to physical constraints such as drought, low fertility, salinity, and waterlogging on the other is attempted. The effect of some of the principal yield reducers is revealed by the following broad estimates made by ICRISAT scientists through surveys and field assessments.[42] In the case of pearl millet, downy mildew and ergot diseases cause losses in India of about U.S. $20 million a year, estimated in 1982 prices. Wilt and sterility mosaic in pigeon pea cause annual losses of about $38 million and $66 million, respectively, in India and Africa together. Leaf spot and rust in rainy-season groundnut reduce the yields by half, causing a loss of about $53.3 million a year. Grain molds that substantially reduce the grain price of sorghum cause a loss of about $45 million in India. Annual losses to chick-pea and pigeon pea growers in India caused by the pod borer (Heliothis armigera) are estimated at $300 million. Other diseases such as

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[40] Riley, "Inheritance of Lysine Content."

[41] Kumar et al., "Nutritional Quality Characters and Grain Yield in Pearl Millet."

[42] ICRISAT, Challenge and Response, 1972-82 (Patancheru, Andhra Pradesh, India: ICRISAT, 1982).

Ascochyta blight in chick-pea; insect pests, such as shoot fly, in sorghum; and the deadly parasitic weed Striga, particularly troublesome in Africa, can also have disastrous effects on crops. They, too, are high on the resistance-research agenda of ICRISAT.

Similarly, breeding for resistance to environmental stresses--drought, high temperatures, soils of marginal fertility, soil crusting, soil salinity, and occasional waterlogging--is a high-priority research activity. Breeding for different maturity periods and increased nitrogen fixation also indirectly complement research on stress resistance. They are included in the miscellaneous category, however. This category also accounts for 11-42 percent of projects under different crops. It is really a leftover or catchall category where agronomic prerequisites, cross-location adaptation possibilities, and other behavioral aspects of crops are studied.

In comparison to research on resistance to yield reducers, research directed toward yield increase per se for different crops accounts for only 2-16 percent of all research projects.

The distribution of projects shown in Table 9.4 relates only to work done at the ICRISAT Center in India. Inclusion of research projects in Africa and other countries, however, would not change the broad pattern discussed earlier.

Thus in the final analysis the ICRISAT approach to nutritional problems emphasizes increased and stabilized crop production rather than increased protein content and improved protein quality in its mandate crops. This is reinforced by farming-systems research (not covered in this paper), which also has the aim of stabilizing and increasing crop production. Similarly, several attributes of the technology and production systems evolved by ICRISAT (not covered in this paper) that have to do with employment and the generation and distribution of income also influence nutritional status.[43]

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[43] R. D. Ghodake, "Economic Evaluation of Traditional and Improved Technologies in Dryland Agriculture," paper presented at the Workshop on Technology Options and Economic Policy for Dryland Agriculture: Challenge and Potential, ICRISAT, Patancheru, Andhra Pradesh, India, August 22-24, 1983.

10
Nutrition-Related Food Policy Research at IFPRI

Per Pinstrup-Andersen

The nutritional implications of agricultural research are determined both by the nature of the research results and by the socioeconomic and political environment within which these results are introduced and applied. Thus, the effects of agricultural research on human nutrition may be altered through changes either in the nature of the research results or in related public policies. In some instances improvements in nutrition can be facilitated most efficiently through modifications in agricultural research, while in others policy changes would be more efficient. The best solutions to nutrition problems may not be politically feasible, and second-best or third-best approaches may need to be sought.

Food policies vary among countries and with the passage of time. Thus, decisions about agricultural research should not be made on the assumption that existing policies cannot or will not be changed. On the other hand, it is unrealistic to assume that food policies will be optimal from a particular point of view, such as that of improving human nutrition and that therefore socioeconomic factors that are most effectively dealt with through public policies need not be considered in planning agricultural research. In research planning, the interaction between the nature of agricultural technology and government policies should be taken into account and judgments should be made as to the likelihood of future changes in policy. Thus, efforts to incorporate nutritional goals into the design of international agricultural research must confront the question of the distribution of responsibility between agricultural research and public policy to assure that nutritional goals are met to the fullest extent possible.

A great deal of IFPRI research produces information useful for incorporating nutritional goals into the design of agricultural research and food policy. In this paper only those research areas that are most directly linked with this topic are presented, but it should be noted that research on other aspects of policy that may not at first sight appear to be relevant to nutrition--issues in foreign trade and international food security, for example--may in fact have important nutritional implications.

IFPRI research is presented under the four headings suggested for all center papers in order to facilitate making syntheses across papers. It should be noted, however, that these headings are less appropriate for IFPRI than for most of the other centers because IFPRI does not undertake agricultural and biological research and is therefore not faced with internal decisions regarding commodity priorities,

commodity characteristics, technology characteristics, and production systems to be pursued by the center. The utility of IFPRI's nutrition-related research is in decisionmaking outside the center--by national policymakers, advisors, and analysts, for example, as well as by sister institutions within the CGIAR and by other international institutions.

COMMODITY PRIORITIES

Five areas of IFPRI research seem to be of particular interest for explicit consideration of nutritional issues in decisions on commodity priorities in agricultural research and food policy. These are trends in food production, consumption, and trade; structural changes in patterns of food consumption; consumption patterns and food-acquisition behavior of the poor and the malnourished; better analytical approaches for estimating and monitoring the nutrition effects of existing and proposed policies and research concerning agriculture and food; and policies concerning food prices and subsidies. Each of these five areas will be discussed briefly in this section. In keeping with the purpose of the workshop, emphasis will be on activities rather than results.

Food Trends

This work provides general indications of the changes in food production, consumption, and trade in third world countries and a trend-based projection of their food situation in the future. Thus, the magnitude, nature, and location of emerging food gaps will be identified, and implications for future agricultural research and technological change will be indicated.

An assessment of the cereal situation in 83 developing countries was reported in 1976, and a second assessment appeared in 1977, which, in addition to cereals, included the principal noncereal food crops, such as root crops, pulses, and groundnuts in countries in which they are important food items.[1] A further analysis of a smaller number of developing countries with high rates of growth in food production was completed in 1979, and in a study completed in 1980 trends in food production and consumption in China were examined and projections to

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[1] International Food Policy Research Institute, Meeting Food Needs in the Developing World: Location and Magnitude of the Task in the Next Decade, Research Report 1 (Washington, D.C.: IFPRI, 1976); International Food Policy Research Institute, Food Needs of Developing Countries: Projections of Production and Consumption to 1990, Research Report 3 (Washington, D.C.: IFPRI, 1977).

the year 2000 were made.[2] In two studies now being completed, food trends in third world countries during the past two decades are being analyzed and projections of production and market demand are being developed for the primary food crops to the year 2000 and for the primary livestock and poultry products to 1990 and 2000. Other current research on food trends and projections include regional and country-level studies.

While these studies are not focused specifically on the poor and malnourished, they nevertheless provide useful indicators of changes in the overall availability of food and thus provide a framework within which nutritional needs must be met. A more direct focus on nutrition was provided in a study completed in 1977, in which the present and prospective situation of low-income households with respect to food consumption was analyzed.[3]

Structural Changes in Food Consumption Patterns

While the effects of changes in incomes and growth in population on the demand for individual food commodities are well understood, insufficient knowledge of changes in structural demand and their causes is available. Such knowledge is important if projections of food demand are to be improved, better estimates of the nutritional consequences of these changes are to be made, and assistance in setting commodity priorities in research and policy is to be offered. Work has been completed on parameters of demand, patterns of food consumption in rural and urban areas, and the potential effects of demographic shifts on the demand for rice in the Philippines and Indonesia.[4] Current research is of an exploratory nature and, while focused on important causes of changes in structural demand, is limited to two relatively small projects, one on rural to urban migration in Mexico and one on the interactions among scarcity of firewood, allocation of women's time, and nutrition in Nepal.

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[2] Kenneth L. Bachman and Leonardo A. Paulino, Rapid Food Production Growth in Selected Developing Countries: A Comparative Analysis of Underlying Trends, 1961-76, Research Report 11 (Washington, D.C.: International Food Policy Research Institute, 1979); Anthony M. Tang and Bruce Stone, Food Production in the People's Republic of China, Research Report 15 (Washington, D.C.: International Food Policy Research Institute, 1980).

[3] International Food Policy Research Institute, Recent and Prospective Developments in Food Consumption: Some Policy Issues, Research Report 2 (Washington, D.C.: IFPRI, 1977).

[4] Eugenia C. Bennagen, Staple Food Consumption in the Philippines, Working Paper 5 (Washington, D.C.: International Food Policy Research Institute, 1982); John A. Dixon, Food Consumption Patterns and Related Demand Parameters in Indonesia: A Review of Available Evidence, Working Paper 6 (Washington, D.C.: International Food Policy Research Institute, 1982).

Research is under way to increase understanding of the factors and processes underlying the rapid rate of substitution of wheat for sorghum and millet in several African communities, the related economic implications, and how public policy may influence this situation. This work will be discussed in the section on technology characteristics.

Findings from work on structural changes in the demand for food include estimates of differences between urban and rural patterns of consumption and the implications for the demand for various food commodities in a number of countries, including Egypt, Brazil, the Philippines, and Indonesia.

Consumption Patterns and Food-Acquisition Behavior of Low-Income Households

Present understanding of the food-acquisition behavior of the poor and malnourished is insufficient for the purpose of estimating the effects of agricultural research and food policies on consumption and nutrition. Three issues are of particular importance: the integrated production-consumption decisionmaking process among semisubsistence farmers and how it translates policy interventions into food consumption, the effects on food consumption and nutrition of changes in intrahousehold distribution of income control and allocation of time by the individual members of the household, and parameters of incomes and prices for low-income households.

These issues are being studied as parts of various IFPRI research projects. The integrated producer-consumer decisionmaking process is an integral part of a study of food subsidies in Egypt, case studies of the effects on nutrition of cash cropping, and research on traditional food grains in West Africa. Intrahousehold control of income and its interaction with various policies on nutrition is being studied in analyses of food subsidies in Sri Lanka and the Philippines and will be studied in cash-cropping case studies.

Many of the studies of specific policy issues require estimation of consumption patterns and income and price parameters of demand for individual food commodities for each of several population groups. While these estimates are necessary for the particular policy analyses, they are also important in their own right because they increase the knowledge of the household food-acquisition behavior of certain population groups, particularly of the poor and malnourished. Estimation of such parameters has been completed for a number of countries, including Brazil, Egypt, and Thailand.[5]

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[5] Cheryl Williamson Gray, Food Consumption Parameters for Brazil and Their Application to Food Policy, Research Report 32 (Washington, D.C.: International Food Policy Research Institute, September 1982); Harold Alderman and Joachim von Braun, The Effects of the Egyptian Food Ration and Subsidy System on Income Distribution and Consumption, Research Report 45 (Washington, D.C.: International Food Policy Research Institute, 1984); Prasarn Trairatvorakul, Rice Price Policy and Equity Considerations in Thailand: Distributional and Nutritional Effects (Washington, D.C.: International Food Policy Research Institute, forthcoming).

Preliminary results of recently initiated comparative analysis of estimates of price and income parameters for the demand for food by low-income groups in various countries--including but not limited to those mentioned above--indicate surprisingly strong similarities in the relation between the price elasticity of demand for rice and the income level in a number of countries when both are expressed in relative terms--that is, relative to the respective means for each country. Such similarity was also found with respect to meat but not root crops. A tentative explanation for this difference may be that rice and meat are more homogenous commodities than root crops. Research is under way to analyze this and related issues more closely. In particular, efforts will be made to develop and test methods for estimating or approximating price elasticities for the poor on the basis of estimates for society as a whole, thereby significantly reducing data requirements for future estimations.

Enhancing National Analytical Capacity

Attempts are now being made in a few developing countries to strengthen national institutional capabilities to deal with the interaction between agriculture and public policy on the one hand and food consumption and nutrition on the other. Past and current IFPRI activities in this area are a combination of research, training, and technical assistance. Technical assistance and training has been provided to the Food and Nutrition Unit of the Indonesian Ministry of Agriculture, research has been completed on parts of an analytical approach for Brazil, research is being initiated for the Philippines, and research is expected to be initiated in other countries during 1984-85. A number of conceptual papers have been completed on methods for incorporating nutritional considerations into the design of agricultural research, projects, and policies.[6]

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[6] Per Pinstrup-Andersen, "An Analytical Framework for Assessing the Nutrition Effects of Policies and Programs," paper presented at the Rockefeller Foundation workshop on Strengthening National Food Policy Capabilities, Bellagio, Italy, November 1-4, 1982; Per Pinstrup-Andersen, "Estimating the Nutritional Impact of Food Policies: A Note on the Analytical Approach," paper prepared for the Food Policy Symposium, Eleventh International Congress of the International Union of Anthropological Sciences, Vancouver, Canada, August 20-25, 1983; Per Pinstrup-Andersen, "Ex Ante Assessment of Consumption and Nutrition Effects of Agricultural Research," paper prepared for the Symposium on Methodology for Evaluation of Agricultural Research, Minneapolis, Minnesota, May 12-13, 1980; Per Pinstrup-Andersen, "Food Policy and Human Nutrition," paper presented for the workshop on the Interfaces between Agriculture, Food Science and Human Nutrition in the Middle East, Aleppo, Syria, February 21-25, 1982; Per Pinstrup-Andersen,"Introducing Nutritional Considerations into Agricultural and Rural Development," Food and Nutrition Bulletin 4 (April 1982); Per Pinstrup-Andersen, Nutritional Consequences of Agricultural Projects: Conceptual Relationships and Assessment Approaches, World Bank Staff Working Paper 456 (Washington, D.C.: World Bank, 1981).

One of the principal components of an analytical framework for estimating the nutrition effects of broader food and agricultural policies is a set of estimates of income and price elasticities of demand for individual food commodities by income stratum. Such a set of elasticities has been estimated for Brazil, and its usefulness for policy analysis was illustrated by means of analyses of the nutrition effects of shifting current wheat subsidies to other commodities, and of alternative formulations of the Brazilian fuel-alcohol program.[7]

Food Price and Subsidy Policies

Analyses to improve the understanding of the ways various subsidy policies can be expected to influence human nutrition, the real incomes of the poor, fiscal costs, food production, and foreign trade have been given priority in research by IFPRI throughout its existence. Although this research is not directly focused on assisting the establishment of commodity priorities for agricultural research, commodity-specific price policies and subsidies greatly influence the demand for individual commodities, and the interaction between unit-cost-reducing research and price subsidies is an important consideration in research planning.

Initially, case studies of subsidy policies in three countries were completed.[8] This work was complemented by studies of broader food price policy issues, including subsidies, and by additional case studies of consumer-oriented food subsidy policies.[9] Furthermore,

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[7] Gray, Food Consumption Parameters for Brazil.

[8] Shubh K. Kumar, Impact of Subsidized Rice on Food Consumption and Nutrition in Kerala, Research Report 5 (Washington, D.C.: International Food Policy Research Institute, January 1979); P. S. George, Public Distribution of Foodgrains in Kerala--Income Distribution Implications and Effectiveness, Research Report 7 (Washington, D.C.: International Food Policy Research Institute, 1979); Raisuddin Ahmed, Foodgrain Supply, Distribution and Consumption Policies Within a Dual Pricing Mechanism: A Case Study of Bangladesh, Research Report 8 (Washington, D.C.: International Food Policy Research Institute, 1979); James D. Gavan and Indrani Sri Chandrasekera, The Impact of Public Foodgrain Distribution on Food Consumption and Welfare in Sri Lanka, Research Report 13 (Washington, D.C.: International Food Policy Research Insitute, 1979).

[9] Roger Fox, Brazil's Minimum Price Policy and the Agricultural Sector of Northeast Brazil, Research Report 9 (Washington, D.C.: International Food Policy Research Institute, June 1979); Raisuddin Ahmed, Agricultural Price Policies Under Complex Socioeconomic and Natural Constraints: The Case of Bangladesh, Research Report 27 (Washington, D.C.: International Food Policy Research Institute, 1981); Raj Krishna and Ajay Chhiber, Policy Modeling of a Dual Grain

studies are now under way on the food-stamp programs of Sri Lanka and Colombia, price policies for maize in Zambia, wheat subsidies in Sudan and Brazil, food-discount programs for rice and edible oils in the Philippines, maize subsidies in Mexico, food-ration shops in selected states of India, and a food-for-work project in Bangladesh.

While each of these case studies is expected to increase understanding of the principal processes and factors that determine the effects of policies on the poor and malnourished and to assess the actual performance of the particular policies being studied, the ultimate research objective of enhancing the existing body of policy-relevant knowledge that is generalizable beyond the particular study location and, therefore, more useful for the design of future policies, is best achieved if findings from case studies are integrated and generalizable lessons are identified.

Such integrative analyses are now being initiated. The objectives of these analyses are to increase present policy-relevant knowledge of the performance of various types of consumer-oriented food-subsidy programs, of the processes and relations that lead to such performance, and of the way changes in program design would influence performance by bringing together findings from a series of case studies. The ultimate goal is to provide guidelines for future choice and design of consumer-oriented food policies beyond the cases studied.

The integrative analyses will be directed toward the identification of commonalities and differences among the case studies and specific elements of these studies for the purpose of generalizing knowledge and methodology and clearly identifying issues with a high degree of location specificity. Issues to be dealt with in these analyses include:

1. The effects of the particular program or policies on the real incomes and nutritional status of the poor and malnourished.
2. Fiscal costs and foreign-exchange implications.
3. Cost-effectiveness.
4. The effects on domestic food production.
5. Questions of design and implementation, with emphasis on commodity selection, targeting, and leakage to nontarget groups.
6. Political considerations.

Market: The Case of Wheat in India, Research Report 38 (Washington, D.C.: International Food Policy Research Institute, 1983); Gray, Food Consumption Parameters for Brazil; Harold Alderman, Joachim von Braun, and Sakr Ahmed Sakr, Egypt's Food Subsidy and Rationing System: A Description, Research Report 34 (Washington, D.C.: International Food Policy Research Institute, 1982); Grant M. Scobie, Food Subsidies in Egypt: Their Impact on Foreign Exchange and Trade, Research Report 40 (Washington, D.C.: International Food Policy Research Institute, 1983); Joachim von Braun and Hartwig de Haen, The Effects of Food Price and Subsidy Policies on Egyptian Agriculture, Research Report 42 (Washington, D.C.: International Food Policy Research Institute, 1983); Alderman and von Braun, The Effects of the Egyptian Food Ration and Subsidy System.

An overview of some of the principal findings of the subsidy research is provided elsewhere and will not be repeated here.[10]

COMMODITY CHARACTERISTICS

Research at IFPRI that is directly useful in making decisions on commodity characteristics to be pursued in agricultural research is limited. Current work on the etiology of malnutrition and patterns of consumption of the poor provide information on calorie-protein deficiencies and their causes. Results of most IFPRI studies indicate that present diet combinations provide sufficient protein when calorie requirements are met; that is, calorie-protein-deficient households react to increases in income by alleviating protein deficiencies before calorie deficiencies or at the same time. Changes in relative food prices, however, could cause shifts in patterns of consumption that would cause protein deficiencies even after calorie needs had been met.

Since most consumption research by IFPRI in the past has been focused on the household, little information has been provided on nutrition problems specific to individual members of the household, such as low energy-density diets for small children. Intrahousehold food distribution is being analyzed in some current studies, however. Similarly, most work has been focused on calorie-protein deficiencies, and little emphasis has been placed on other nutrients. Thus, little information is available on the extent to which the attempt should be made in agricultural research to alter the content of specific nutrients other than protein in staple commodities.

TECHNOLOGY CHARACTERISTICS AND PRODUCTION SYSTEMS

Five areas of research by IFPRI are of direct relevance to the incorporation of nutritional goals into decisions about the technology characteristics and production systems that should be pursued through agricultural research. These are the consumption and nutrition effects of technological change; shifts from semisubsistence farming to cash-crop production; fluctuations in food production, prices, and rural incomes; linkage effects of technological change; and substitution among foodgrains in both production and consumption in West Africa.

Other IFPRI research on production and trade policies may also offer information relevant to the subject under consideration. In order to keep the paper to a reasonable length, however, only the five areas believed to be of most direct relevance will be discussed here.

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[10] Per Pinstrup-Andersen, "Food Subsidies: The Concern to Provide Consumer Welfare While Assuring Producer Incentives," paper prepared for IFPRI workshop on Food and Agricultural Price Policy, Belmont Estate, Elkridge, Maryland, April 29-May 2, 1984.

Consumption and Nutrition Effects of Technological Change

Although considerable research has been done on the effects of technological change on the distribution of income and assets in the rural sector, very little is known about its effects on food consumption and nutrition among low-income urban and rural households. Additional knowledge on this topic is likely to be useful for the formulation of public policy and the setting of priorities for agricultural research.

Research on technological change is under way at IFPRI for two countries: an irrigation and double-cropping scheme for rice in Malaysia and a technical assistance and fertilizer scheme for Nigeria. A study of the changes in food consumption caused by the introduction of new varieties of rice in the North Arcot region of India is also under way.

While these studies are concerned primarily with short-run effects on consumption and nutrition, the long-run effects are being studied in the linkage projects that will be discussed below. No research project has yet been completed in this area.

Effects on Consumption and Nutrition of Shifts from Semisubsistence Farming to Cash-Crop Production

The question of the nutritional effects of expanding production of cash crops among semisubsistence farmers is widely disputed. While the effects are generally believed to be positive, a number of studies of specific projects and policies promoting a shift from semisubsistence farming to cash-crop production claim either that the effects are negative or that positive effects are much smaller than originally expected.

Insufficient consumption of food to meet nutritional requirements is closely related to poverty, and a significant share of increasing incomes among the poor would be expected to be spent on more food. If low-income farmers and landless laborers captured at least part of the economic surplus generated by shifts from subsistence farming to cash-crop production, and if some of these people were malnourished, why did their nutritional status not improve or why was the improvement less than expected? A review of the literature just completed does not provide a satisfactory answer to this question. Neither does it offer effective guidelines for the choice and design of future technology, production systems, and projects and policies to avoid negative effects on nutrition and enhance positive effects.

Unintended negative effects on nutrition can be avoided and positive effects enhanced either by a more appropriate design of cash-cropping projects and policies or by the introduction of compensatory policy measures. Ideally, nutritional goals would be considered explicitly alongside other goals in the choice and design of future projects and policies and in modification of existing ones. This can be done, however, only if more is known about the processes by which expanded cash cropping affects food consumption and nutrition and the likely importance of each of the principal components of these processes in a particular situation.

In order to gain such knowledge, IFPRI is initiating research in this area. The principal objective of the research is to gain knowl-

edge in a form in which it can be of direct use in the design of future projects and policies. The specific objectives are:

1. To assess the effects of shifts from semisubsistence food cropping to cash-crop production on real household incomes, family food consumption, expenditures for goods and services other than food, and the nutritional status of preschoolers in various settings; and
2. To describe the process by which nutritional status and household food consumption are affected by such shifts, to identify the most important elements of the process, and to estimate how each of these elements is influenced by the change, and in turn, how this influences food consumption and nutrition in various settings.

One case study in which the effects of the introduction of a dairy-development scheme in Karnataka and Madhya Pradesh, India, are being analyzed is under way. Two other case studies to analyze the effects of shifts from semisubsistence maize farming to production of sugarcane in the Philippines and Kenya are just being initiated.

Consumption and Nutrition Effects of Fluctuation in Food Production, Prices, and Rural Incomes

On the basis of the available evidence, it appears that fluctuations in production, prices, and incomes contribute significantly to rural malnutrition in many countries. Additional knowledge of the relevant processes and how they can be manipulated by agricultural research and technology, public policy, and project design is urgently needed. While this issue is dealt with in some current studies, such as the study of price policies in Zambia and technological change in Nigeria, no current project is focused specifically on this subject. As studies that include this issue are completed--all case studies on the nutrition effects of shifts from semisubsistence farming to cash cropping, for example--attempts will be made to extract and integrate the findings most relevant to this question.

Although they are not focused on nutritional effects, an attempt is made in IFPRI studies on instability in the production of foodgrains to quantify the sources of instability in selected countries and to contribute a better understanding of the way fluctuations can be reduced, thereby reducing the nutritional risk.[11]

Growth Linkages

In IFPRI research on growth linkages the attempt is made to provide a better understanding of the rural-based growth processes.

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[11] Shakuntla Mehra, Instability in Indian Agriculture in the Context of the New Technology, Research Report 25 (Washington, D.C.: International Food Policy Research Institute, 1981); Peter B. R. Hazell, Instability in Indian Foodgrain Production, Research Report 30 (Washington, D.C.: International Food Policy Research Institute, 1983).

Linkages both to demand and to transfer of resources are being studied. Links between household consumption and employment and technological change are of particular interest from a nutritional point of view. Research on this subject, which will provide a better understanding of long-term self-sustaining nutritional effects of technological change and agricultural policies, complements other research on the short-run effects. Research has been completed for Nigeria and Malaysia and is in progress for various parts of India.[12]

Production and Consumption of Foodgrains in West Africa

Millet, sorghum, and maize together constitute a large share of the food staples produced in West Africa. Policies designed to increase the supply and consumption of domestically produced food in the region must take the underlying market conditions for these crops into account. On the demand side it is important to know the importance of coarse grains in the satisfaction of current and future urban demand, in view of income growth and the observed rapid substitution of wheat and rice for millet, sorghum, and maize. On the supply side, it is important to ascertain the sensitivity of production to prices of food items that account for as much as half of the budgets of poor families in the region.

Trend projections typically show demand outpacing production and marketed supply on a regional basis, with consequent upward pressure on the prices of coarse grains. Little work has been done so far, however, to ascertain the likely effects of these price rises on producer incomes, on-farm consumption, aggregate production, marketed surplus, and consumption by the nonproducing poor.

Yet information on these issues is important to assist in the design of agricultural research, technology, and policies for the region and IFPRI has initiated research to provide such information in several West African countries.

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[12] Peter B. R. Hazell and Ailsa Röell, Rural Growth Linkages: Household Expenditure Patterns in Malaysia and Nigeria, Research Report 41 (Washington, D.C.: International Food Policy Research Institute, 1983).

11
Nutrition in the Research and Training Activities of IITA

Bede N. Okigbo and Peter Ay

In this paper we shall review various aspects of the research and training of the International Institute of Tropical Agriculture (IITA) that have nutritional implications for the commodities, farming systems, and geographical areas covered by its mandate, which more or less establishes the boundaries of its international activities. As recommended by Pinstrup-Andersen, consideration is given to the establishment of commodity priorities, the specification of desired characteristics of commodities, the specification of desired characteristics of technology, and the choice of production systems to be researched.[1]

Some consideration is given to stages in the food chain that are affected by IITA's research, the problem of evaluating the nutritional effects of IITA's work, and directions that can be taken to ensure that its future research, training, and related activities will have more effective nutritional content.

IITA AND THE SCOPE OF ITS MANDATE

Within the network of the CGIAR and as interpreted and modified by the IITA Board of Trustees in 1976, the mandate of the Institute, to the extent that funds are available, entails:

- Research on farming systems of humid and subhumid zones to develop viable alternatives to shifting cultivation by means of which productivity can be maintained under continuous cultivation.
- Global responsibility for cowpea, yam, and sweet potato in all climatic zones.
- Research on and improvement of maize, rice, cassava, pigeon pea, and soybean in cooperation with other international institutes and organizations.

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[1] Per Pinstrup-Andersen, "Incorporating Nutritional Goals into the Design of International Agricultural Research," revised version of a paper discussed at a meeting of the international agricultural research center directors on November 5, 1982, International Food Policy Research Institute, Washington, D.C. (mimeographed).

- Improvement of other crops such as lima bean, winged bean, cocoyam and other aroids, and plantain and other forms of *Musa* that are important in the farming systems and contribute substantially to the diets of peoples in the humid and subhumid tropics.
- Making the results of its work available to interested countries and institutions through regional and national cooperative programs.
- Undertaking, in cooperation with IBPGR, exploration, collection, conservation, and documentation of genetic materials of food legumes, roots and tubers, and rice in humid and subhumid regions of Africa and making the materials available to breeders and scholars.
- Responding to requests from appropriate authorities through cooperation with regional and national programs in the improvement of farming systems and crops in which IITA has competence in the humid and subhumid tropics of Africa and, outside Africa, in cooperation with other international institutes and organizations, especially those associated with the CGIAR.
- Responding, in cooperation with other institutions when it is appropriate, to requests from governments in humid and subhumid regions of Africa for cooperation in developing the agricultural systems of their countries, including their agricultural research capabilities.

On the basis of this mandate, the programs of IITA are organized into three groups: crop improvement, farming systems, and international training. The crop-improvement programs consist of the cereal improvement program, which emphasizes improvement of maize and rice for various environments and various needs of tropical Africa, in cooperation with CIMMYT and IRRI, respectively; the grain legume improvement program, which emphasizes cowpea and soybean; and the tubers and roots improvement program, in which priority is given to improvement of yam, sweet potato, aroids, and cassava, in cooperation with CIAT and AVRDC. The other two programs are the farming systems program and the international training program. As in other IARCs, priority is given to the improvement and production needs of small farmers, who produce the bulk of the food in tropical Africa.

COMMODITY PRIORITIES

The multicommodity-improvement mandate of IITA, at both the global and the continental level, has a built-in nutritional concern with respect to achieving dietary balance at the farm level. Commodities of concern to IITA include the starchy staples that are the main sources of calories and consist of cereals--maize and rice--and roots and tubers--cassava, yam, sweet potato, and aroids--that are of relatively low protein content, especially the latter group. Included also are plantain and starchy banana, the production systems of which are being studied in the farming systems program at the Onne high-rainfall station. These high-energy carbohydrate staples are supplemented by the legumes cowpea and soybean, which are richer in protein and of slightly higher biological value than the starchy staples. Sometimes nonmandate crops, such as pigeon pea, lima bean, okra, tomato, and melon (*Colocynthis vulgaris*) are included in certain cropping patterns. The commodity mandate and the flexibility of its

farming systems program give IITA the widest scope among the IARCs in choice of commodities that have the potential of attaining nutritional or dietary balance.

The legumes usually feature in various combinations and rotational sequences of crops. The objectives of including various crops in combinations and sequences are both nutritional and nonnutritional when subsistence crops are grown with or in sequence with nonfood or cash crops, and some are grown as supplementary sources of income. The choice of crops to be grown in various cropping patterns is the outcome of farming systems research, which identifies the preponderance of certain species, local preferences, and environmental adaptation of various commodities. A recent development at IITA in the choice of commodities is the cooperative program with the International Livestock Center for Africa (ILCA), which involves integration of crops and livestock--small ruminants--in the development of improved agrisilvopastoral systems. The primary interest in this approach is maintenance of soil fertility through the use of animal manures and nitrogen enrichment by means of fast-growing leguminous shrubs. But equally important is the use of animals as sources of protein and as occasional sources of additional income. Of probable relevance to nutrition is research in agroforestry that involves fast-growing legumes, which are sources of fuel wood, the scarcity of which may, especially in rural areas, significantly reduce the consumption of legumes such as pigeon pea that require prolonged cooking. Fast-growing legumes also constitute cheap sources of nitrogen, which may affect the nutritional qualities of various food crops grown in association with or in sequence with them--by increasing their protein content, for example. Such increases may seem marginal, but they may actually be substantial in contributing significantly to the amount of plant protein in the diet of rural peoples whose consumption of animal protein is often quite low.

SPECIFICATION OF CHANGES IN COMMODITY CHARACTERISTICS

The commodities of concern to IITA are the principal food crops of the humid and subhumid tropics, including rice, maize, cowpea, soybean, yam, cassava, sweet potato, aroids, and plantain, in addition to other crops that may be found to be of value in some farming systems. The commodity characteristics that are given priority in the crop-improvement programs of IITA include high yield, appeal to consumers, resistance to disease and pests, suitability to the needs and production systems of the grower, protein quality, and ability to adapt to environmental stresses.

Research in farming systems and observations of breeders and field collectors are crucial to the identification of the characteristics of various crops, such as their functions in different production systems, their suitability for local preferences and nutritional problems, their adaptation to the environment, their reactions to disease and pests, the harvesting requirements and problems that they present, their ease of storage, their uses, methods by which they can be processed, and their cooking qualities. One or more of these observations are taken into account in crop improvement. In crop-improvement programs and in cropping-systems research, the highest priority is given to ways of achieving high yields and increasing

production, which are sometimes detrimental to nutritional quality. Increased availability of food is usually but not always reflected in greater consumption and better nutritional status. Increased yields of various commodities that are marketed may bring more income, which may be reflected in greater nutritional well-being in some situations and not in others. Examples of high-yielding crop varieties and yield-boosting technologies that have been developed at IITA will be discussed in various sections of this chapter. In cowpea the preference for large-seeded, rough-seed-coated, white varieties that are easy to cook and process has had considerable effect on improvement of cowpea for certain areas, especially West Africa. Similarly, the consumption of cowpea leaves as vegetables in East Africa has been taken into account in the screening of elite cowpeas in studies of the effects of defoliation on cowpea yields. The introduction of a new IITA variety of cowpea (TVX 3236) in the Ilorin agricultural development program was accompanied by surveys of taste preferences and assessment of nutritional values of different varieties in various dishes of the locality.

Work on improvement of soybean at IITA was at the beginning aimed at its use as a cash crop, as a source of oil, and in the form of soybean meal as poultry feed. Monitoring of its current uses has, however, indicated that its consumption as a condiment and substitute for the locust bean (*Parkia clappertoniana*) has increased. IITA is also giving greater priority to improvement of vegetable cowpea for the humid tropics over seed cowpea for subhumid areas and savannas. Considerable attention has been paid to evaluation of cowpea lines for protein content and the amino-acid spectrum of breeding lines. Protein content in some advanced lines of cowpea varied from 18.5 percent to 23.0 percent, while the content of some essential amino acids such as methionine ranged between 1.31 and 1.50 grams per 100 grams.[2] Such variations present opportunities for selection and improvement of nutritional quality.

In the tubers and roots improvement program, some attention has been paid to production of lines of cassava that are low in cyanide, improvement of both root and leaf yields in cassava, and improvement of both tuber yield and use of leaves as a vegetable in sweet potato. Cassava contains linamarin and lotaustralin, which release hydrogen cyanide (HCN) during degradation. Consumption over long periods of cassava roots not adequately processed to remove most of the cyanide may contribute to the incidence of endemic goiter, cretinism, and ataxic neuropathies.[3] Screening lines for low cyanide content at IITA was first accomplished through the picrate leaf test and is now done

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[2] S. R. Singh, "Amino acid analyses of 25 cowpea varieties as determined by B. Dronzek and colleagues," Department of Plant Science, University of Manitoba, Winnipeg, Canada, 1983.

[3] F. Delange and R. Ahluwalia, eds., *Cassava Toxicity and Thyroid: Research and Public Health Issues*, proceedings of a workshop held in Ottawa, Canada, May 31-June 2, 1982 (Ottawa: International Development Research Centre, 1983); O. L. Ekpechi, "Endemic Goitre and High Cassava Diets in Eastern Nigeria," in *Chronic Cassava Toxicity*, proceedings of an interdisciplinary workshop, London, January 29-30,

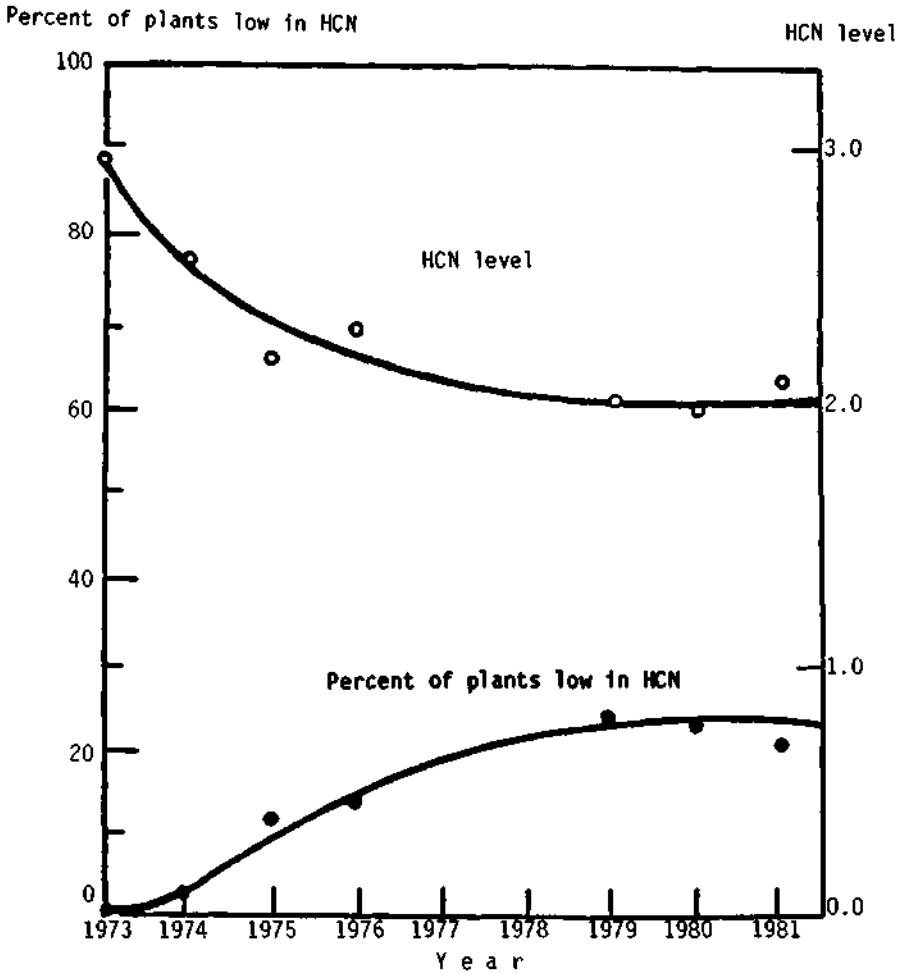
by the automated enzymatic method using linamarase.[4] The results of breeding for low-cyanide lines are shown in Figure 11.1. Hahn reports that a frequency of 25 percent in the low-cyanide cassava lines was reached after five or six years of continuous recombination and selection.[5] Picrate-leaf test-screening indicates that low-cyanide selections have cyanide content of 80 milligrams per 100 grams; medium-cyanide lines, 80-200 milligrams per 100 grams; and high-cyanide lines, more than 200 milligrams per 100 grams. Automated enzymatic screening of 568 lines in the low-cyanide population indicated that cyanide content varied from 0 to 2 milligrams per 100 milligrams of fresh weight of peeled roots. Breeding for low cyanide, while sometimes associated with lower root yields, is pursued at IITA partly to facilitate production of unfermented or only partly fermented nontoxic better-flavored cassava flour for blending with wheat or soybeans with or without pentosans in bread making and other food preparation, thereby eliminating some of the cost of imported wheat. Selection for high protein content has produced roots that contain up to 10 percent protein. But this is now being given low priority since there are several other ways of achieving protein enrichment. Cassava leaves, on the other hand, contain as much as 20-30 percent protein in dry weight; and in the screening of cassava cultivars for Zaire and Sierra Leone, some priority is given to the yield, quality, and protein content of the leaves. Selection for characteristics such as root yield, for resistance to diseases, for gari (a grated, partly fermented, fried cassava product) yield, and for HCN content based on standardized screening methods are routine breeding methods. Evaluations of root (chikwangue and fufu) and leaf (pondu) preparations from high-yielding clones grown in Zaire in 1979-80 are presented in Table 11.1. In improvement of sweet potato, some consideration has been given to preference for starchy, white-fleshed tubers over less-starchy, orange-fleshed ones, which though more nutritious are less well liked. Consideration is also given to leaf yield in selecting varieties for some countries, such as Sierra Leone, where both leaves and tubers are eaten.

1973, ed. B. Nestel and R. MacIntyre (Ottawa: International Development Research Centre, 1973); B. O. Osuntokun, "A Toxic Neoropathy with Associated with High Cassava Diets in Eastern Nigeria," in Chronic Cassava Toxicity, proceedings of an interdisciplinary workshop, London, January 29-30, 1973, ed. B. Nestel and R. MacIntyre (Ottawa: International Development Research Centre, 1973).

[4] S. Sadik and S. K. Hahn, "Cyanide Toxicity and Cassava Research at the International Institute of Tropical Agriculture, Ibadan, Nigeria," ibid., pp. 41-42; R. D. Cooke, "An Enzymatic Assay for Total Cyanide Content of Cassava (Manihot esculenta Crantz)," Journal of Scientific Food Agriculture 29 (1978): 345-352.

[5] S. K. Hahn, "Cassava Research to Overcome the Constraints to Production and Use in Africa," in Delange and Ahluwalia, eds., Cassava Toxicity and Thyroid.

Figure 11.1--Improvement of cassava for low cyanide as judged, on t basis of the picrate-leaf test, by the frequency of lo cyanide plants and cyanide levels during the nine-ye period 1973-81 through continuous recombination and sele tion



Source: S. K. Hahn, "Cassava Research to Overcome the Constraints to Production and Use in Africa," in Cassava Toxicity and Thyroid: Research and Public Health Issues, proceedings of a workshop held in Ottawa, Canada, May 31-June 2, 1982, edited by F. Delange and R. Ahluwalia (Ottawa: International Development Research Centre, 1983).

Table 11.1--Tuber- and leaf-preparation quality of seven high-yielding varieties of cassava grown in Zaire, 1979-80

Variety	Root Taste	Leaf Preparations (Pondu)	Root Preparations[a]		
			Chikwangue		
			Ndika	Nsesa	Fufu
A56	Sweet	Very good	1.8	1.7	0.6
179/2	Bitter	Bitter	1.9	2.0	1.8
70/4	Sweet	Good	1.9	0.9	1.0
344/6	Sweet	--	1.6	2.0	1.8
Coll.45	Bitter	Not liked	1.9	1.6	2.0
174/2	Sweet	--	1.9	1.2	0.4
122/2	Sweet	Very good	2.1	1.5	0.2
02864	Sweet	Good	1.6	1.8	1.6

Source: International Institute of Tropical Agriculture, Annual Report, 1980 (Ibadan, Nigeria: IITA, 1981).

[a] 0 = not liked; 1 = good; 2 = better; and 3 = best.

In the cereal-improvement program, it has been observed that white varieties of maize that are not very chaffy are preferred in parts of Nigeria for local food preparations and for eating green from the cob. In parts of Mali, on the other hand, yellow flinty types are preferred for making couscous, but even then the crucial factor is early ripening since maize is grown as a cash crop with late-maturing sorghum. Selection for early ripening both in Nigeria and Mali is of strategic importance to ensure that adverse nutritional effects of the hungry season, when most crops have been planted, are minimized. As a result of differences in local preferences for white or yellow maize and the nutritional preference for the latter in poultry feed, this program has as a matter of policy tried always to produce both yellow and white variants of any new maize cultivars being developed. Not much breeding is done by IITA for protein content in maize as is being done in CIMMYT. In rice improvement some priority is given to local preference and to evaluation of quality in relation to storage, milling, and market quality. In West Africa, for example, long-grained varieties of rice that are not subject to breakage on milling and are not waxy are preferred. Quality evaluation has not been given much attention at IITA in the past, but facilities are now being developed there for its incorporation into the breeding and varietal improvement of rice.

SPECIFICATION OF DESIRED CHANGES IN TECHNOLOGY CHARACTERISTICS

IITA like other IARCs gives priority to quantitative and qualitative improvement of food crops, with emphasis on the production

systems of small farmers, who grow more than 90 percent of the locally produced foods consumed in Sub-Saharan Africa. Farming-systems research and studies of various food crops has made possible better understanding of the environment, traditional and transitional production systems of small farmers, constraints on their improvement, and the needs and situations of small farmers. IITA has thereby been able to identify the following technology characteristics that should constitute guidelines for strategies to ensure the suitability of the technology to their needs and its rapid adoption by a majority of farmers:

- Should have a high potential for increasing the quantity of high-quality food produced.
- Should significantly reduce the drudgery in farming, thereby making it more attractive and minimizing migration from rural to urban areas.
- Should significantly reduce the cost of inputs for small farmers who lack credit.
- Should considerably minimize the acute shortage of labor at peak periods in the production system.
- Must include a range of appropriate technologies and practices for all stages of the production system, from clearing and tillage of the land to harvesting and postharvest operations, such as threshing, drying, and storage.
- Should as far as possible be within the means of small farmers to own, use, maintain, or hire.
- Should minimize hazards to man and environment.
- Should be based on an understanding of past, present, and future trends in relation to socioeconomic pressures and other pressures of modernization.

There are a number of technologies in IITA's research programs that possess one or more of these characteristics and that have direct or indirect nutritional implications. In the crop-improvement programs--for cereals, grain legumes, and tubers and roots--high-yielding varieties of maize, rice, cowpea, soybean, cassava, and sweet potato have been developed. In addition to higher yields, higher quality, and resistance to disease and pests, all of which help increase the available food supplies and minimize the costs and hazards of chemical disease and pest control, have been achieved. Achievements in the development of varieties that are resistant to or tolerant of disease and pests and identification of sources of resistance at IITA include, in cassava, cassava mosaic disease and bacterial blight (*Xanthomonas manihotis*); in sweet potato, mosaic virus; in cocoyam, root rot blight complex; in maize, maize rust (*Puccinia polysori*) and maize streak virus; in cowpea, cowpea rust (*Uromyces appendiculatus*), Cercospora leaf smut, and bacterial pustule; southern bean virus; golden mosaic; and mottle virus. Cowpea lines resistant to bruchid, a storage beetle, were developed that exhibited only 22-31 percent damage after about three months in storage, whereas in a susceptible check damage was 94 percent. Related to this is the significant reduction of postharvest loss by treatment of cowpeas with small amounts of groundnut oil, which remains effective for about six months. Cowpeas have been developed (IT82 E-18, IT82 E-60, and IT82E-77) that mature in 60-65 days with yields of 1.5-2.0 tons per hectare, while unimproved varieties yield only 300-600 kilograms per hectare. The remarkable progress made in

cowpea improvement is of significant nutritional importance in areas where starchy staples are dominant. Besides the development of lines resistant to pests and disease, which is a component of integrated pest- and disease-management systems, the following appropriate technologies used at various stages in production and post-harvest operations are noteworthy:

- A rolling injection planter that facilitates seeding through plant residue mulches in zero-tillage practice.
- A cassava harvester or hand-operated cassava-root lifter.
- A rotary maize sheller.
- A cowpea harvester that is still under trial.
- Improved maize storage bins developed in cooperation with the rural storage unit of the Food and Agriculture Organization of the United Nations (FAO).

All these help to increase food production and supplies or to conserve better what has been produced thereby minimizing seasonal fluctuations in supply.

CHOICE OF PRODUCTION SYSTEMS

The development of more efficient alternative production systems of permanent agriculture for sustained increases in yields of various commodities must be based on an understanding of traditional farming systems. These are characterized by small farm size--more than 70 percent two hectares or smaller; mixed cropping and diversification of production to minimize the risk of crop failure at the same time assuring greater total yields and more nearly uniform availability of food at low input levels; the use of manual labor with simple tools, making them subject to acute shortages of labor during peak periods of clearing, tilling, planting, weeding, and so on; widespread use of slash-and-burn clearance systems; and reliance on letting the land lie fallow for long periods to maintain the fertility of the soil, with consequent degradation of the soil and loss of fertility when fallow periods are reduced because of increasing population pressure. In recognition of these characteristics of traditional farming systems and constraints to their improvement, we offer the following components of production systems or alternative production systems from which reasonable choices of production systems or their component technologies could be made:[6]

1. Better land development and soil management by using methods of minimizing degradation of the soil and loss of fertility and reducing the cost and amount of fertilizers used through greater efficiency of fertilizer use and some reliance on biological methods such as nitrogen fixation.
2. Improved cropping patterns, including intercropping, relay cropping, multiple cropping, and rotation of these, in addition to improved technologies for crop management.

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[6] Bede N. Okigbo,"Introducing Nutritional Considerations into Research and Training in Farming Systems," paper presented at the seventh session of the United Nations Administrative Committee on Coordination/Sub-Committee on Nutrition Symposium, Rome, March 2-6, 1981.

3. Improved agroforestry systems using fast-growing nitrogen-fixing leguminous shrubs or growing food crops along with multiuse trees and shrubs.
4. Integrated crop and livestock systems wherever and to whatever extent possible.
5. Low-cost input technologies such as those already discussed, including integrated systems for management of pests and disease.

The use of better systems of land development and soil management ensures that high levels of yields will be maintained throughout long periods and that fertility and an adequate balance of nutrients will also be maintained.

Improved cropping patterns that involve diversification of crops or commodities through the use of various cropping intensities and systematized rotation facilitate the fulfillment of subsistence requirements by making possible the consumption of balanced diets; integration of subsistence production with cash-crop production thereby ensuring that increasing market opportunities and cash requirements of the farmer are met; more nearly uniform distribution of labor and food supplies throughout the year; and greater total yields and sustained productivity, with lessened risk and reduced inputs through intercropping. Rotation of maize and cowpea has been demonstrated to give high yields of cereals and legumes.

Improved systems of agroforestry have the potential to facilitate the growing of arable food crops along with tree crops, which may be food crops, nitrogen-fixing plants, or plants that are otherwise useful. The use of alley-cropping systems with Leucaena minimizes the area of land that must lie fallow and increases production. Similarly, plantain-mixed cropping considerably increases production per unit of area. There is now an IITA cooperative project with ILCA in which the possibilities of integrating crops with livestock are being investigated. This will facilitate not only maintenance of soil fertility and increased yields but also production of animal protein for the use of the farm family or for sales to generate income.

Cropping-systems research at IITA is conducted in the farming systems program, in which existing production systems, the overall farm environment, constraints to increased production, the adoption of technology, and so on are also studied. Appropriate technologies are developed for all stages of the production system from clearing and planting to postharvest handling and storage. Deficiencies in infrastructure and in policies faced by the small farmer are identified. Through cooperation with the crop improvement programs, the development of varieties for different production systems and technologies that will meet the farmer's needs and circumstances is assured. Various aspects of the research of the farming systems program are not directly of nutritional significance, but even those that appear not to be may interact with those that are. All aspects of farming-systems research that directly bring about greater yields have nutritional significance if the resultant technologies are adopted. Socioeconomic research in which preferences for certain crop varieties or commodity characteristics that affect their consumption or their use in the preparation of certain dishes are identified as definitely of nutritional relevance. Thus, Ay reported the characteristics of certain varieties of cassava in relation to production systems and farmers' preferences for cassava cultivars of varying HCN content and

their suitability for various food preparations.[7] Socioeconomic considerations highlight the fact that urbanization, rising income, increasing affluence, mobility, and the like make it impossible to meet the rising demand for convenience foods merely by increasing the production of such crops as roots and tubers. Their low elasticities of demand make it necessary that increased production be associated with processing, not only to enhance their consumption by people of different income classes in both rural and urban areas, but also to increase their shelf life and make them uniformly available throughout all seasons. Continuous interaction among farming systems program scientists and those in crop improvement is necessary in order to ensure that the commodities have the characteristics that facilitate various operations in the production system besides processing. In the IITA tubers and roots improvement program, for example, varieties of cassava with compact root conformation are being developed to facilitate mechanized harvesting, as are varieties with low HCN content and suitable properties for processing into various food preparations. A development in postharvest technology of nutritional significance is the IITA/FAO cooperative rural storage project in which low-cost storage structures for maize were developed.

NUTRITIONAL EFFECTS OF THE RESEARCH AND TRAINING ACTIVITIES OF IITA

It is rather difficult to assess quantitatively or observe and document the nutritional effects of the research and training activities of IITA. Whatever the extent of nutritional concern in the priorities, strategies, and design and development of technologies of its crop-improvement and farming-systems programs may be, such nutritional concerns are not easily observed directly; and there is no choice but to find ways of imputing the nutritional effects indirectly by assessing the extent to which the technologies are adopted in the first instance. An accurate assessment of the extent to which IITA's technologies are adopted, for example, may give information on increases in yields and production of the commodities and cropping systems on which IITA is conducting research that are being extended to the farm level. Increased production means increases in the available food supplies from which the amount of extra calories, proteins, fats, minerals, and other nutrients that are being harvested or sold can be inferred. From observation of the quality, quantity, and variety of the foods being consumed, it would be possible to determine whether the increase in consumption significantly affects the nutritional status of the communities involved. Even then only an average assessment can be made. It may also be possible to observe in time any changes in the incidence of malnutrition, from which it would be possible to determine whether any significant changes have taken place in levels of undernutrition and overnutrition, as manifested by individuals exhibiting known symptoms of malnutrition. Since, to begin

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[7] Peter Ay et al., "Cassava Survey: Ijaiye Area Report on a Field Study in the Ijaiye Area," Farming Systems Program, Agricultural Economics Unit, IITA, Ibadan, Nigeria, 1983 (draft report, mimeographed), p. 27.

with, there is a lack of reliable statistical data in all countries of tropical Africa where IITA's technologies are being tried on farms, special nutritional surveys must be undertaken if accurate assessment of nutritional effects is to be possible. This will involve correlation of positive changes in nutritional status with the increase in consumption of food that is attributable to adoption of IITA's technologies in the course of time. Even then, increased production of some food crops or greater earnings from increased agricultural production may have positive or negative nutritional effects, depending on the prevailing nutritional knowledge and various socioeconomic and cultural factors.

Here only a rough indication of the extent of adoption of some of IITA's technologies that may somehow bring about significant increases in food production can be given. The following summary of past achievements of IITA's research and training programs may indicate roughly where possible yield and production increases have been initiated.

ADOPTION OF HIGH-YIELDING VARIETIES AND THE DEVELOPMENT OF PRODUCTION TECHNOLOGIES AT IITA

Some indications of the extent of adoption or activities of the crop improvement programs that are hastening the adoption process are summarized in Table 11.2. Similar developments in other program activities will be presented briefly here.

Table 11.2--Improved crop varieties produced at IITA and the extent of their adoption in several countries

Crop	Countries	Characteristics
1. Cassava	Sierra Leone, Zaire, Gabon, Tanzania, Seychelles, Rwanda, Liberia, and Cameroon	Many improved varieties with yields 2-4 times as great as those of locals released from IITA lines. Some varieties in Zaire and Sierra Leone selected for leaf vegetable. Low-cyanide lines selected for certain food preparations.
2. Sweet potato	Sierra Leone and other countries	4 varieties resistant to sweet potato weevil among 18 varieties so far distributed. Some in Sierra Leone selected for leafy vegetable.

Table 11.2 (continued)

Crop	Countries	Characteristics
3. Cowpea	Nigeria, Brazil, Venezuela, Tanzania, Nicaragua, Upper Volta, South Yemen, Botswana	More than 5,000 hectares of 60-day extra early cowpea grown during second year of release in Nigeria. Five varieties released and being grown in Brazil. Several varieties grown or being multiplied in other countries.
4. Maize	Nigeria, Cameroon, Benin, São Tomé	More than 200,000 hectares of TZB and TZPB being grown in Nigeria. Two streak-resistant varieties TZSR and TZSR-Y released in São Tomé. All promising lines being converted to streak-resistant lines.
5. Rice	Liberia and Sierra Leone	Suakoko 8 released in Liberia for tolerance of iron-toxicity. Many new upland varieties and elite lines promising in trials throughout West Africa and Brazil.

In the farming-systems program, considerable progress has been made in pushing the land-development and soil-management technologies of IITA off site; among these are alley cropping, which not only ensures that yield and productivity are sustained without keeping large areas lying fallow but also facilitates the production of fuel wood, stakes, and fodder. The West Africa Farming Systems Network has made it possible for appropriate technologies and cropping patterns generated by farming systems to become components of the international programs or outreach of IITA, which in the past was limited to the crop-improvement program.

The training program has conducted group courses in crop-production technology and extension, including a few specialized courses on postharvest technology, tillage systems, and soil microbiology. By June 1970, 1,859 participants from 41 African countries had been trained. In addition to these, research training leading to advanced degrees in various programs included 144 masters theses and 87 doctoral dissertations, which have contributed in no small measure to the generation of technology and the development of new varieties besides significantly improving national research capabilities.

Although the nutritional effects of both farming-systems programs and crop-improvement programs are not easy to evaluate directly, their effects on trainees can in time be measured by their contributions to

increased food production and supplies by means of new cropping patterns and appropriate technologies. Assessment of training in crop production and international programs involving on-farm adoption of technology can be regarded approximately as a short-term measure to increase food production and, indirectly, nutritional well-being. Advanced training can be seen as more of a long-term measure to ensure development toward increasing food production and improving nutrition.

The international programs office is responsible for planning, conducting, coordinating, and assessing progress in special research on projects in evaluation, adaptation, and adoption of technology that ensure linkage of national research institutions and development programs with IITA programs for crop improvement, farming systems, and training. The programs are financed through special contributions of donors. Their overall objective is cooperation and interaction with national programs, including training programs, that assist various countries to develop capabilities in research and in adaptation and adoption of technologies developed at IITA, at the same time encouraging feedback to planners and researchers. In 1982 the international programs office had 22 projects, which consisted of 15 mandated research projects and 7 cooperative special projects involving more than 25 African countries.

Almost all these projects have the dual aim of developing national capabilities in research and production of food crops and of accelerating the adoption of improved crops in more efficient production systems. All of them have explicit or implicit nutritional implications. While the effectiveness of the various programs and the technologies of IITA in improving nutrition cannot be measured quantitatively, the international programs serve to indicate opportunities and potentials for significantly affecting the amount of food produced and the supplies that are available. They also at least assist in setting the stage for development of local capability to achieve these goals.

THE FUTURE

The nutritional implications of the work of IITA in its various programs have been reviewed and the difficulties of assessing their effect on nutrition have been stressed. But at the moment such an effect can only be imputed from their effects on increases in yields and the resultant effects on food supplies and consumption. The future holds promise of more opportunities for widespread adoption of IITA technologies and quantitative observations on components of yields, food supplies, and increased consumption that can be attributed to these innovations. There will be similar opportunities in the future for the development of technologies that will produce more direct nutritional benefits than have ever been achieved in this way in the past. These present and future developments of nutritional importance in the work of IITA can be summarized as follows:

1. With increasing yields from root and tuber crops that are low in protein, are high in calories, and constitute cheap staples for the majority of poor people in humid and subhumid tropical Africa, it is imperative that more processing and food-fortification programs be undertaken to facilitate their storage and handling and to increase the elasticity of demand. Since crops

such as cassava are famine crops in some cereal-dominant semiarid areas and more rapid advances are now being made in increasing the yields of these crops, processing also provides an opportunity for dealing with any surpluses, whether for human consumption or animal feed; their use as animal feed becomes a more likely possibility after human needs have been met.

The present unfavorable balance of payments in many countries of Africa and the huge amounts of money being spent to import food, especially grains, call for more research on ways of minimizing imports and loss in foreign exchange through the use of composite flours and protein fortification of starchy foodstuffs.

2. Advances in biotechnology, including tissue culture and genetic engineering, now make it likely that wide crosses among roots and tubers and protein-rich crops or incorporation of genes for protein synthesis into roots and tubers will open a new avenue for increasing the protein content of roots and tubers to significantly higher levels than have been reached through conventional plant breeding.
3. There is also the possibility of improving the nutritional value of starchy foodstuffs through microbial protein enrichment.
4. The growing interest in the potential use of several tropical food crops as renewable sources of energy poses a danger from the nutritional point of view, since increasing fuel prices could lead to the diversion of many staples in developing countries to use as raw materials for fuel, which might bring higher returns to small farmers than they would realize from marketing these staple foodstuffs.

12
Incorporating Nutritional Goals into International Agricultural Research — An ILCA Perspective

Guido Gryseels and Irene T. Whalen

The International Livestock Centre for Africa (ILCA) was established during the mid-1970s. Its task is to carry out research, training, and documentation to assist national efforts to increase the production of livestock in Africa. Those activities and programs of ILCA that affect the nutritional status of the malnourished human population, who in general are the landless or nearly landless, the urban poor, nomadic herdsmen, and marginal subsistence farmers, will be outlined here.

This chapter will begin with a brief overview of the linkage between livestock production and human nutrition. This will be followed by background information on ILCA and its research programs and a discussion of commodity priorities, characteristics, production systems and technology characteristics, together with a review of the implications of alternative choices for nutritional improvement of the malnourished. Some of the important socioeconomic factors that affect nutrition will be highlighted, and specific suggestions will be made for strengthening nutritional concerns in ILCA research.

THE CONTRIBUTION OF LIVESTOCK PRODUCTION TO HUMAN NUTRITION IN SUB-SAHARAN AFRICA

Human diets in Sub-Saharan Africa are dominated by the consumption of cereals, roots, and tubers. In most African countries these provide more than 65 percent of daily energy consumption.[1] The contribution of animal products to the energy supply is generally less than 20 percent, often even less than 10 percent. Even in countries in which there are large concentrations of nomadic people or where cattle raising is particularly important, as in Botswana, the bulk of the national diet is still derived from cereals, roots, and tubers. In Ethiopia, which has the largest livestock population of Sub-Saharan

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[1] U.S. Department of Agriculture, Food Problems and Prospects in Sub-Saharan Africa: The Decade of the 1980's (Washington, D.C.: USDA, 1981).

Africa, some 75 percent of daily energy consumption per capita is from cereals, roots, tubers, and plantains.[2]

Despite this dominance of food crops, animal products are critical in human nutrition in Africa. They supply high-quality protein that is occasionally sufficient to counteract energy shortages. Animal protein combines effectively with a wide variety of foods, particularly cereals, to facilitate the achievement of balanced diets. Nutritional deficiencies or imbalances have been found to be much more common in diets that are lacking in animal protein.[3] In research in the Sahel nutritional deficiencies were found among human populations that were wholly dependent on crops. In one report it was observed that the protein content and amino-acid composition of sorghum and pearl millet, primary crops in the Sahel, are inadequate to fulfill the nutritional needs of children regardless of the quantity consumed.[4] In the same report settled populations dependent on cereals were found to have deficiencies in riboflavin and calcium that could be eliminated by increasing the consumption of animal protein. The dietary importance of livestock products is well demonstrated by various pastoral groups such as the Maasai, the Somali, and the Borana, who are almost totally dependent on milk for several months of each year and for whom cereals are a seasonal supplement rather than a staple element of the diet.

As is true of crop production, meat and milk production per capita in Africa have decreased during the last 20 years, even though some increases in production have been realized, principally through expansion of the sizes of herds. Productivity of both meat and milk in Africa remains among the lowest in the world. It is important to note, however, that livestock provide a number of products besides meat and milk to African subsistence farmers. Meat yields of bovines rarely exceed 12 kilograms per animal a year, whereas they are 17 kilograms per head a year in other developing countries and 80 kilograms per head a year in developed countries with market economies. Under traditional management, cows of indigenous breeds in Africa seldom produce more than 600 liters of milk a year, while the world average is 1,900 liters and in developed countries it is 3,700 liters.[5] While supplies remain low, the demand for such products is growing rapidly. Africa imported some 2.5 billion U.S. dollars' worth

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[2] Ibid.

[3] R. O. Wheeler, "Problems and Prospects for Increasing Livestock Production through Improved Production Systems," in Increasing Agricultural Productivity, Proceedings of the Third Annual Agricultural Sector Symposium, ed. Ted J. Davis (Washington, D.C.: World Bank, 1982).

[4] International Development Research Centre, Nutritional Status of the Rural Population of the Sahel: Report of a Working Group, Paris, France (Ottawa, Canada: IDRC, 1981).

[5] Claude De Montgolfier-Kouévi and Annie Vlavonou, Trends and Prospects for Livestock and Crop Production in Tropical Africa, Working document No. 5 (Addis Ababa: International Livestock Centre for Africa, 1981).

of livestock products in 1982. There is considerable potential for increasing productivity and thus for expanding the food supply that is available to Africa. Expansion is urgently needed if a food crisis is to be averted. Several recent reports have highlighted the deteriorating condition of African agriculture.[6] While there is disagreement on particular minimum energy requirements, there is agreement that on the average the energy available per capita per day in many African countries is below acceptable levels.

Beyond their direct contribution to human nutrition in the form of meat and dairy products, livestock support the cropping systems in a number of ways that lead to expansion of output. Brumby has identified several factors that account for this:[7]

- In many subsistence-farming systems livestock and livestock products such as milk, meat, skins, and manure are an important source of cash income. Increasing the sale of livestock products in a mixed crop-and-livestock system may generate the cash to purchase crop inputs such as fertilizer, improved seeds, and pesticides. Adding to this is the expansion of agropastoralism, in which livestock provide security and allow the taking of risks in an uncertain cropping environment.
- Livestock provide draft power. In many African countries the type and number of livestock kept by farmers are determined by their need for draft power. An ILCA study in Ethiopia shows that farmers who own more work oxen have substantially larger cropped areas than those who have less draft power.[8]
- Livestock provide manure, which can be a vital factor in maintaining the fertility and structure of the soil. The livestock held by the average farmer in the Ethiopian highlands produce sufficient manure, if it were applied on cereal crops, to increase yields by 300 kilograms of grain per farm. Sedentary farmers in northern Nigeria have long valued the manure from their pastoral neighbors, and in Kenya Kikuyu farmers purchase manure from Maasai pastoralists.
- Crop productivity can be increased through the benefits to the soil that come from the inclusion of legumes or forage crops in the crop rotation. In turn these high-quality feedstuffs provide a valuable supplement to livestock in the dry season.

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[6] Food and Agriculture Organization of the United Nations, The State of Food and Agriculture: The Least Developed Countries (Rome: FAO, 1981); USDA, Food Problems and Prospects; World Bank, Accelerated Development in Sub-Saharan Africa: An Agenda for Action (Washington, D.C.: World Bank, 1981).

[7] Peter J. Brumby, "Foreword" to ILCA Annual Report 1982 (Addis Ababa: ILCA, 1983).

[8] Guido Gryseels, "On-Farm Animal Traction Research: Experiences in Ethiopia with the Introduction of the Use of Single Ox for Crop Cultivation," paper presented at the Third Annual Farming Systems Research Symposium, Kansas State University, Manhattan, Kansas, October 31-November 2, 1983.

Thus, from a nutritional standpoint livestock contribute by being consumed as food, by increasing crop productivity, and by producing income that can be used to purchase food. Livestock in Africa are largely complementary rather than competitive with crop agriculture in expanding food production. ILCA seeks through its research to exploit the close links between the production of crops and the production of livestock.

ILCA RESEARCH AND HUMAN NUTRITION

ILCA has focused its initial research activities on ruminant livestock because of their numerical and economic importance in Africa. The organization of the Centre provides a combination of field-research programs and central research units based at headquarters in Addis Ababa. The field research programs are located in five ecological zones of Sub-Saharan Africa. They include:

- Pastoral and agropastoral systems in the arid and semiarid zones (Mali and Niger).
- Pastoral systems in the rangelands of Eastern and Southern Africa (Ethiopia, Kenya, and Botswana).
- Sedentary livestock-production systems in the subhumid zone (Northern Nigeria).
- Sheep and goat production in the humid forest zone (Southern Nigeria).
- Mixed smallholder farming systems in the highlands (Ethiopia).

The extent and rural human population of each of these large ecological zones is indicated in Table 12.1.

Table 12.1--Land area and human rural population by ecological zone in Sub-Saharan Africa

Ecological Zone	Land Area		Rural Population	
	(1,000 km)	(percent)	(1,000)	(percent)
Arid	8,327	37.3	24,768	10.4
Semiarid	4,050	18.1	65,382	27.5
Subhumid	4,858	21.7	59,442	25.0
Humid	4,137	18.5	50,307	21.2
Highlands	990	4.4	37,927	15.9
Total	22,362	100.0	237,826	100.0

Sources: H. E. Jahnke, Livestock Production Systems and Livestock Development in Tropical Africa (Kiel, West Germany: Kieler Wissenschaftsverlag Vauk, 1982); and Claude De Montgolfier-Kouévi and Annie Vlavonou, Trends and Prospects for Livestock and Crop Production in Tropical Africa, Working document No. 5 (Addis Ababa: International Livestock Centre for Africa, 1981).

Notes: Ecological zones are defined by the number of growing days (GD). A growing day is one in which precipitation exceeds potential evapotranspiration. Arid is defined as less than 90 GD; semiarid, 90-179 GD; subhumid, 180-269 GD; and humid, more than 270 GD a year.

Most of the arid and semiarid zones are distributed in West and Southern Africa, while most of the humid zone is to be found in Central Africa.

Although the arid zones cover more than 37 percent of the total land mass of Sub-Saharan Africa, they contain only 10 percent of the rural population. In contrast, almost 16 percent of the rural Africans live in highland areas, although they cover only 4 percent of the land area. Three quarters of the African highlands are located in Eastern Africa.

Most of the subhumid and humid zones are infested with tsetse flies and are therefore at most seasonally usable by livestock. The distribution of the ruminant livestock population is shown in Table 12.2.

Table 12.2--Ruminant livestock population, by species and ecological zone, in Sub-Saharan Africa, 1979

Ecological Zone	Cattle	Sheep	Goats	Ruminants[a]
		(1,000 TLU)[b]		
Arid	31,462	37,063	48,287	41,697
	(21.3)	(35.7)	(38.6)	(30.4)
Semiarid	45,454	23,071	33,215	37,446
	(30.8)	(22.2)	(26.5)	(27.3)
Subhumid	32,758	14,153	20,266	26,370
	(22.2)	(13.6)	(16.2)	(19.2)
Humid	8,814	8,177	11,586	8,148
	(6.0)	(7.9)	(9.2)	(5.9)
Highlands	29,022	21,401	11,933	23,646
	(19.7)	(20.6)	(9.5)	(17.2)
Total	147,510	103,865	125,287	137,308
	(100)	(100)	(100)	(100)

Source: H. E. Jahnke, Livestock Production Systems and Livestock Development in Tropical Africa (Kiel, West Germany: Kieler Wissenschaftsverlag Vauk, 1982).

Note: Figures in parentheses are percentages.

[a] Including camels.
[b] The tropical livestock unit (TLU) is commonly taken to be the equivalent of an animal of 250 kilograms liveweight.

Zone-specific research is carried out in the field programs, while studies of systems components common to more than one zone are coordinated from headquarters. These headquarters units concentrate on topics as diverse as livestock policy, animal nutrition, legume agronomy, and the productivity of trypanotolerant livestock. ILCA has also established several research networks, including those for the study of forage germ plasm, agricultural by-products, and trypano-

tolerant livestock. The approach to research followed by ILCA is multidisciplinary on the premise that effective research depends on a detailed understanding of the production systems to be improved.

Commodity Priorities and Characteristics

Different species of livestock vary in their productivity, in the products they supply, and in the functions they fulfill. The same species may be kept for multiple functions. Cattle, for example, may be kept to produce beef for sale, milk for consumption, dung for field fertilization or fuel, and as draft animals in farm work. The various functions for which they are kept affect the style of management and the type of intervention acceptable to both livestock owners and managers.

Baseline studies at the household level have been made before experimental research has been undertaken in all of the field programs of ILCA, thereby providing knowledge about the diets of local people, seasonality in patterns of food intake, household budgets, degree of subsistence, and the function of animal products in household consumption. Results of these studies help to identify and rank the priority of component research studies. In the Ethiopian highlands, for example, most of the farmers in the ILCA study areas are followers of the Ethiopian Orthodox Church. The fasting rules of this religion prohibit everyone above the age of ten from eating food that contains animal protein, except fish, on Wednesdays and Fridays and during the longer fasting periods, including the eight weeks before Easter and the second and third weeks of August. Most families are thus vegetarian for some 140 days a year. For those who also observe the optional fasting days, the total may be as high as 220 days a year.[9] As a result research to increase the production of milk had to be accompanied by research for more efficient dairy technologies so that fresh milk could be processed into more storable products to overcome the extended fasting periods.

Although demand factors may explain some of the variability in the diet of farmers in the Ethiopian highlands, supply factors are far more important in explaining the seasonality in the pattern of food intake of most African farmers, particularly among the low-income groups. Research in each of the field programs of ILCA has shown that diets vary greatly with the years, seasons, and communities and even among members of the same family. Seasonal food shortages are especially notable among subsistence farmers before the onset of and during the rainy season. In Anglophone Africa this period is generally referred to as the "hungry season"; in Francophone Africa it is the "soudure." It is a time of general scarcity, when the previous year's harvest has been depleted and the current year's crops must be planted. The phenomenon of high labor output at a time when energy supplies are low causes significant seasonal losses in body weight,

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[9] Guido Gryseels and Frank M. Anderson, Research on Farm and Livestock Productivity in the Central Ethiopian Highlands: Initial Results, 1977-1981, Research Report 6 (Addis Ababa: International Livestock Centre for Africa, 1983).

which are particularly deleterious to the health of pregnant and lactating women.

A similar process is evident in pastoral systems during the dry season, when milk production decreases because of inadequate fodder for animals and a greater output of labor is required to find water and pastures for them. Such seasonality in the production of milk has a strong influence on management practices and stocking rates, for consumption needs during the dry season dictate the keeping of a large number of cows. Herds in African pastoral systems are typically 70 percent female.[10]

The seasonal nature of the production and consumption of milk is revealed in a study by White and Meadows of the Maasai in Kenya.[11] Their data showed a high level of dependence on purchased cereals during the dry season, when milk production decreased. The largest quantities of cereals were purchased at the end of the dry season, when the prices were at their highest but when cereals were most needed to supplement subsistence milk supplies. Purchase of cereals gradually decreased as the rainy season advanced. Among the higher-income groups cereals were bought regularly throughout the year, suggesting a change in diet and a preference for maize. Despite the inclusion of maize in the diet, milk remained the principal source of energy, ranging through the year from a high of 72 percent to a low of 51 percent. Meat constituted an average of only about 6 percent of total calorie intake. The increase in purchases of maize was dependent on a larger sale of livestock, and those with fewer livestock to sell were able to buy fewer cereals, suggesting that poor pastoralists may suffer disproportionately during the dry season.

In an ILCA study in Kenya other variables related to nutritional status were identified.[12] Protein-energy malnutrition proved to be the most prevalent form of malnutrition in Kenyan children.[13] Two groups of Maasai under different environmental conditions were studied in order to examine the factors that affect malnutrition among Maasai women and children.[14] Preliminary findings indicated that more children in the harsher environment were undernourished. In this area rainfall is more precarious both in quantity and in distribution.

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[10] International Livestock Centre for Africa, The First Five Years (Addis Ababa: ILCA, 1980).

[11] J. M. White and S. J. Meadows, "Evaluation of the Contribution of Group and Individual Ranches in Kajiado District, Kenya, to Economic Development and Pastoral Production Strategies," Ministry of Livestock Development, Nairobi, Kenya, 1981 (mimeographed).

[12] P. Nestel, Some Preliminary Findings of Factors Related to the Nutritional Status of Maasai Women and Children, Documents prepared for the Programme Committee (Nairobi, Kenya: International Livestock Centre for Africa, November 1982).

[13] Central Bureau of Statistics, Report of Child Nutrition Survey, 1978/79 (Nairobi: Government of Kenya, 1979).

[14] Nestel, Some Preliminary Findings.

Grazing conditions are therefore poorer, and cattle consequently provide less milk. Poor pastoralists were noted to be less well nourished than richer ones. Children did not grow as well in the dry season as in the wet season.

Age-group responsibilities and nutritional status were found to be related: the young children who stayed around the home were nutritionally better off than the older ones who went herding.

The consumption of maize meal increased as the dry season progressed and milk yields became low. Milk available for human consumption differed according to wealth, because of both the structure and the size of the herds.

A difference was observed in the food made with the maize meal by different income groups; the poorer households concentrated on porridge and the wealthier ones on ugali, a heavy, doughy preparation generally accompanied by a sauce. Porridge eaten alone was a cheaper substitute for milk than ugali or maize and beans. Purchases of fats and oils also rose as the dry season advanced. Babies were no longer fed ghee but a substitute of purchased fats.

In the ILCA field program for the arid zones in Mali, studies of nutritional status were conducted in two Tuareg camps. One camp raised cattle, for the most part, while the other kept goats. Grain, milk, and meat were the main food items in both camps. Only a few cases of malnutrition were observed in either camp. Women in the richer, cattle-owning camp derived more than half their energy intake from milk alone. Cereals were more important in the goat-owning camp. In the cattle-owning camp, no grain was consumed during July and August, the onset of the rainy season. This decrease in the consumption of grain was attributed to high prices, the inability of cattle owners to sell stock in poor condition, and the long distance from seasonal grazing areas to urban markets.

These studies exemplify some of the ways in which nutritional studies are related to livestock development. The seasonal nature of milk supply and the need for supplementation with grains, the prices of which also fluctuate with seasonal availability, highlight the linkage between the livestock and cropping sectors.

Technology Characteristics and Production Systems

At the outset of its research activities, ILCA assumed that there would be a direct positive link between increases in livestock and crop productivity and human nutrition, both because of greater direct consumption and because of the income effect. The latter would be accelerated because of the high income elasticity of demand for livestock products, a premise that needs to be investigated further. Though Reutlinger and Selowsky have shown that calorie consumption increases with rising income in Africa, other researchers have questioned the reduction of malnutrition in the normal course of social and economic development in market economies.[15]

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[15] Shlomo Reutlinger and Marcelo Selowsky, Malnutrition and Poverty: Magnitude and Policy Options (Baltimore: Johns Hopkins University

ILCA has focused its studies so far on the effects of new technologies on livestock and farm productivity and incomes. Insufficient time has passed, however, for much to have been learned from study of the effects on food consumption and nutrition of most of the improved technologies under test.

ILCA has adopted the farming-systems approach to research, emphasizing on-farm testing and appraisal of technology supported by relevant station research on components whenever greater experimental control is advantageous.[16] As indicated earlier, baseline studies have been made in each of the ILCA study areas before component research has been initiated. Systems studies describing the local traditional farming systems are being published for each of the ecological zones in which ILCA is active. These studies have helped to identify constraints on the system and have suggested commodity priorities and lines of intervention. Research results and their nutritional implications will be summarized below.

In the Ethiopian highlands average milk yields of indigenous cows are 400 liters a year. Climatic conditions suggest that there is significant potential for increasing dairy production. Grazing resources are limited in the dry season, and the genetic potential of local cows for milk production is considered poor. The identification of these two constraints led to the introduction of crossbred cows and the incorporation of a forage component into the cropping system. Crop yields were increased simultaneously through fertilizer and improved seeds and management practices. Farmers testing this technology package achieved annual yields per cow of 2,000 liters and increases of U.S. $200 to $600 in net cash incomes. Crop yields rose 40 percent. Farmers benefited from both increased sales of milk and greater household consumption. Data on household expenditure and consumption are now being collected in order to obtain a better quantification of nutritional effects.

An innovation that is likely to have a direct positive effect on low-income families in the Ethiopian highlands is the use of the single ox. The primary contribution of cattle to agricultural production there is as draft animals. It is customary for oxen to plough the land in pairs, but about 30 percent of the farmers have one ox and 20 percent have none.[17] Consequently many farmers must hire, borrow, or share oxen, which means late or inadequate cultivation of their land. Perceiving these as serious impediments to any increase in food production, ILCA modified the traditional plow making it possible for

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Press for the World Bank, 1976); Carl K. Eicher and Doyle C. Baker, Research on Agricultural Development in Sub-Saharan Africa: A Critical Survey, International Development Paper 1 (East Lansing: Michigan State University, 1982).

[16] Guido Gryseels, "Livestock in Farming Systems Research for Smallholder Agriculture: Experiences of ILCA's Highlands Programme," paper presented at the Seminar on Agricultural Research in Rwanda, Kigali, Rwanda, February 5-12, 1983.

[17] Gryseels, "On-Farm Animal Traction Research."

it to be pulled by a single ox. Poor farmers are thus assured of a more timely plowing and more intensive cultivation of their own lands. The results should be greater crop yields both for consumption on the farm and for sale to obtain additional income.

Though the use of a single ox may be especially attractive now to low-income farmers, it will become important to a much larger share of the population as the pressure on land resources increases. The population of Ethiopia is growing rapidly, the size of the average farm is decreasing, and the number of draft animals that can be kept for agriculture will become inadequate. It will be possible to apply this power-saving technology in other countries in which land resources per farmer are diminishing.

Alternative uses of animal power are being explored in the Ethiopian highlands. These include the use of oxen to draw metal scoops in excavation for ponds and for the construction of dams. The ponds and dams can significantly improve the water supply. In Ethiopia only 6 percent of the population has access to safe water for drinking.[18] The synergistic relation between disease, often carried by contaminated water, and malnutrition has been well documented.[19] Improvement in the water supply is one of the many factors involved in decreasing malnutrition. The water made available from these ponds and dams by means of low-cost technology can then be used for direct consumption by human beings and livestock and for irrigation and dry-season crop production.

In its humid-zone program in southern Nigeria, ILCA decided to concentrate its efforts toward a decrease in the prevalence of "peste des petits ruminants," which was identified as the principal constraint on production in the area. Dwarf, trypanotolerant sheep and goats are the main livestock used for home consumption and for generation of income, but mortality rates are high. ILCA has developed and tested a veterinary package consisting of a tissue-culture rinderpest vaccine and a dipping program to check mange. As a result kid survival has greatly increased, the reproductive efficiency of does has improved, and mortality has declined significantly.

In the semiarid zone of Mali, millet is the staple cereal of sedentary agropastoralists and increasing grain production is seen as the first step in improving both the nutrition and the wealth of the agropastoralists. Expansion of cropping depends largely on the availability of work oxen and their efficiency. If they are to plow efficiently, they must be better fed, particularly through the long dry season that precedes their peak working period. Increasing supplies of animal feed is therefore a primary factor in increasing the production of grain. ILCA has demonstrated that the intercropping of forage legumes with millet can increase dry-season fodder for livestock without decreasing millet yields. Other positive benefits are realized in increased production of milk and meat and a decrease in the prevailing seasonality of food availability.

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[18] World Bank, Accelerated Development in Sub-Saharan Africa.

[19] Robert J. Saunders and Jeremy J. Warford, Village Water Supply: Economics and Policy in the Developing World (Baltimore: Johns Hopkins University Press for the World Bank, 1976).

ILCA is thus involved in a diverse set of activities directed toward increasing the productivity of the livestock sector in the belief that greater productivity of land and labor will promote a better standard of living among the rural poor.

Other Activities and Information Needed for Incorporation of Nutritional Considerations into ILCA Research

Several caveats must be observed in assessing the effects of income on human nutrition. Increased income may be used for nonfood items or for food items of low nutritional value. Intrafamily patterns of food distribution may mean that an increasing amount will go to nonvulnerable members of the household, while increases in income may be seasonal and may not come when need is greatest.

The position of women has been identified as an especially strong linkage in the nutritional status of households.[20] Without explicitly identifying their position in the farming systems and monitoring the effects of technology on them, it can be observed that negative effects may undermine what is already in many instances a precarious position. Less is known about women in pastoral systems than about women in other agricultural systems, and the effects of technological interventions on women in such societies have been less well documented.[21] In several livestock production systems, women milk the cows and are the owners of that milk, the sale of which is often their only source of income. There is some evidence that women use a greater portion of their income to buy food than do men.[22] A greater emphasis on beef breeding at the expense of milk production, for example, could ad-versely affect the incomes of women and thus the nutritional status of the household. It cannot be assumed, as it often is, that increasing the income of male heads of households will automatically produce increases in the available food supply. Men may choose to spend their incomes on nonfood items.

The effect of yield-increasing technologies on women's labor must also be considered as it is related to nutrition. It has been noted that during times of high labor output in the cropping season, women have less time to prepare food, so diets may suffer, not only from the

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[20] Per Pinstrup-Andersen, "Incorporating Nutritional Goals into the Design of International Agricultural Research," paper presented at the meeting of the directors of the international agricultural research centers, Washington, D.C., November 5, 1982.

[21] Michael Horowitz, "Research Priorities in Pastoral Studies: An Agenda for the 1980's," in The Future of Pastoral Peoples, ed. John G. Galaty, Don Aronson, Philip Carl Salzman, and Amy Chouinard (Ottawa, Canada: IDRC, 1981); Vigdis Broch-Due, Elsie Garfield, and Patti Langton, "Women and Pastoral Development: Some Research Priorities for the Social Sciences," in Galaty, Aronson, Salzman, and Chouinard, eds., The Future of Pastoral Peoples.

[22] Hoda Badran, Women of the Third World: Some Thoughts on Improving Their Situation (Paris: UNESCO, 1982).

lack of food but also from the lack of time to prepare it. The introduction of technologies into livestock systems that increase the labor of women may reduce the amount of time available for food preparation.

Farmers in the highlands of Ethiopia have been encouraged to adopt crossbred cows for smallholder dairying. Because these animals are stall-fed, however, women spend more time caring for them. Another aspect of this intervention is that women have customarily used milk from local cows to make butter and cheese, which they then sell in the market. The larger amount of milk obtained from crossbred cows makes it feasible to sell to the fluid milk market. The sale of milk and the resultant acquisition of income then reverts to men, who generally market fluid milk. Women are thereby deprived of an important source of income. Though a negative effect on nutrition does not necessarily follow, a careful monitoring of such changes in household economics is appropriate.

SUMMARY

Livestock are multipurpose commodities; besides providing milk, meat, and hides or skins, they are also used as draft animals, provide fuel and fertilizer, and offer security for African farmers and pastoralists. The nutritional effect of research on livestock production must therefore be measured not only for its direct contribution of livestock products to the diet but also indirectly in the form of greater productivity of land and labor and consequently greater production and incomes.

ILCA has attained positive research results that may lead to increases in food production and higher incomes in many areas of Africa. Insufficient time has passed for a thorough investigation of the nutritional effects of the interventions on the target populations. The following lines of research are felt to be particularly relevant to the improvement of nutritional status of the malnourished.

The available evidence indicates that the poor place a greater reliance on small ruminants, even in production systems in which cattle are dominant. Partly in response to this consideration ILCA has set up a pan-African network for research on small ruminants in addition to work on sheep and goats undertaken by the central research units, which concentrate on activities that are relevant to more than one ecological zone.

Nutritional status is a composite of the food intake and health of the individual. The nonconventional use of livestock by ILCA to improve water supply is another illustration of the indirect effect on nutrition of research on livestock production.

Africa is in the most critical position of all the continents in its food deficits, and advances in food production are urgently needed. Through its continuing research on increasing the productivity of livestock for milk and meat, reducing the seasonality of the food supply, making better use of draft animals, expanding the productivity of crops in agropastoral systems, and increasing farm incomes, ILCA will do much toward alleviation of malnutrition in one of the poorest parts of the world.

13
ILRAD's Research Program — Its Relevance to Improved Human Nutrition

J. J. Doyle

The International Laboratory for Research on Animal Diseases (ILRAD) was established in 1973 by a memorandum of agreement signed by the government of Kenya and the Rockefeller Foundation acting as executive agent for the CGIAR. Construction of the ILRAD center in Nairobi began in 1976 and was completed in 1978.

The mandate of the Laboratory is as follows:

> The purpose of the Laboratory will be to serve as a world centre for research on ways and means of conquering, as quickly as possible, major animal diseases which seriously limit livestock industries in Africa and in many other parts of the world. The Laboratory will concentrate initially on intensive research concerning the immunological and related aspects of controlling Trypanosomiasis and Theileriosis (mainly East Coast fever). It may, however, eventually extend its research to other serious animal disease problems for which its facilities and expertise are appropriate, provided such extension is approved by its Board of Directors and the Government of Kenya does not object from a disease safety standpoint. In carrying forward its programme, the Laboratory will develop close linkages with governmental and regional organizations undertaking research on the same or related disease problems.

COMMODITY PRIORITIES

In a broad sense the mandate establishes domestic livestock as the commodity priorities of ILRAD, and domestic ruminants are initially its primary concern since these are the species affected by the target diseases, theileriosis and trypanosomiasis.

Domestic livestock are of fundamental importance in agriculture throughout the world. In Africa and other developing regions, most people depend directly on agriculture for their income and their food supply. Not only do domestic livestock produce high-quality protein to supplement the staples of moderate quality in the human diet, but they do so by using, primarily, cellulose materials that are not directly usable as food by man. The potential value of a milk cow in

a small farming system is great. A small maize farm of two hectares provides man with 23,500 megacalories of energy and 246 kilograms of protein from the grain alone. If the grain from one hectare is consumed and the grain and residue from the second hectare are fed to a cow, there is a loss of 8.4 percent in total energy provided as human food but an increase of 165 percent in total available protein. A total of 530 kilograms of protein comes from milk, a better balanced protein than maize grain itself.[1]

Livestock are also important in other forms of agriculture. They provide power for traction; their manure serves as fertilizer, as a solid fuel, and as a potential source of biogas; and the animals themselves serve as a means of generating capital, as insurance against risk, and as a convenient mode of exchange.

Throughout the world animal products contribute protein of high biological value equivalent to more than 50 percent of the protein produced from all cereals. FAO has estimated that by 1990 the demand for animal products in developing countries will have doubled from 1976 levels. While these countries possess approximately 60 percent of the world livestock population, they produce only 20 percent of world livestock products. Approximately 65 percent of the land available in the world is not suited directly to farming or human occupancy; and production of livestock is one means of exploiting this resource, complementing agricultural development of the more productive areas.

Food production is critical in Africa, where there are 400 million people, high rates of population growth, and a shrinking agricultural sector. African farmers and herdsmen keep an estimated 160 million cattle and 286 million sheep and goats, but their productivity is low. Thirteen percent of the cattle in the world are raised in Africa, but these produce only 5 percent of the world's beef.

CHANGES IN COMMODITY CHARACTERISTICS

There are several factors contributing to the low levels of animal production in Africa and other developing regions. These include poor animal nutrition, the limited production potential of many local breeds, inadequate marketing outlets, and management systems that are not geared toward maximum production.

Disease is an important constraint on animal production in Africa and throughout the developing world; in many areas it is the primary constraint. An estimated 50 million cattle and buffalo and 100 million sheep and goats die from disease each year, but mortality figures alone do not reflect the full effects of these diseases. While many animals become diseased but eventually recover, the expense of treating them and the losses in growth and productivity add enormously to the total cost of livestock disease.

Measures have been developed that are effective in controlling many of the most deadly bacterial and viral diseases that affect

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[1] R. E. McDowell, Animal Production in World Food Supplies, Cornell International Agriculture Mimeograph 45 (Ithaca, N.Y.: Cornell University Department of Animal Science, 1974).

livestock. For many parasitic diseases, however, safe, effective, and inexpensive control measures have not yet been developed. Among these diseases, theileriosis and trypanosomiasis are particularly important. In Africa alone theileriosis and trypanosomiasis are believed to be responsible for the deaths of 3 million head of cattle a year; they inhibit the use of cattle; and in the case of trypanosomiasis, they even inhibit human settlement of 7 million square kilometers of land that could probably support an additional 120 million head of cattle or equivalent numbers of small ruminants.

In view of the magnitude of these problems, any change that can be made in the ability of domestic livestock to withstand the deleterious effects of these diseases would significantly increase productivity, not only of meat and milk, but also of agriculture in general, by making available more tractive power, manure, capital, and so on.

CHARACTERISTICS OF THE DESIRED TECHNOLOGY

Prevention and control of any infectious animal disease can be approached in a number of different ways. These include efforts to break the pattern of transmission of the disease. In the area in which theileriosis and trypanosomiasis are prevalent, the efforts include vector control, development of measures such as chemotherapy to eliminate the causative agent, and steps to increase the level of innate or acquired immunity in the animals at risk. Research at ILRAD is not directly concerned with vector control but is concerned with the development of vaccines, the improved use of chemotherapy, and the exploitation of genetic traits of resistance to disease that are present in certain breeds of domestic livestock. The ultimate objective is, of course, to provide better measures for control of theileriosis and trypanosomiasis that will be economically effective and will bring about a substantial increase in agricultural productivity.

The results of research so far indicate that effective immunization measures against Theileria can be put in place today to protect particularly valuable livestock and that better, more widely applicable vaccines are likely to be available within the next decade. Significant improvements in the productivity of areas affected by trypanosomiasis can also be expected in the foreseeable future. On the basis of research findings at ILRAD, this would be achieved by means of greater exploitation of trypanotolerant livestock, improved use of chemotherapeutic and chemoprophylactic agents, and integrated vector control programs. The feasibility of using embryo-transfer technology to facilitate the increased use of trypanotolerant livestock has also now been demonstrated for the first time by ILRAD.

CHOICE OF PRODUCTION SYSTEMS

Because theileriosis and trypanosomiasis impose a severe constraint on the production of livestock throughout a large range of ecological zones and management systems, ILRAD must develop measures for control of these diseases that will have the widest possible applicability and will be usable by the small farmers, who own more than 90 percent of the domestic ruminants in Africa.

It should be realized, however, that certain control measures may not be practicable in certain types of production systems. The present means of immunization against theileriosis, for example, requires a cold chain and careful supervision following immunization. This is a practical means of vaccination of expensive animals that are highly productive of both milk and meat and are owned by a sedentary population. It is not easily applied to livestock owned by nomadic pastoralists. Improvement in production of beef in tsetse-infested areas by the use of the breeds of trypanotolerant livestock that are now available may also be feasible, but production of milk for human consumption may not be greatly increased. Whether chemotherapy can be used to increase milk production may depend on whether significant amounts of drug residues are present in milk as a result.

ILRAD is therefore aware of the potential problems in identifying and developing measures suitable for control of theileriosis and trypanosomiasis under varying ecological and management systems. ILRAD itself, however, has neither the mandate nor the infrastructure to carry out farming-systems research in these different situations to determine the most effective means of controlling theileriosis or trypanosomiasis or to determine the economic effects on an integrated land-use policy for optimizing agricultural productivity in general. ILRAD will collaborate with any other center or national or international program that is concerned with agricultural productivity and hence with human nutrition where theileriosis or trypanosomiasis is a problem in the livestock sector. The collaboration between ILCA and ILRAD in the trypanotolerance network is a good example of effective collaboration. This project has also laid the basis for a large program on the improvement of the use of trypanotolerant cattle in Africa developed in collaborative efforts of the government of the Gambia, the African Development Bank, the European Community, Overseas Development Administration, ILCA, and ILRAD.

CONCLUSION

The function of ILRAD in improving human nutrition is defined by its mandate as improvement through control of serious diseases of domestic livestock. No particular production system of domestic animals has been selected for study. ILRAD has chosen, however, because of their importance, to focus its efforts on both milk cattle and meat-producing breeds. It also has an interest in small ruminants, such as goats and sheep, in areas in which trypanosomiasis is a problem. It is worth remembering that domestic ruminants are significant in agricultural systems in general; besides providing meat and milk, they also provide tractive power, fertilizer, and fuel and generate capital, all of which are important to the improvement of tropical agriculture in the less developed countries.

14
Contributions of Modern Rice Varieties to Nutrition in Asia — An IRRI Perspective

J. C. Flinn and L. J. Unnevehr

The International Rice Research Institute (IRRI) has global responsibility for rice within the network of the CGIAR. Its main focus is on Asia, where more than 90 percent of the world's rice is produced and consumed. IITA and WARDA accept similar joint regional responsibility for rice in Sub-Saharan, Central, and West Africa, while CIAT is primarily responsible for research on rice in Latin America. These CGIAR-sponsored centers also collaborate with other research agencies including the Institut de recherches agronomiques tropicales et des cultures vivrières (IRAT), implementing agencies such as FAO, donors such as IDRC, UNDP, and USAID, and the private foundations in support of international and national rice research.

The research and training done by IRRI are conducted in partnership with national rice programs. Thus the contribution of the Institute to rice production and human nutrition cannot be isolated from the achievements of national rice programs. The greatest effect of collaborative research by IRRI on either production or consumption of rice has been in Asia (Table 14.1). Modern rice varieties covered some 30 million hectares in 10 rice-growing countries of South and Southeast Asia by 1980 and now provide more than 37 percent of all the rice grown in those countries.

ASIAN DIETS AND RICE CONSUMPTION

Income and Nutrition

Food production per capita has generally increased in Asia during the past 10 years except in Bangladesh, India, Kampuchea, and Nepal; and in the aggregate it has grown faster there than in other regions of the developing world.[1] Trends in per capita calorie and protein supplies calculated by FAO for Asian countries are similar. An impression of the current nutritional status of Asian populations is gained by comparing estimates of consumption with calorie and protein

[1] Asian Development Bank, Key Indicators of Developing Member Countries of ADB 14 (1983): 1-13.

Table 14.1--Estimated population and rice hectarage in countries of the world where rice is the major food, 1980

Country	Population	Rice Consumers	Rice Hectarage: Total	Rice Hectarage: Percent of World Total	Rice Hectarage: Percent of Modern Rice Varieties
	(millions)		(thousand hectares)		
China, People's Republic of	956	600	34,400	23.9	66
India	660	416	39,794	27.9	37
Indonesia	147	118	8,917	6.2	55
Japan	116	81	2,474	1.7	98
Bangladesh	90	81	10,233	7.1	16
Pakistan	80	24	1,991	1.4	47
Vietnam	50	45	5,407	3.7	20
Philippines	49	38	3,521	2.4	70
Thailand	48	38	9,449	6.6	10
Korea, Republic of	38	36	1,232	0.9	32
Burma	35	32	4,751	3.3	40
Taiwan	17	12	704	0.5	100
Sri Lanka	15	14	785	0.5	56
Nepal	15	9	1,257	0.9	26
Malaysia (Peninsular)	13	10	680	0.5	44
Korea, Democratic People's Republic of	15	14	773	0.5	-
Africa[a]	70	35	5,229	3.6	-
Latin America[b]	137	69	8,228	5.7	-
Total[c]	2,572	1,688	144,164	100.0	-

Source: A. C. Palacpac, World Rice Statistics (Los Baños: International Rice Research Institute, 1982).

[a] Egypt, Malagasy, Sierra Leone, Gambia, Guinea, Ivory Coast, Liberia, Senegal, and Mauritius have an average annual consumption of 50 kilograms per hectare per person. It is assumed that 50 percent of the people are rice eaters.

[b] This includes Brazil, Costa Rica, Panama, Cuba, the Dominican Republic, Guyana, and Suriname. It is assumed that 50 percent of the people are rice eaters.

[c] Includes Kampuchea, Lao People's Democratic Republic, Hong Kong, Singapore, Bhutan, Portuguese Timor, and Macao in addition to the above.

requirements recommended by FAO and WHO. Calorie deficiencies on the average appear to be most pronounced in Bangladesh, India, Kampuchea, Laos, Nepal, and Vietnam. Average dietary figures are deceptive because they mask the extent of poverty-induced malnutrition. Proportionally, poverty--defined by FAO as occurring when basic needs are scarcely met at the minimum level required for survival--is probably most extensive in Bangladesh, India, Indonesia, and Nepal, but in absolute numbers the greatest poverty is in India.

As incomes rise in low-income countries, so does per capita consumption of calories and protein (Table 14.2). Reutlinger and Alderman combined this relation with data on the distribution of income to estimate the proportions of the populations of developing countries whose calorie intake fell below FAO/WHO recommendations.[2] They estimated that the calorie intake of more than 600 million Asians was inadequate in the early 1970s. If food production were to increase fast enough to ensure that prices would remain constant through 1990, the proportion of the population whose diets were inadequate would decline, but the absolute number would still increase more than 100 million. If food prices increased by as little as 1 percent a year, the number of people in Asia whose diets were inadequate would increase by an additional 50 million and Asia would continue to be the region with the largest number of malnourished people.

Rice in Asian Diets

Patterns of consumption of cereal grain differ throughout Asia, but rice and wheat dominate. Rice is the most important source of food in the major river deltas--the Ganges-Brahmaputra in Bangladesh, the Irrawady in Burma, the Chao Phraya in Thailand, and the Mekong in Laos, Kampuchea, and Vietnam--and in Nepal, where nearly 90 percent of dietary calories are derived from rice. It is also the dominant food of millions of rice-dependent peoples in India and China. Countries in South Asia--Pakistan, India, and Nepal--produce rice and wheat, often in rotation, although Pakistan, the second largest exporter of rice in Asia, is the one country in which, in aggregate, consumption of wheat is more important than rice. The countries of insular Asia produce little wheat, rice forming 40-60 percent of their dietary intake of energy. Where rice is the dominant source of calories, it is also the dominant source of protein. More than half the dietary intake of protein in Bangladesh, Burma, Indonesia, Kampuchea, Laos, Thailand, and Vietnam comes from rice. Rice protein, however, lacks some of the essential amino acids. Diversity in the composition of the diet is clearly necessary to ensure a nutritionally balanced diet.

The contribution of rice to dietary intake of calories and protein in Burma, China, Indonesia, Nepal, and Pakistan increased more than 1 percent a year during the period 1963-75. The relative importance of rice has declined, however, in India, Japan, and Sri Lanka. Wheat, supplied either by growth in national production, as in

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[2] Shlomo Reutlinger and Harold Alderman, "The Prevalence of Calorie-Deficient Diets in Developing Countries," World Development 8 (May/June 1980): 399-411.

Table 14.2--Per capita daily consumption of calories and proteins for households of different income levels in Indonesia, India, Philippines, and Sri Lanka

Area	Income Group					
	All	1st (Lowest)	2nd	3rd	4th	5th (Highest)
	(calories)					
Java, Indonesia, 1963/64	1,600	1,072	1,347	1,572	1,868	1,809
Maharashtra, India, 1958	2,100	1,120	1,560	1,850	2,315	2,935
Sri Lanka, 1969/70	2,264	2,064	2,272	2,474	2,540	2,641
India, rural, 1960	2,028	1,557	1,805	1,945	2,933	-
India, urban, 1960	2,028	1,094	1,214	1,421	1,324	-
Philippines, rural, 1978	1,769	1,660	1,830	1,976	1,966	2,194
Philippines, urban, 1978	1,872	1,576	1,711	1,909	2,015	2,228
	(total grams of protein)					
Java, Indonesia	29.4	17.7	23.0	28.9	35.6	37.0
Maharashtra, India	59.7	30.7	45.0	52.8	63.3	78.7
Sri Lanka	53.8	47.4	54.0	59.7	62.2	66.0
India, rural	52.4	38.7	47.3	52.8	83.5	-
India, urban	52.4	33.6	34.3	40.0	35.9	-
Philippines, rural	50.3	46.4	51.7	54.7	59.8	93.4
Philippines, urban	58.2	45.6	52.5	63.5	72.4	-

Sources: Randolph Barker and R. W. Herdt, Asian Rice Economy (Baltimore: Johns Hopkins University Press, forthcoming). Philippine data are from the First Nationwide Nutrition Survey, 1978.

Notes: Income groups for each country are as follows: Java, Indonesia: households with per capita monthly expenditure of below 6,000; 6-10,000; 10-16,000; 16-30,000; and more than 30,000 rupiahs. Maharashtra, India: households having 0-8, 8-11, 11-13, 13-24, and 24 and more rupees expenditure per capita per month. Sri Lanka: households with monthly expenditures of 0-200, 200-399, 400-799, 800-999, and more than 1,000 rupees. India, rural and urban: households with monthly per capita expenditures of 0-20, 21-35, 36-80, and more than 80 rupees. Philippines: households with monthly per capita expenditures of 0-499; 500-999; 1,000-1,499; 1,500-1,999; and more than 2,000 pesos.

Bangladesh and India, or by increased imports, as in Bangladesh, Japan, and Sri Lanka, has been substituted for it.

The Importance of Rice in Providing Better Nutrition

The aggregate nutrition problem in Asia is lack of calories, and making more rice available can meet energy needs and also contribute substantially to dietary intake of protein. Malnutrition is not just a problem of the availability of food, however. It is also a problem of the distribution of income. Since production of rice is a principal source of income in rural Asia, greater productivity of inputs can reduce malnutrition by increasing the incomes of the rural poor. Thus increased yields improve nutrition in two ways: they make more food available and they increase the incomes of the producers.

IRRI RESEARCH, BY TYPE OF RICE CULTURE

A concern of the multiple-commodity IARCs is that of allocation of resources among the range of crops included in their mandates. Priority among commodities is not an issue at IRRI because its mandate is explicitly on rice, although, as will be discussed later, IRRI does collaborate actively with other research institutes in the development of improved varieties of and management systems for crops other than rice that are grown in rice-based farming systems. What does concern the Institute is the distribution of its research activities among the various types of rice culture--irrigated, rainfed wetland, deep-water, and dryland.

Three broad sets of factors are considered in the setting of research objectives by IRRI.[3] First, there are considerations of efficiency: the benefits to be expected from investment of research funds in each type of culture. Second, IRRI seeks to order its research in line with its comparative advantage in solving problems that national programs cannot yet or are unwilling to handle. Third, there are equity implications in the sense that IRRI is concerned to develop technology for those regions in which modern varieties have had the least effect. In these less-favored deep-water and dryland areas, people have remained poorer and more malnourished than those in the more favorable rice environments.

More of IRRI's resources are directed toward rainfed and deep-water environments than considerations of efficiency alone would dictate (Table 14.3). Considerations of equity and the comparative lack of progress unquestionably justify the concern to develop rice technology in an effort to reduce the gap between the income and nutrition of communities residing in less favorable environments and others. This has therefore become an important objective of research by IRRI as it enters its third decade.[4]

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[3] International Rice Research Institute, A Plan for IRRI's Third Decade (Los Baños, Philippines: IRRI, 1982).

[4] Ibid.

Table 14.3--Past and projected balance of IRRI senior scientific staff efforts aimed at major rice-growing environments, compared with anticipated economic returns from production increases at each area

Environment	1978-1980 Average Distribution	1984-1985 Projected Distribution	Projected Benefits[a]
		(percent)	
Irrigated	41	37	67
Rainfed wetland	38	42	23
Rainfed dryland	13	13	4
Deep-water and floating	8	8	6
Total	100	100	100

Source: International Rice Research Institute, A Plan for IRRI's Third Decade (Los Baños: IRRI, 1982).

[a] The projections are based on the intention of shifting some activities from irrigated to rainfed rice, as the national programs overcome their own capacities for work on irrigated rice. Provided that some expansion of total staff occurs, the research effort on dryland and deepwater and floating rice will increase, although the relative input remains constant.

ENHANCING NUTRITIONAL CHARACTERISTICS

In nutritional value rice compares favorably with other cereals and is superior to root crops. One hundred grams of brown rice, for example, provide 7.6 grams of protein and 1.8 grams of fat, whereas the same amount of cassava flour gives only 1.1 grams of protein and 0.5 gram of fat and sweet-potato flour gives only 2.2 grams of protein and 0.9 gram of fat. The prevalence of calorie-protein malnutrition in rice-eating Asia therefore reflects low levels of consumption because people are poor, not because of the inherent nutritional composition of rice. Technical change that increases rice yields per hectare therefore directly enhances supplies of calories and protein. It also increases returns to producers, and because supplies are increased, it helps keep rice prices at reasonable, stable levels--a particular advantage for low-income consumers.

BREEDING FOR HIGHER YIELDS PER HECTARE

A principal objective of the crop-improvement program of IRRI is to develop better germ plasm with high total and head-rice yields, which agronomically and in quality are well adapted to the range of physical and market environments in which rice is important. The

objective of high, stable yields has apparent implications for nutrition; milled rice endosperm is about 90 percent carbohydrate, so increasing rice yields per hectare increases supplies of calories.

The potential yield of modern varieties of rice has not changed materially since 1966, when IR8 was released. The high levels of resistance of recent cultivars to disease and insects, however, has allowed farm yields to remain high, with reduced dependence on insect protection and less likelihood of infestation by disease. Second-generation cultivars also mature more quickly thereby allowing in many instances two or three rice crops to be grown where in the past it was possible to grow only one or two. Most IRRI cultivars were bred primarily for irrigated conditions; many perform equally well in shallow, rainfed environments, however. Other varieties such as IR46 and IR52 were selected for rainfed conditions, while those such as IR43 and IR45 were selected for uplands.

In 1978 IRRI established a breeding program for F_1 rice hybrids in close collaboration with Chinese rice scientists. Under commercial farm production in China hybrid rice have shown at least a 16 percent advantage in yield over conventional rice, although the advantage has been somewhat higher under experimental conditions.[5] The general suitability of hybrid rice to South and Southeast Asian farming systems and social and institutional organization has yet to be determined. This innovation provides an opportunity to shift yield potential significantly, however, and where it has been adopted, to shift farm yields and rice supplies, similar to F_1 corn hybrids, which have already been widely introduced.[6]

IRRI scientists located in Thailand participate in an active collaborative deepwater-rice-improvement program.[7] Within the CGIAR network IRRI is also responsible for the coordination of dryland rice-improvement programs among the centers--IRRI, IITA, WARDA, and CIAT--other international agencies, such as IRAT, and national programs such as the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), the Institut des Savannes (IDESSA) in the Ivory Coast, and the Central Rice Research Institute (CRRI) in India. A recent series of workshops has helped define responsibilities and improve coordination in global dryland rice research.[8]

IRRI has not released any varieties since 1975; those with "IR" designations are named and released by the Philippine National Seed

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[5] Guiting He et al., The Economics of Hybrid Rice Production in China, Research Paper Series 102 (Los Baños, Philippines: International Rice Research Institute, 1984).

[6] S. S. Virmani, R. C. Aquino, and G. S. Khush, "Heterosis Breeding in Rice (Oryza sativa L.)," Theory of Applied Genetics 63 (1982): 373-380.

[7] International Rice Research Institute, "Deep-Water Rice," proceedings of a workshop held at Bangkok, Thailand, November 8-10, 1976.

[8] International Rice Research Institute, "Report of the Upland Crops Varietal Improvement Monitoring Tour," Asian Farming Systems Network, Los Baños, Philippines, February 14-21, 1983.

Board. Many IRRI-bred cultivars are released directly by national programs; IR36, for example, was released as PB36 in Indonesia, as NN3A in Vietnam, and as IR36 in India. National rice-improvement programs also select cultivars that are particularly well suited to target environments by segregating materials of IRRI crosses. IRRI fixed lines are widely used as parents in national rice-hybridization programs.[9] By 1980 more than two-thirds of the locally developed rices in Asia had IRRI lines in their percentage.[10]

The international evaluation of cultivars bred by IRRI, other centers and agencies, and national rice improvement programs is facilitated through the International Rice Testing Program (IRTP). More than 80 countries participate in the IRTP, with nurseries designed to cover the range of ecosystems, growth durations, and conditions of environmental and biological stress in which rice is grown.

Breeding for Higher Protein Content

Increasing the protein content of rice should have a marked effect on dietary intake of protein because of the dominance of rice in Asian diets. A breeding program was therefore initiated in 1966 with the objective of increasing the protein content of milled rice by 2 percentage points.[11] More than 26,000 accessions from the world collection of germ plasm have been screened by IRRI for protein content. The brown rice protein content of these samples ranged from 4.3 percent to 18.2 percent; the frequency distribution was positively skewed, most entries having about 8 percent protein in brown rice. A number of these high-protein entries had been crossed with IR8. The lines in which protein levels were higher than in IR8, however, yielded less well or were susceptible to disease and insects. The heritability of high protein also proved to be low when these selections were crossed with a pest-resistant parent.

The range of protein observed in the rice collection did not serve as a sound basis for a program designed to increase protein content: the trait is strongly influenced by environment--that is, by weather and by fertility management;[12] its heritability is extremely

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[9] T. R. Hargrove, Genetic and Sociological Aspects of Rice Breeding in Asia, Research Paper Series 10 (Los Baños, Philippines: IRRI, 1977).

[10] T. R. Hargrove and V. L. Cabanilla, "Sources of Semidwarfism in Locally Developed Varieties," International Rice Research Newsletter 5 (February 1980): 3-4.

[11] B. O. Juliano and H. M. Beachell, "Status of Rice Protein Improvement," in Centro Internacional de Mejoramiento de Maíz y Trigo/Purdue University, High-Quality Protein Maize (Stroudsburg, Pa.: Dowden, Hutchinson and Ross, 1975), pp. 457-469.

[12] K. A. Gomez, "Effect of Environment on Protein and Amylose Content of Rice," in Proceedings of the Workshop on Chemical Aspects of Rice Grain Quality (Los Baños, Philippines: International Rice Research Institute, 1979), pp. 59-68.

low; and after a point there is a trade-off between grain yield and protein content. The result of an assessment of the difficulties and uncertainty of success in breeding for protein content against the urgency of breeding for yield, resistance to pests, and tolerance for environmental stress was that protein became an objective secondary to others.[13]

A specific protein-improvement program no longer exists at IRRI. All entries in replicated yield trials are analyzed for protein content, however, and any with consistently low scores are excluded from consideration for varietal release. Some entries have shown consistently higher protein levels than the 7 to 8 percent modal value generally found in the Philippines. A classical example is IR480-5-9, which is high in protein--more than 11 percent--and equivalent in yield to IR8.[14] This cultivar is frequently used as the standard high-protein rice in feeding experiments with which IRRI is associated. It is highly susceptible to bacterial leaf blight, however, and has not been released as a variety.

As duration of growth decreases, level of rice protein increases. This relation was initially thought to be associated with the lower yields of early-maturing varieties. IRRI's more recently selected short-duration cultivars, however, are equal in yield to those of longer duration but have retained an advantage in protein content. The protein content of IR36, for example, now grown on an estimated 11 million hectares throughout the world,[15] and IR58, which has a similar yield but earlier maturity than IR36, have been found in many tests to have about 1 percent more protein than other varieties.

Increasing Protein Content through Management

Improving fertilizer efficiency is an important collaborative research effort of the International Fertilizer Development Center (IFDC), IRRI, and national rice programs. Research has shown that basal application of slow-release N-fertilizers such as sulfur-coated urea or deep-point placement of urea super granules increases N efficiency by as much as a third above that of urea applied in split doses.[16] These efficient methods of application also increase the protein content of rice as much as 1 percent above that achieved with

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[13] G. S. Khush and B. O. Juliano, Status of Rice Varietal Improvement for Protein Content at IRRI (Los Baños, Philippines: International Rice Research Institute, 1982).

[14] S. K. De Datta, W. N. Obcemea, and R. K. Jana, "Protein Content of Rice Grain as Affected by Nitrogen Fertilizer and Some Traizines and Substituted Urea," Agronomy Journal 64 (1972): 785-788.

[15] International Rice Research Institute, Research Highlights for 1982 (Los Banos, Philippines: IRRI, 1983).

[16] J. C. Calabio and S. K. De Datta, "Increasing Productivity and Protein Content by Using Early-Maturing Rices and Efficient Nitrogen Management," Fertilizer Research (forthcoming).

conventionally applied prilled urea. The protein content is also increased by top-dressing N fertilizer at the heading stage and, because the grain is slightly harder, this also increases milling recovery of head rice (whole grains).[17]

Grain Quality

All IRRI breeding materials are evaluated for milling recovery, for size, shape, and appearance of grains, and for cooking and eating characteristics. Milling recovery is the quantity of milled and head rice produced from a unit of rough rice. Cooking quality is important because it determines palatability which, with grain size, shape, and appearance, determines market acceptability and price.

The maximum milling recovery possible per unit of rough rice is about 70 percent because unmilled rice also contains 20-22 percent hulls and 8-10 percent bran and embryo. Head-rice recovery is an inherited trait, although environmental factors such as temperature and humidity during ripening and postharvest handling influence breakage of the grain during milling.[18]

Cooking and eating characteristics are largely determined by the properties of the starch in the rice kernel. The most important determinant of the texture of cooked rice is its amylose content--that is, the linear starch fraction in the grain.[19] Intermediate-amylose rices cook to a moist, tender state and do not become hard upon cooling. Many traditional varieties of rice grown in Southeast Asia are of this type. High-amylose rices harden after cooling and are less well liked; most IR varieties have this characteristic. Consumers show a distinct preference for low- to intermediate-amylose rices and, in the Philippines at least, the potential returns of breeding for intermediate amylose content seems attractive.[20] Among high-amylose rices those with soft gel consistency and intermediate gelatinization temperature are preferred because they approach the quality of intermediate-amylose rices.

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[17] Wittaya Seetanum and S. K. De Datta, "Grain Yield, Milling Quality, and Seed Variability of Rice as Influenced by Time of Nitrogen Application and Time of Harvest," Agronomy Journal 65 (1973): 390-394.

[18] G. S. Khush, C. M. Paule, and N. M. de la Cruz, "Rice Grain Quality Evaluation and Improvement at IRRI," in Proceedings of the Workshop on Chemical Aspects of Rice Grain Quality (Los Baños, Philippines: International Rice Research Institute, 1979), pp. 21-31.

[19] B. O. Juliano, "The Chemical Basis of Rice Grain Quality," in Proceedings of the Workshop on Chemical Aspects of Rice Grain Quality (Los Baños, Philippines: International Rice Research Institute, 1979).

[20] L. J. Unnevehr et al., Consumer Demand for Grain Quality, Agricultural Economics Paper 83-26 (Los Baños, Philippines: International Rice Research Institute, 1983).

Improving yields and pest resistance will continue to be accorded higher priority than grain-quality factors. However, in the 1980s, improving grain quality is also one of the main goals of the IRRI breeding program for irrigated rices.[21] The low correlations between yield and quality suggest that improvement in quality can probably be realized without reducing the potential yield.

NUTRITIVE EVALUATION OF RICE

An increase in protein content is accompanied by a slight decrease in protein quality. The greater protein content of brown rice means more endosperm protein with a slight drop in lysine, the limiting amino acid in rice proteins. The Cereal Chemistry Department of IRRI has conducted nutrition experiments in cooperation with the Agricultural Research Laboratory in Denmark, the Harvard School of Public Health, Osaka City University, and the Food and Nutrition Research Institute in Manila. The results indicate that the increase in protein content more than compensates for the slight drop in protein quality since usable protein increases with an increase in protein content.[22] Thus protein content is the primary indicator of the nutritional value of milled rice.

Brown rice has more protein, minerals, and lipid, and the lysine content of its protein is greater than that of milled rice.[23] Because of this and of the fact that it contains more vitamins, brown rice has been advocated as more nutritious than milled rice. However, comparison of the protein absorption and retention of brown, undermilled, and milled rice in N-balance studies of children and rats showed no differences.[24] Less of the energy and fat content of brown rice were used than of milled rice.

As a weaning food rice gruel has a low energy density and inadequate protein. IRRI and the Food and Nutrition Research Institute of the National Science and Technology Authority in Manila conducted a nutritional evaluation of rice-based weaning foods. As a result the Nutritional Evaluation Laboratory (NEL) in Manila, financed by USAID, was created. The facilities of the NEL were used in the study of protein requirements of young Filipino children who consumed local rice-based diets. Studies of the effect of starch properties on energy

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[21] G. S. Khush, "Improved Varieties in Retrospect and Prospect," paper presented at a conference on Women in Rice-Farming Systems, held at the International Rice Research Institute, Los Baños, Philippines, September 26-30, 1983.

[22] B. V. Roxas, C. L. Intengan, and B. O. Juliano, "Protein Quality of High-Protein and Low-Protein Milled Rices in Preschool Children," Journal of Nutrition 109 (1979): 832-839.

[23] A. P. Resurreccion, B. O. Juliano, and Yonemi Tanaka, "Nutrient Content and Distribution in Milling Fractions of Rice Grain," Journal of the Science of Food and Agriculture 30 (1979): 475-481.

[24] IRRI, Research Highlights for 1982.

density of gruels indicated that energy density may be improved 14-22 percent by the addition of oil and 20-50 percent by parboiling the rice.

Earlier studies of parboiling indicated that it decreased the thiamine content of brown rice through heat degradation. Parboiling also caused the movement of thiamine into the endosperm, however. Both degree of loss and degree of diffusion are dependent on the severity of heat treatment.[25] Studies of the effect of prolonged parboiling on nutritive value were prompted by the increasing popularity of pressure-parboiled rice in India. Rat-feeding trials indicated that the energy and protein in rices parboiled at varying lengths of time were slightly less digestible than in rice that was not parboiled. But the greater biological value of parboiled rices makes up for the lower digestibility, so net protein absorption is similar whether or not the rice is parboiled.[26] Postharvest losses of parboiled rice, moreover, are lower.

RICE-PRODUCTION SYSTEMS

IRRI develops technology that increases rice production, which is of value to the majority of resource-poor Asian rice farmers and which enables more intensive use of land through multiple cropping of rice and other crops. Production technology, therefore, is designed to be scale neutral if not biased specifically toward the circumstances of small farms. There is strong evidence that resource-based factors such as tenure and farm size are not principal determinants of the adoption of modern varieties by farmers.[27] The suitability of the variety to the environment, which tends to be dictated by water and soil regimes, is instead the principal determinant.

Modern rice varieties have two significant effects in irrigated and favorable rainfed areas. First, they have produced higher yields in the monsoon season than have been realized before. Yield increments in the range of 1.5 to 2.5 tons per hectare are now frequently reported.[28] Second, because they are of shorter duration and are photoperiod insensitive, they have provided the opportunity to plant a second wet-season crop or a dry-season rice crop as well. The principal effect of modern varieties of rice in irrigated and favorable rainfed areas, therefore, is larger supplies of rice rather than greater production of dryland crops that would contribute to greater diversity in the diet. In Iloilo in the Philippines, for example,

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[25] A. B. Padua and B. O. Juliano, "Effect of Parboiling on Thiamin, Protein, and Fat of Rice," Journal of Food Science and Agriculture 25 (1974): 697-701.

[26] IRRI, Research Highlights for 1982.

[27] R. W. Herdt and Celia Capule, Adoption, Spread, and Production Impact of Modern Rice Varieties in Asia (Los Baños, Philippines: International Rice Research Institute, 1983).

[28] Ibid.

the adoption of early-maturing varieties and early-seeding techniques derived from IRRI research now makes it possible for farmers to grow more crops each year on their rainfed and wet-season irrigated land than they could formerly. In Iloilo, cropping intensity increased 72 percent and rice yields 42 percent. The introduction of early-maturing modern varieties and associated technology increased the total income per hectare of crops grown in these villages 140 percent without reducing labor use and with only small increases in variable costs.

The objective of IRRI to develop early-maturing varieties and techniques to allow earlier establishment of crops was intended primarily to facilitate double cropping of rice in rainfed areas. Another advantage has been the opportunity to increase production of dryland crops, notably grain legumes, in rainfed, rice-based farming systems. Probably the most important advantages of increased cropping intensity, however, are the more frequent harvests, the regular supply of food and income, the reduced fluctuations in prices, and the greater employment opportunities that it brings about. In combination these help reduce the incidence of seasonal malnutrition and associated ill health, a common problem in regions where there are only one or two sizable harvests a year.[29]

Increasing cropping intensity frequently contributes to larger supplies of rice. It also makes the total food balance more favorable in Asia when dryland crops, such as grain legumes and other cereals, are also introduced or their productivity is increased. A serious constraint in this regard is the lack of dryland-crop cultivars suited to planting before and after the rice crops. In collaboration with IDRC and the Institute of Plant Breeding in Los Baños, therefore, a varietal-improvement program for dryland crops grown in rice-based systems has now been established.[30] Mung bean, soybean, peanut, corn, and sorghum are the principal crops; the dominant breeding objectives are high and stable yields, early maturity, and tolerance of drought and waterlogging.

IRRI collaborates with other international centers to facilitate increases in the overall productivity of rice-based cropping systems. An IITA scientist based at IRRI, for example, provides liaison for cowpea improvement in Asia--with emphasis on increasing the productivity of cowpea in rice-based farming systems. Another collaborative project between national programs, IRRI, and CIMMYT is designed to increase the productivity of cropping systems that are based on rice and wheat, which are dominant throughout vast areas of South Asia. The introduction of short-duration varieties of rice into these patterns offers substantial possibilities for also introducing and improving the yields of grain legumes such as mung bean, black gram, and chick-pea and of fodder or green manure crops produced within the rice- and wheat-based cropping pattern.

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[29] A. Chowdhury, S. Huffman, L. C. Chen, "Interaction of Agriculture, Dietary Practices and Infection on Seasonal Dimensions of Energy Malnutrition," paper presented at a conference on Seasonal Aspects of Rural Poverty, University of Sussex, Brighton, England, July 3-6, 1978.

[30] IRRI, Research Highlights for 1982.

Cultivars identified from the rice and dryland crop-improvement programs are evaluated for local suitability throughout Asia under the general auspices of the Asian Rice-Based Farming Systems Network. In the 1982-83 cropping year, dryland crops before rice were tested in 47 trials and dryland crops following rice in 152, the more common sequence in rice-dryland crop patterns.

Cropping patterns designed on the basis of nutritional criteria, however, have little chance of being adopted when relative prices demonstrate that other crops or production practices are more profitable from the farmer's point of view. Also, the evidence is mixed whether the increased production of a nutritionally superior crop leads to better nutritional status for the household that produces that crop.

ARTIFICIAL DRYING OF PADDY

Modern varieties of rice make it possible for more farmers to grow more than one rice crop each year. The first crop is generally harvested during the wet season rather than at the beginning of the dry season. The traditional method of sun drying is therefore frequently delayed or becomes impractical because of rain or cloudy weather. Much of this wet-season rice crop is harvested at more than 25 percent moisture, and delays in drying cause some deterioration of the grain.[31] This environment may also be conducive to the growth of fungi such as Aspergelles, which in some crops--peanut, for example--produce mycotoxins which, if digested are reported to lead to liver ailments.

The problem of storing wet paddy led IRRI to develop prototype dryers for use in villages or farmer cooperatives. Conventionally fueled dryers have been built, as dryers heated with local fuels, and drafts have been provided by vortex wind machines.[32] A constraint to the adoption of rice dryers, in the Philippines at least, is the low price margin on high-quality dried grain. It has proved difficult to reduce the cost of artificial drying to the point at which these dryers will be economically attractive to farmers.

BENEFITS FROM NEW TECHNOLOGY

Technical progress as embodied in modern varieties of rice reduces production costs and increases supply. The effect of this change on prices and incomes depends on government policies and

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[31] E. V. Araullo, D. B. de Padua, and M. Graham, Rice Postharvest Technology (Ottawa, Canada: International Development Research Centre, 1976).

[32] L. S. Halos, Y. W. Jeon, and C. W. Bockhop, "Design and Performance of a Multi-Purpose Dryer Using Non-Conventional Energy Sources," paper presented at the 33rd Annual Convention of the Philippine Society of Agricultural Engineers, IRRI, Los Baños, Philippines, April 28-29, 1983.

initial factor-market conditions. In general the increased supply reduces market prices, benefiting consumers who purchase rice at the expense of producers who sell their output. Small farmers who retain much of their production for home consumption also gain because they can produce their food with a lower real expenditure of resources.[33] The greater productivity of the modern varieties also increases returns to factors of production and hence the income of landowners, farmers, and laborers. Their effect on nutrition depends on the size and distribution of the price and income effects and on whether the malnourished tend to be urban consumers or rural laborers. There is little hard evidence on the latter. Following convention we assume that falling prices improve nutrition by making food cheaper for both the urban poor and small farmers. Furthermore, absolute increases in the income of hired labor are also assumed to improve nutrition by increasing the purchasing power of the rural landless.

THE EFFECT OF MODERN VARIETIES ON THE PRODUCTIVITY AND AVAILABILITY OF RICE

In the eight Asian countries that produce 85 percent of the world's rice, the principal way in which production of rice was increased between 1955 and 1965--before the introduction of modern varieties--was by the addition of new land to production. As the potential for expansion declined, the development of high-yielding varieties during the 1970s made possible the intensification of production. Yields per hectare during the past decade have increased through greater use of modern varieties and complementary inputs such as fertilizer and irrigation. The most dramatic increases in yield per hectare occurred in Burma, the Philippines, and Indonesia, where aggressive government programs extended modern rice technology in irrigated and favorable shallow rainfed areas. In the Philippines and Indonesia, the governments also invested heavily in irrigation infrastructure. The lower increase in yield during this period was realized in Thailand, where lack of water control limited the productivity of modern rice technology. The addition of new area continued to contribute to increases in production in Pakistan and Sri Lanka, where dry areas were brought under irrigation, and in Thailand where there is still a frontier of arable land for expansion of cultivation.

Modern varieties have contributed directly to global availability of food. Herdt and Capule estimate that these varieties have contributed 27 million tons--23 percent--or about $4.5 billion annually to the increase in Asian output of rice during the past 15 years.[34] Modern varieties have also contributed indirectly to greater output of rice because varieties responsive to fertilizer increase the profitability of investing in fertilizer and irrigation.

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[33] Yujiro Hayami and R. W. Herdt, "Market Price Effects of New Rice Technology on Income Distribution," in Economic Consequences of the New Rice Technology (Los Baños, Philippines: International Rice Research Institute, 1978), pp. 283-302.

[34] Herdt and Capule, Adoption, Spread, and Production Impact.

Modern varieties have contributed about a quarter or more of the growth in output of rice in most Asian countries; they have contributed less than 8 percent in the deepwater or dryland areas of Bangladesh, Thailand, and Eastern India. Growth in production has been most rapid in those countries in which modern varieties have been adopted most widely. In both Indonesia and the Philippines, growth in production has accelerated since 1976, when IR36, the first short-duration, multiple pest-resistant variety, was introduced.

Growth in production through intensification of land use has caused the amount of available rice per capita to rise in seven of the principal rice-producing countries. In Bangladesh, where modern varieties contributed the least growth in production, production lagged behind population growth. In Indonesia the very rapid increase in availability reflects large imports of rice during the 1970s, but because domestic production also grew rapidly, imports as a percent of total supply declined after 1977. Imports also declined sharply during the 1970s in Sri Lanka, the Philippines, and India because of growth in domestic production.

The amount of rice available grew faster than the total amount of food available in most of the principal rice-producing countries, reflecting greater technological change in production of rice than in production of other crops in insular Asia. In Indonesia, for example, rice contributed 56 percent of the total calories consumed in 1975, up from 49 percent during the early 1960s.

PRICE EFFECTS

Modern varieties have caused the global supply of rice to increase. In real terms world rice prices during the late 1970s were the same as in the 1960s. The price increase of the early 1970s reflected both the bad weather and global shortfalls in grain production and the reduced productivity of early modern varieties caused by susceptibility to pests. The second generation of modern varieties, released during the mid-1970s, have made possible steady growth in production and contributed substantially to the present stable to declining prices. The effect of modern varieties on supplies has been concentrated in the traditional rice-importing countries of Sri Lanka, Indonesia, the Philippines, and--to a lesser extent--India.[35] These countries have made substantial investments in irrigation infrastructure in pursuit of self-sufficiency.

In three importing countries declining real world prices and growth in domestic supply led to declining real domestic prices of rice and declining nominal protection for rice. In the Philippines the ratio of domestic prices to world prices declined to less than 1 as domestic supply grew in the 1970s. Domestic prices in the Philippines in importing years were frequently higher than world

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[35] Ammar Siamwalla and Stephen Haykin, The World Rice Market: Structure, Conduct, and Performance, Research Report 39 (Washington, D.C.: International Food Policy Research Institute, 1983).

prices, because of the difficulty of obtaining funds to import.[36] As domestic supply grew large enough to meet demand at world prices, the government was hesitant to export because of a desire to build up large buffer stocks and because of the low quality of domestic rice by international market standards.[37] Domestic rice prices in the Philippines have thus been below world levels since 1977. In real terms domestic rice prices have declined substantially: from ₱7 per kilogram during the late 1960s to ₱5 per kilogram during the late 1970s.

Indonesian price policy sought to buffer domestic rice prices against world price instability. Oil-export revenues in the 1970s allowed the government to finance large imports of rice--up to 2 million tons a year. As domestic production grew after 1977, the share of imports in domestic consumption began to decline. Domestic rice prices were usually lower than world prices during the 1970s, and real domestic prices have been stable or declining since 1974 (Figure 14.1). Growth in domestic production and declining international prices made it cheaper and easier for Indonesia to reduce domestic rice prices.

In India there was a shift in nominal protection from high domestic prices in relation to world prices during the 1960s to low prices during the 1970s as imports declined from around 500,000 tons to zero. Real rice prices also declined during the late 1970s. Again, growth in domestic production reduced the need for imports and hence the cost of lowering domestic prices.

Consumption by the Poor

What effects have greater availability and a decline in real prices of rice had on consumption by the poor? Unfortunately, little recent data exist to quantify this relation. A number of extensive cross-section household expenditure surveys from India, Indonesia, and the Philippines have been reported. The latest available surveys made in India and the Philippines, however, were conducted during the mid-1970s before the decline in rice prices. In India consumption of rice appeared to fall from the early 1960s to 1973-74 for all income groups. This may be largely a reflection of the high food prices that prevailed at the end of that period (see Figure 14.1). In the Philippines there was no significant increase in per capita consumption of rice by the poor between 1970 and 1976 even though the real price per kilogram fell from ₱0.72 to ₱0.63.[38]

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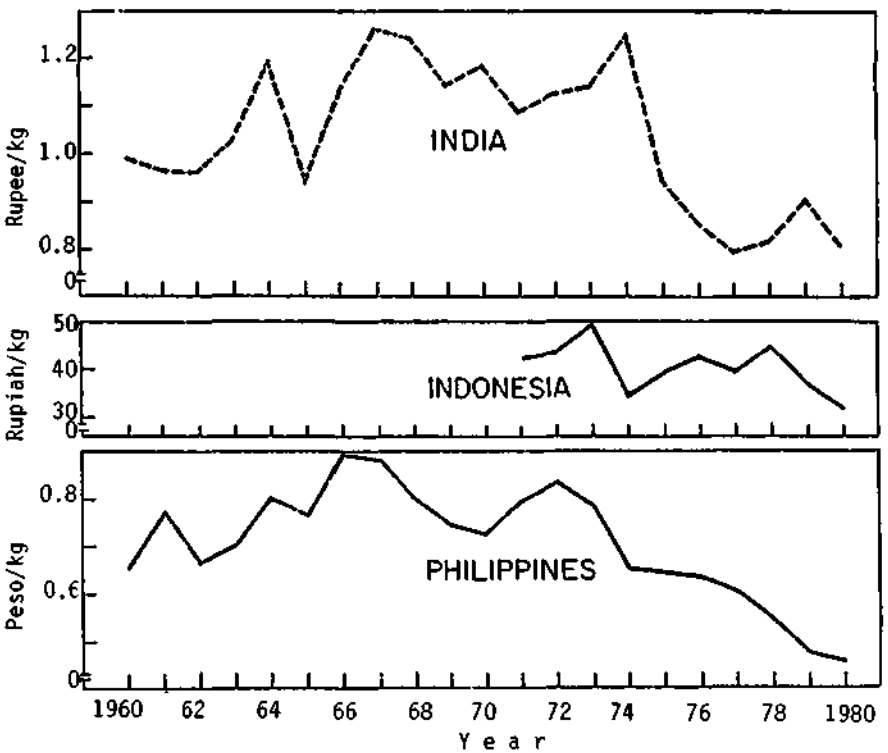
[36] H. E. Bouis, "Rice Policy in the Philippines" (Ph.D. dissertation, Stanford University, 1982).

[37] L. J. Unnevehr, "The Hidden Costs of Philippine Government Intervention in Rice Markets," working paper for the project on Assessment of Food Demand and Supply Prospects and Related Strategies for Developing Member Countries of the Asian Development Bank, International Rice Research Institute, Los Baños, Philippines, 1983.

[38] E. F. Aviguetero et al., "Food Consumption Patterns, Summary of Twelve Economic Surveys," Special Studies Division, Ministry of Agriculture, Diliman, Quezon City, Philippines, 1981(mimeographed).

Figure 14.1--Real domestic wholesale rice prices in India, Indonesia, and the Philippines



Source: A. C. Palacpac, World Rice Statistics (Los Baños: International Rice Research Institute, 1982).

The effect of declining real prices of rice on consumption by the poor during the late 1970s can be inferred from estimates of price elasticity. Income-group-specific price elasticities have been estimated for the Philippines on the basis of 1970-76 survey data and for Indonesia on the basis of 1976 survey data.[39] These estimates imply that consumption of rice by the poor is extremely sensitive to price changes (Table 14.4). In part this is due to the large income effect of price changes on poor households since expenditures for rice constitute a large proportion of total expenditures (Table 14.5).

Table 14.4--Estimated own-price and income elasticities for rice by income group for Indonesia and the Philippines

Income Group	Own-Price Elasticities	Expenditure Elasticities	Percent of Population
Indonesia			
Low	-1.28	0.78	53
Medium	-0.45	0.49	38
High	n.s.	0.16	9
Philippines			
1st (lowest)	-0.73	0.1	32
2nd	-0.69	0.1	31
3rd	-0.68	0.2	26
4th (highest)	-0.43	0.0	11

Sources: For Indonesia the data came from J. A. Dixon, Food Consumption Patterns and Related Demand Parameters in Indonesia: A Review of Available Evidence, Working Paper 6 (Washington, D.C.: International Food Policy Research Institute, 1982); and for the Philippines from Howarth Bouis, "Rice Policy in the Philippines" (Ph.D. dissertation, Stanford University, 1982) and was based on 1970-75 data.

Note: n.s. means not significant, based on 1976 data.

[39] Bouis, "Rice Policy in the Philippines"; John A. Dixon, Food Consumption Patterns and Related Demand Parameters in Indonesia: A Review of Available Evidence, Working Paper 6 (Washington, D.C.: International Food Policy Research Institute, 1982).

Table 14.5--Rice consumption and expenditures on food, by income group, in the Philippines, 1970-76, and Indonesia, 1976

	Indonesia			Philippines		
Income group	Kilogram of Rice/ Capita/ Year	Percent of Population	Budget Share of Rice	Kilogram of Rice/ Capita/ Year	Percent of Population	Budget Share of Rice
1st(lowest)	58.35	15	0.36	91.8	32	0.31
2nd	92.56	23	0.38	100.2	31	0.23
3rd	116.64	33	0.33	100.7	26	0.19
4th(highest)	136.29	28	0.24	105.0	100	0.14
All	113.62	100	0.33	101.9	100	0.23

Sources: Data for Indonesia are from John A. Dixon, Food Consumption Patterns and Related Demand Parameters in Indonesia: A Review of Available Evidence, Working Paper 6 (Washington, D.C.: International Food Policy Research Institute, 1982); and those for the Philippines are from L. A. Gonzales and B. M. Regalado, The Distributional Impact of Food Policies to Nutritional Intakes: A First Approximation for the Philippines (Los Baños: International Rice Research Institute, 1983).

Gonzales and Regalado estimated that a decline of 7-8 percent in the price of rice would allow the lowest income group in the Philippines to satisfy its minimum calorie intake.[40] Between 1975 and 1980 real rice prices declined 20 percent in Indonesia and 30 percent in the Philippines. Other things being equal, this should have caused a 26 percent increase in consumption of rice by the poor in Indonesia and a 21 percent increase in the Philippines (Table 14.6). The

Table 14.6--Price effect on rice consumption by the poor

Category	Indonesia	Philippines
Own-price elasticity	-1.3	-0.7
Average consumption (kg/capita/year)	70	92
Percentage change in real price, 1975-80	-20	-30
Estimated percentage change in consumption	26	21
Estimated total consumption by the poor, 1980 (kg/capita/year)	88	113

Source: Tables 14.4 and 14.5 and Figure 14.1.

[40] L. A. Gonzales and B. M. Regalado, The Distributional Impact of Food Policies to Nutritional Intakes: A First Approximation for the Philippines (Los Baños, Philippines: International Rice Research Institute, 1983).

Indonesian survey data show that these estimates probably overstate the expected changes in consumption. This might be because the poor have received a smaller-than-average share of the growth in income. Pinstrup-Andersen et al. found that shifts in the food-supply curve are less effective in improving nutrition than increased income for the poor because both the rich and the poor increase consumption when prices fall.[41]

INCOME EFFECTS

Although there is some controversy about the link between increased income and better nutrition, the elasticities of expenditure for rice imply that a substantial share of any increase in the income of the poor is used to increase calorie intake.

Herdt and Capule and Barker and Herdt reviewed studies from many Asian countries concerning the distribution of benefits from new rice technology.[42] They found that in most instances low-resource farmers adopted modern varieties as rapidly as did richer farmers and used comparable levels of cash inputs per hectare. Furthermore, labor use (days per hectare) and labor productivity (kilograms per day) increased in most instances after the adoption of modern varieties. They concluded that "most studies show that new rice technology has had rather broad benefits to laborers and farm operators as well as landowners." Technological change in rice has in general been neutral, so benefits from new technology are distributed in proportion to the ownership of resources.[43] The existing distribution of assets will therefore be the greatest determinant of distribution of gains, but the absolute gains for labor can be large.

As an example of the changing benefits from rice production, in Laguna, the Philippines, rice output in the wet season more than doubled between 1977 and 1981 from 2.2 tons of paddy per hectare to 4.6 tons. The share of hired labor remained about the same, but the absolute income of labor more than doubled because both wages and employment increased. The income of farm operators grew faster and at the expense of that of landowners because of the imposition of land reform during this period. These findings from Kikuchi et al. demonstrate that while ownership of assets may determine income

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[41] Per Pinstrup-Andersen, N. Ruiz de Londoño, and Edward Hoover, "The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research Policy," American Journal of Agricultural Economics 58 (May 1976): 131-142.

[42] Herdt and Capule, Adoption, Spread, and Production Impact; Randolph Barker and R. W. Herdt, Rice Economy in Asia (Baltimore: Johns Hopkins University Press, forthcoming).

[43] C. G. Ranade and R. W. Herdt, "Shares of Farm Earnings from Rice Production," in Economic Consequences of the New Rice Technology (Los Baños, Philippines: International Rice Research Institute, 1978), pp. 87-104.

shares, the new technology can greatly increase the absolute incomes of laborers and small operators.

INCORPORATING NUTRITION INTO THE RESEARCH GOALS OF IRRI

The dominant nutritional problem in rice-eating Asia is an inadequate quantity of food, which stems from the linked issues of rice supplies, rice prices, and low consumer purchasing power. The principal goal of research done by IRRI is to increase rice yields and reduce unit production costs for small farmers. Thus the goals and programs of IRRI serve to increase both the quantity of rice available in the market and farm incomes. These objectives, therefore, are generally suited to solve the major nutrition problems caused by poverty and a lack of rice supply.

The main source of income of rural landless populations, however, is wage incomes. IRRI recognizes that its emphasis on production may not necessarily improve the income or nutrition of this disadvantaged group; technologies that maximize yields or farm incomes are not necessarily those that maximize wage incomes. Whether innovations are labor saving or labor using, therefore, and under what sets of relative prices they may be adopted, are considerations that are becoming more important in IRRI's ex ante evaluation of technological options.

15
Incorporating Nutritional Goals into the Design of International Agricultural Research — The Role of ISNAR

International Service for National Agricultural Research

There are significant differences between the mandate of the International Service for National Agricultural Research (ISNAR) and that of all the other institutes supported by the CGIAR. These do not reduce its potential importance as an instrument for furthering the goals of improved nutrition in relation to that of other members of the CG system--indeed they may enhance it--but they do mean that its function and its influence will be different.

ISNAR was not established primarily to undertake research, as were most other CGIAR institutes; it is developing an active program of research on issues related to the planning, organization, and management of agricultural research, however, to assist it in its primary task, which is to help strengthen national agricultural research systems in Third World countries, on request from those countries.

ISNAR concentrates on four activities, all of which are aimed at the central objective: to strengthen national agricultural research. Its main emphasis is on establishment and maintenance of working relations with officials in the governments and the agricultural research systems of developing countries. In collaboration with those officials, ISNAR examines the systems to identify constraints and seek improvements.

ISNAR wishes to maintain a continuing working arrangement with a country, so as to assist the government or the national research system to put into effect the changes the need for which has been mutually determined. To this end, ISNAR may deploy a wide range of activities, such as helping to use the available human, physical, and financial resources more efficiently; identifying suitable training locations and sources of scholarships in order to meet identified needs for education and training; making periodic visits for direct consultation; and carrying out further studies.

ISNAR complements this main thrust with its other programs. It does research on issues in the organization and management of research in national programs and keeps abreast of the work of others to gain a better understanding of important factors in research organization and management, both for the benefit of its own staff and, through publications, for that of national agricultural research systems and others. Through training activities and seminars, it helps research managers improve their professional abilities and stimulates collaboration among persons of like interests in different organizations

and locations. It communicates its own experience and insights and those of others through publications, data, conferences, and the interaction of its staff with others concerned with management of agricultural research.

In performing its functions, ISNAR assists in establishing links between national agricultural research systems and other national, regional, and international agricultural research centers. It also works closely with international, regional, and bilateral agencies and others to promote complementarity of effort so as to maximize the benefits of technical and financial support of national programs.

In many respects these are not too different from the means employed by the other CGIAR centers, but in trying to assess the effect of ISNAR's work--or for that matter its probable future effect--on human nutrition, two important points must be borne in mind. First, it is the newest member of the CG system, having begun work only in 1980, so its programs, methodology, and approaches are still evolving. Second, as an international service to national agricultural research rather than an international agricultural research institute per se, it will exercise its influence mainly through national agricultural research systems, and the range of tasks it may have to undertake will be different from, and probably more diverse than, those of most other institutions in the CGIAR system. The incorporation of nutritional goals into national priorities and programs, and possibly advising on appropriate mechanisms for doing so, may be one task with which countries will seek the help of ISNAR, but this is only one among many aspects of its mandate. In this respect it is strategically situated between national and regional or international research institutions; it can help to keep the latter informed of and sensitive to the views, actions, and needs of the national systems with which it works on matters such as nutrition, at the same time keeping itself informed on issues of international concern and--to the extent that these fall within its purview--increasing awareness of national research planners concerning them.

It is in the light of these considerations that ISNAR's actual and potential contribution to the topic under discussion must be judged. However, because of the differences between its function and that of other IARCs the characterization of its activities within the suggested four categories of commodity priorities, commodity characteristics, technology characteristics, and production systems is not really valid. A more generalized attempt will therefore be made to identify the ways ISNAR might assist in the incorporation of nutritional goals into research planning, although wherever this is relevant to one of those four categories attention will be drawn to it.

PAST, CURRENT, AND PLANNED ACTIVITIES OF ISNAR WITH RELEVANCE TO NUTRITIONAL CONCERNS

Direct Cooperation with National Research Systems

ISNAR may cooperate directly with national agricultural research systems, or with components of them, such as the crop subsector. It may provide broad-based assistance with analysis and determination of possible improvements in all or part of a system, helping as well to

identify sources of funds to support activities that have been decided upon; or it may collaborate with a specific system to try to strengthen one of its functions, such as program planning or development of human resources. More narrowly focused assistance of this type may be the outcome of a specific ISNAR review-and-planning mission, or it may be the result of a felt need of a government to remedy a weakness that has been identified. Sometimes such a problem may have been identified by a donor or by an international agency or institute with which ISNAR may cooperate, together with national staff, to seek corrective action.

No country has yet explicitly asked ISNAR to assist in setting up a nutritional research program or to take nutritional goals into consideration in its advisory capacity, but it is not impossible that ISNAR would be asked to do so in the future. It seems unlikely that assistance in planning a research program on nutrition would be seen as central to ISNAR's mandate, and it would almost certainly have to call on resources beyond its core staff to undertake such a task. These caveats, however, would not preclude an ISNAR review-and-planning mission from diagnosing a need for a country to take nutritional goals into account in its planning or to undertake research related to nutrition--and possibly, if the country requested it, helping to identify an institution with which it could cooperate in such research.

In its function of directly assisting national agricultural research systems, ISNAR has so far fielded 17 missions--8 to African, 6 to Asian, and 3 to Latin American countries. The countries concerned are the Ivory Coast, Kenya, Madagascar, Malawi, Morocco, Rwanda, Somalia, and Upper Volta in Africa; Fiji, Indonesia, Papua New Guinea, the Solomon Islands, Sri Lanka, and Western Samoa in Asia and the Pacific; and Costa Rica, the Dominican Republic, and Guyana in Latin America. The main focus of ISNAR activities is to help strengthen the developing countries' capabilities to do research that will help solve critical problems related to national priorities. In doing so, it goes beyond emphasis on specific areas, such as increasing food production and improving nutrition; the goal is to contribute to self-sustaining research systems capable of turning out useful research whatever the needs and priorities of the countries may be. Through this process, ISNAR can influence the achievement of nutritional goals in various ways.

The first and perhaps most important way, though indirect, is through the development of an improved research-planning capacity, which in turn will facilitate the identification of nutritional goals and incorporation of them into research priorities and programs. Second, a greater national research capacity will lead to more efficient research and consequent generation of more effective technology. This should lead to increases in the production of food and feed crops, livestock, and fisheries or, through better processing or preservation, reduced losses and better quality of food.

Helping build better linkages within the research organization and to its clients on farms or in government and develop awareness among national researchers of the existence, resources, and programs of international and regional research institutions is another area ISNAR emphasizes in its assistance to national systems. The resulting improved flow of materials, information, training opportunities, and cooperative research activities can be seen as having a multiplier

effect on the national research efforts and through this on the effectiveness of international and regional research in all areas including those more directly related to nutritional issues. The overall effect is symbiotic, with ISNAR acting as the catalyst.

Finally, ISNAR's assistance to national research institutions and programs can help those institutions achieve their objectives, which may include increasing rural incomes, improving equity, and creating employment, although its efforts may strengthen not only food production, but also production of crops such as jute or rubber, forest products, and postharvest technology. Here the improved research of a country could help to enhance social welfare and economic benefits by increasing purchasing power and enabling people to obtain more food and a better-balanced diet.

Thus through its direct assistance to national programs ISNAR may have an important effect on nutrition, even though it plants no crops and husbands no animals. This is perhaps its most striking difference from most other international centers and at the same time its main source of strength. Its potential in this direction has yet to be reflected in large changes in output of food or growth rates of productivity, because ISNAR is new and the time lag between investment in new research programs or institutions and their effect on production takes much longer than ISNAR has been active so far.

For this reason its contribution to food and nutrition, which in any case is unlikely to be easily measured directly, has still to be fully consummated. Given the fact that by the time ISNAR has been in operation for five years it will probably have provided direct advisory and research organization missions to about 25 countries and will have assisted a great many more through its seminars, workshops, training, communications, and research activities, the long-run effects of its work may be large. Whether they are, however, will depend materially on national agricultural research systems having sound nutritional policies. As indicated earlier, ISNAR may help diagnostically here but it will not be a primary source of expertise in nutritional research. At the level of individual food crops and livestock, moreover, the achievement of nutritional goals may depend on progress at international research institutions as well as national institutions. Again, these are outside the realm of ISNAR's direct influence, although its cross-linkage activities between them is potentially valuable.

Internationally Oriented Activities of ISNAR

In support of its work toward strengthening individual national agricultural research systems, ISNAR undertakes numerous activities that go beyond the boundaries of single countries. Most of these are concentrated in the three programs--training, communications, and research--which, together with its reviews of national agricultural research systems, make up the bulk of ISNAR's current effort; but they are part of its overall institutional approach to strengthening national systems. A good example of the latter is ISNAR's support of the International Federation of Agricultural Research Systems for Development Limited (IFARD), with which it maintains close contacts and which it has helped to sponsor and organize several joint meetings, bringing together research managers from many countries, but

mainly on a regional basis. Although the subject of nutritional goals and the best ways of incorporating them into the design of agricultural research programs has not specifically been on the agenda of these meetings, the meetings may very well provide an excellent forum for discussion in the future.

Another such opportunity exists through the training program of ISNAR, which is focused principally on the improvement of research organization and management through seminars, workshops, and case studies. Meetings may be organized at various levels, internationally, regionally, or nationally. Well-attended meetings have been organized during the last 12 months, for example, in Rwanda and Nigeria--the latter in close cooperation with IITA. It would seem appropriate to consider at such meetings how the subject of research planning for the attainment of nutritional goals might be incorporated more explicitly into the training activities of ISNAR. It is certainly an important aspect of research organization, management, and program development, but not, of course, the only one that must be covered by ISNAR in its training work. Perhaps the development of a case study related to this topic would be one way of achieving the objective.

The program of research on the planning, organization, and management of agricultural research, ISNAR's newest program, is also a source of potentially valuable information. In looking at the issues that might be explored in greater depth during the planning of this program, it became obvious that a large field of potentially researchable and interesting topics had still not been fully exploited, much past research in this field of agriculture having been directed toward assessment of returns on research and methods of defining priorities and allocating resources and less toward many other aspects of programming, structural organization, research management, and evaluation. A screening process had to be instituted to narrow the field from the merely interesting to the essential and critical issues, the first priority being to illuminate problems that impede ISNAR's own staff in their primary task of assisting countries and helping to strengthen national agricultural research systems.

The final shape and weighting of the items making up the program is still evolving, but among the research topics identified as deserving high priority, and on which work has already been initiated in some instances, are several that may have relevance to nutritional goals.

These include, among others, the following:

1. A review of all the completed reports of ISNAR's review of national research programs to identify their strengths and weaknesses, to help improve future review procedures, to reveal common problems in national systems, and to indicate what information is needed to provide better insights into those systems for the benefit of future ISNAR missions, the countries themselves, donors, and cooperating international or regional research institutions. The collection of more explicit information on nutritional goals and national mechanisms and procedures related to the achievement of those goals by future ISNAR missions should not be an impossible task, although, of course, improving nutrition is an implicit objective of most of its mission work.

2. Intensive analysis of the changes in objectives, functional mechanisms, and structures of selected national systems with the passage of time and the relation of these evolutionary changes to changing political, social, and economic factors in the national history. The importance attached to the achievement of nutritional goals in national policy and by research planners in this process of change and ways in which this may have influenced the structure and direction of the research systems under study will be accorded considerable priority.
3. The role of the private sector. In some Third World countries, especially in Latin America, the private sector is doing increasingly significant work in agricultural research. In addition to its long-standing association with certain export commodities and with fertilizers, pesticides, veterinary medicine, and farm machinery, private enterprise is taking a more active part in plant breeding, seed production, livestock improvement, feed milling, irrigation, fish culture, land reclamation, and forestry. In some instances the prime mover is the activities of an international corporation, in some a farmer's association or cooperative; in others large-scale local operations are managed by individual entrepreneurs or quasi nongovernment organizations. The extent to which they complement, support, cooperate with, or draw on the research system of the public sector is often unclear. From studies now being pursued in South America, ISNAR is trying to learn more about these activities, about where their effects are most likely to be felt, and who is most likely to benefit. One important and controversial aspect that could be studied from the viewpoint of the achievement of nutritional goals is the work being done by private organizations in research on food processing, preparation, and preservation, including baby foods.
4. On-farm research and the dissemination of research results. It is evident from reports of ISNAR missions and from other studies that despite much lip service research at the farm level and the linkages between research, extension, and the farmer at the "downstream" end of the research system are often weak, sometimes nonexistent.

There are several reasons that a feeding-feedback process is important to the achievement of nutritional goals. Food is generally produced as part of a complex cropping or farming system to a much greater extent than perennial crops and is often a small-scale family-farming operation rather than a corporate enterprise. A substantial proportion of the food produced is usually consumed by the farm family, so their nutritional goals and preferences should have a considerable influence on what is demanded from the researchers. Even the marketed portion of farm output is strongly influenced by local preferences and food habits, whereas of export or industrial crops it is dictated largely by external factors over which the individual farmer may have little control. Thus the targets of the research service in quality and end use have to be geared to different and exogenously determined objectives, the nature of which is known largely through market research or buyer specifications. This is not to say that research at the source of production is unimportant for nonfood or export commodities, but the diagnosis of the type of product that is needed may be less critical than it is when food commodities are concerned.

With regard to this area ISNAR is also planning to develop a research program to look at national approaches to on-farm research--including both diagnosis and validation--the place of such research in the national system, its planning and management, the resources and support accorded to it, and its linkages to the farmers. A primary objective will be to clarify the function of on-farm research in guiding or modifying the goals of the national research system as a whole and in providing early warning to disciplinary researchers or program planners of a need to change course or to act to improve technology so as to maximize resources. Since a primary focus of the field work will be on family farmers that produce food, the influence of on-farm research in helping to increase awareness of nutritional goals throughout the research system could be an important side benefit.

Looking Ahead: Better Ways of Incorporating Nutritional Concerns into the Work of ISNAR

So far this paper has dealt with the current activities of ISNAR within its mandate and ways in which they impinge, or might impinge, on the goals of improved nutrition.

From this it will be seen that its function in this respect is direct yet indirect. It is direct in the sense that any action or activity specifically aimed at helping to strengthen a national agricultural research system or regional or international program is likely to have a positive effect on the improvement of nutrition, and all ISNAR's activities are geared to strengthening national systems.

It is indirect in that so far ISNAR has not overtly tried to advise or influence countries with which it is working to establish nutrition research units, to undertake food-consumption surveys, or to direct commodity-research programs toward defined nutritional objectives.

What of the future? Whether ISNAR would eventually wish to have a member on its core staff with nutritional expertise would be a policy decision related to national demand. So far it cannot be said that such a need has emerged strongly; whether it could or should be generated by a more active and explicit approach to nutrition on the part of ISNAR in its advice to countries on organizing their national systems is another matter. It is not inconceivable that nutrition planning and the incorporation of nutritional goals into research priorities could be the subject of work by ISNAR at some future time. Additional emphasis on nutrition by other IARCs might increase the demand for this type of assistance. The availability within the CGIAR of a base of knowledge on nutritional policy at IFPRI might be useful to ISNAR if it were asked for guidance in this field by a national system. In any case a continuing association between ISNAR and a country on research planning would probably in the long run involve nutritional considerations.

This, in turn, could translate into requests to other international and regional centers for commodity research geared specifically to the improvement of nutrition. In addition to commodity-specific research at the centers located in developing countries, IFPRI should expect further pressures for research in this field. It already has an active and dynamic program to illuminate both the

economic and the social factors that affect the nature and magnitude of demand for food and the linkage effects of improved technology on productivity and the economy. It may be valuable, however, for IFPRI to develop continuing relations with the other international institutes to follow up its initiative in convening this workshop.

If ISNAR were to make a more deliberate attempt to identify the mechanisms by which countries take nutritional factors into account in research planning, it is likely that collecting and analyzing this information would have to be undertaken as a by-product of its overriding mandate to help strengthen national systems--so as to improve coordination between the ministries and departments involved in nutrition and related research, for example--and not as a major research effort in its own right. It also seems essential to discuss the nature of the information that would be most generally useful to national research systems and the other international agricultural research centers and that might be assembled by ISNAR within its financial and staff resources.

16
Nutritional Goals and Activities of the AVRDC Research Program

Samson C. S. Tsou and Jack Gershon

The objective of the research program of the Asian Vegetable Research and Development Center (AVRDC) was stated by the first director, Robert F. Chandler, Jr., in the 1973-74 annual report as "to bring higher yield potential to improve food crops that contain more protein, vitamins and minerals than do the staple cereal grains." It is clear from this statement that nutrition is the primary concern of AVRDC.

The administrators and scientists of the center recognize that resolving the problems related to nutrition also requires effective use of the available food, proper patterns of consumption, and appropriate distribution of food among members of the family. From an international point of view, providing balanced diets in developing countries can best be brought about by increasing the amount of food available.

The following are a few of the fundamental concepts that were considered when the nutrition objectives of AVRDC were set:

1. There are many vegetables available in the market. It is unlikely, however, that any one specific vegetable will be consumed every day or that it will make a significant contribution to individual nutritional needs. In other words, a specific vegetable cannot be expected to solve all nutrition problems, but nutritional status can be improved through the promotion of selected vegetables.

2. Most nutrition programs in Asia today emphasize protein, vitamin A, and energy. In the near future iron is likely to receive increased attention as well.

3. Neither producers nor consumers will pay more for better nutrition, especially in the tropics. Thus, in crop-improvement programs breeding for characteristics that might raise prices should be avoided.

4. As a production-oriented international center, AVRDC does not have the built-in capacity to undertake extended outreach programs. When possible the activities of the center are incorporated into national programs, or additional funds are sought for outreach activities.

ESTABLISHMENT OF COMMODITY PRIORITIES

Crop Selection

A broad definition of vegetables is used at AVRDC: a vegetable is any part of an herbaceous plant eaten as a staple food. By this definition, many crops such as starchy roots and pulses are considered to be vegetables despite the fact that some consider them field crops. Vilmorin-Andrieux listed 211 vegetables in his book The Vegetable Garden, and more than a hundred kinds of vegetables are available in Asian markets. Since nutrition is one of the center's most important concerns, the potential nutritional effect of a commodity is one of the primary selection criteria. Three nutritional criteria are applied at AVRDC in the selection of a commodity for research and development--its specific nutrient content, the contribution of selected nutrients that it makes, and its potential for improvement. Five crops were initially selected for attention by AVRDC: soybean (Glycine max), mung bean (Vigna radiata), tomato (Lycopersicon esculentum), Chinese cabbage (Brassica chinensis linn.) and sweet potato (Impomea batatas). The two legumes were selected primarily for their protein content. Sweet potato is high in potential dry-matter yield, and both roots and tips are good sources of vitamin A. Tomato and Chinese cabbage are sources of vitamins C and A and are also good cash crops. With intensive field input and the potential for home processing, these two vegetables can generate income for farmers and provide job opportunities in rural areas.

In 1980, five crops were added to the AVRDC research program for initial investigation: pepper (both bell and hot), mustard green, Chinese radish, cauliflower, and snap bean. Besides their nutritional value, factors in their selection were the availability of resources for training, their acceptability to consumers, and the interest of national programs.

Research Priorities of Given Commodities

The research priorities of a given commodity vary, depending on its production problems, the availability of resources, and the stage of the program; that is, until yields have reached an appropriate level, quality assessment receives less attention. Research can generally be classified into the following complementary approaches:

1. Improvement of yield potential.
2. Production technology.
3. Assessment and improvement of quality and usefulness.
4. Environmental interaction, including economic evaluation and social acceptability.

The adaptation of tomato and Chinese cabbage to tropical environments is the primary concern in work on these two commodities. To work on other factors is meaningless without stable yields. Yield potential and production technology deserve high priority, but once acceptable yields have been achieved, quality and environmental factors will be assessed.

Soybean and mung bean represent two quite different situations. Mung bean is a traditional crop in tropical Asia, and the main factor limiting its consumption is its high price, which is caused by its low yield. Yield improvement by itself would affect the value of this vegetable significantly. Soybean, on the other hand, although it appears in some Asian diets, is a relatively new crop in most tropical countries, and programs are needed to promote both production and use.

Sweet potato is known to have high yield potential, but this potential has never been demonstrated in farmers' fields. Part of the reason is that sweet potato is considered a low-status food and has little market potential. Improving its quality and promoting its use are therefore important concerns. The sweet potato program of AVRDC is primarily concerned with consumption and use.

Methodologies for Assessment of Nutritional Considerations

A workshop called "The Roles of Vegetables and Legumes in Asian Diet" was held at AVRDC in 1975. It was suggested by the participants that AVRDC include more leafy green vegetables in its program and that more emphasis be laid upon nutritional concerns. In response to these suggestions two steps were taken. First, a consulting nutritionist was added to the AVRDC staff in 1980, supported by a grant from the USAID nutrition office. One result of the grant is the AVRDC garden program in which home, school, and market gardens are developed and promoted. Second, sweet potato tips were identified as a leafy green vegetable worthy of more attention in research.

It was realized during the leafy green vegetable assessment process that better methodology is needed for evaluating the nutritional worth of a given commodity and for providing a quantitative basis with which policymakers, administrators, and other biological scientists can determine research priorities. The concept of "relative nutrient cost" was developed and used in the crop selection process. This method rates the nutritional value of any given commodity on the basis of its food composition and the food-consumption patterns and expenditures of a given population.

The relative nutrient cost (RNC) of a given nutrient, $\underline{j}$, for a target population is defined as follows:

$$\text{RNC } \underline{j} = \frac{\text{total food expenditure}}{\text{intake of nutrient } \underline{j}}.$$

Total nutritional value of a given commodity, $\underline{i}$, can then be calculated by using the following formula:

$$\text{Nutrition value of } \underline{i} = \sum^{i} \text{RNC } \underline{j} \times \text{content of } \underline{j} \text{ in commodity } \underline{i}.$$

A nutrient deficiency in the diet generally reflects a high RNC and is thus more significant in the calculation of nutrition values. The unit of nutritional value can be expressed in dollars thereby making it possible to link nutritional effect to an economic term.

SPECIFICATION OF DESIRED CHANGES IN COMMODITY CHARACTERISTICS

Programs for the development of genetic resources for agronomic characteristics will be discussed under technological characteristics. The discussion here will be limited to commodity quality.

At AVRDC specification of the desired changes in quality characteristics of commodities usually follows four steps:

1. Evaluation of the importance and popularity of the characteristics.
2. Feasibility studies to assess the materials--that is, the genetic source--and the technologies available for making the change. A hypothetical approach is then developed and the resources for a work plan are reviewed.
3. A simple, rapid testing method is developed so that large numbers of samples can be handled.
4. A program for improvement and assessment is conducted by a multidisciplinary team.

In Table 16.1 the principal quality concerns of AVRDC in its research on various crops are summarized and the stages of each project are listed. About 80 percent of the resources of the AVRDC chemistry laboratory are devoted to assessment of factors listed in Table 16.1. The emphasis in each project depends in part on the progress that has been made by breeders.

Table 16.1 -- Desired quality characteristics of crops being studied by AVRDC

Crop	Characteristics	Stage of Project
Soybean	high protein content[a]	3-4
	high oil content[a]	3-4
	high methionine content	1-2
	low flatus	1-2
	good processing quality for tofu	2
Mung bean	high protein[a]	2
	high methionine	3-4
Tomato	good processing quality[a]	3-4
	good nutritional quality[a]	4
Chinese cabbage	good marketing quality	1
	good nutritional quality	-[b]
Sweet potato roots		
Staple food and food type		
	high dry matter	4
	high protein	4
	light color	4
	good digestibility	3
	low flatus	2-3
	low sugar	4

Table 16.1 (continued)

Crop	Characteristics	Stage of Project
Snack type		
	high β-carotene	4
Industry starch type		
	high dry matter	4
	high starch	4
	good starch quality	1
Sweet potato tips		
	yellowish color	4
	good nutritional quality[a]	4
	low fiber	4
	good taste	4

[a] The desired quality was maintained without a breeding program to improve the quality.
[b] The nutritional quality of winter tropical Chinese cabbage was found to be better. Early generation lines were not analyzed.

In Table 16.2 the screening and testing methods used at AVRDC are summarized. Efficiency could be strengthened if instruments and facilities such as the auto analyzer and the NIR analyzer were upgraded.

Table 16.2 -- AVRDC screening methods for evaluation of quality

Quality	Screening Method
Crude protein	Udy dye-binding method
Crude protein (SP)	Indicator paper[a]
Crude oil	Purse NMR
Methionine content	Microbiological assay
Flatus	Rat-feeding method
Protein digestibility (mung bean)	Microbiological assay[a]
Color	Hunter color meter
Dry matter (sweet potato)	Density method
Carbohydrate digestibility (sweet potato)	In vitro digestion method
Sugar	Modified refractor meter[a]
β-Carotene (sweet potato)	Dry-powder method[a]
Eating quality (dryness)	Alcohol-insoluble substances[a]

[a] This was developed at AVRDC.

SPECIFICATION OF DESIRED TECHNOLOGY CHARACTERISTICS

Technologies on Genetic Resource Development

One basic assumption in the work of AVRDC is that populations in tropical rural areas whose nutrition status is low also have limited production resources. Low-input technologies need to be developed to serve these populations. As do those working in most other international centers, we believe that providing genetically improved planting materials is the most effective way to help low-income farmers. Improving agronomic characteristics such as resistance to the more serious diseases and insects, and tolerance of environmental stress such as drought, flooding, and heat are given high research priority at AVRDC. The primary emphases of AVRDC's five crop-improvement programs are summarized and the various stages of development for each desired characteristic are presented in Table 16.3.

Table 16.3 -- Primary emphases of the genetic resources development programs of AVRDC

Crop	Characteristic	Development Level
Soybean	High and stable yield	1,2,3
	Adaptation to photo-thermo environment	2,4,5
	Resistance to soybean rust	2,3,5,6
	Resistance to bacterial pustule	1,2,5
	Resistance to downy mildew	1,2,5
	Resistance to soybean mosaic virus	2,4,5
	Resistance to bean fly	2,3,5
	Resistance to pod borer	3,4
	Resistance to stinkbug	2,3,5
	Resistance to defoliate insects	2,3,5
	Adaptation to low input	1,3
	Good seed-stock quality	2,3,5
	Adaptation to intercropping and mixed cropping	4,5
Mung bean	High and stable yield	1,2,3
	Early and uniform maturity	1,2,3
	Resistance to cercospora leaf spot	2,3,6
	Resistance to powdery mildew	2,6
	Resistance to bean fly	2,3,5,6
	Sensitivity to day length and temperature	1,2,6
	Tolerance to lodging	1,2,5,6
	Drought tolerance	4,5,6
Tropical tomato	Heat tolerance	1,2,6
	Resistance to bacterial wilt	2,3,5,6
	Resistance to TMV	2
	Resistance to nematode	2,5,6
	Crack resistance	2,3

Table 16.3 (continued)

Crop	Characteristic	Development Level
	Resistance to blotchy ripening	4
	Firmness	2
	Fruit size	2
	Tolerance to flooding	4,5,6
Tropical Chinese cabbage	High yield	1
	Heat tolerance	1
	Resistance to soft rot	2
	Resistance to downy mildew	2
	Resistance to turnip mosaic virus	2
Sweet potato	High and stable yield	3
	Resistance to sweet potato weevil	4
	Resistance to virus	5,6
	Resistance to witches'-broom	2
	Tolerance of drought	5,6
	Tolerance of flooding	2,4,6
	Adaptability	2,3
	Resistance to stem borer	2

Notes: Development level 1 = genetic resources successfuly incorporated into majority of advanced lines. National programs affected by the improvement of these characteristics. Development level 2 = genetic resources activity being used in breeding program for combination with other desired characteristics. Development level 3 = Genetic resources identified that are equal to or better than local cultivars. An improvement program is under way. Development level 4 = identification of genetic resources required. Development level 5 = developing or improving methods of screening and selection. Development level 6 = conducting necessary basic research on the nature of the characteristics in order to strengthen the program.

Technological Characteristics of Crop Management and Cultural Practices

Few Asian farmers specialize in the production of vegetables. Vegetables, in general, are grown on only a small portion of each farmer's land. Horticultural crops can generate more income per unit of land, but they require more input and are often regarded as high-risk crops. Management technologies designed to maximize profits may not necessarily provide maximum security and are often unacceptable to low-income farmers. Research efforts at AVRDC have been devoted both to maximization of profit and minimization of risk. Development of

low-input technologies and varieties with wide adaptability is given top priority at AVRDC. The following approaches have been emphasized:

1. Wide adaptability: Reduced photoperiod sensitivities, drought tolerance, flood tolerance, high yield under minimum-input conditions, and cultivars bred specifically for intercropping.
2. Application of the appropriate fertilizer, not only for monocropping, but also for various other cropping systems.
3. Post-rice cultivation.
4. Weed control, including the identification of the critical control period.
5. Leaf-tying methods for tropical Chinese cabbage.
6. Methods of cultivation in hot, wet conditions, such as optimum bed height, composting, mulching, and covering.
7. Insect control: besides chemical control, other methods, such as mixed cropping and low input management control, are emphasized.
8. Water management, including drip irrigation, critical irrigation periods, and damage improvement technologies.
9. Seedling-production techniques for better adaptability after transplanting.

Use of the nitrogen-fixing ability of microorganisms is also considered a feasible approach to reduction of production costs. In 1983, a cooperative project was initiated between AVRDC and the International Soybean Program to focus on this concept.

There are many ways to classify vegetable production systems, but the following choices among production systems are the main concern at AVRDC: highland production versus lowland production and commercial production versus production for household consumption.

At present, lowland commercial production receives more attention than other production systems at AVRDC. We believe that this system has greater potential both to improve the nutrition and to increase and stabilize the income of small-scale tropical farmers. There is more land available in lowland areas, and there is a larger population of small farmers there.

Multiple cropping is basic to lowland tropical agriculture. Attention to cropping systems is essential to the development of improved technologies at AVRDC. Rice is the principal staple crop throughout Asia. It is also the dominant crop in multiple cropping systems in the region. Post-rice cultivation of vegetables and legumes for commercial purposes is one of the more important production systems at present. The planting of early-maturing and uniformly maturing varieties, application of fertilizers, control of disease and insects, post-rice, no-till cultivation, weed control, and the use of residual moisture are all considered in the development of new AVRDC technologies. The fact that varieties and technologies appropriate for commercial production systems are not necessarily applicable to production systems for household consumption is, however, considered. A nutrition-oriented household system of production and consumption was initiated in 1980.

A consistent supply of low-priced, nutritious vegetables for the urban poor is also being considered at AVRDC. Specialized, intensive production of vegetables in irrigated suburban areas has been found to be a feasible approach. This system can absorb excess labor and reduce the cost of transportation and storage. Good planning, rapid marketing information, skillful technologies, a reliable supply of seed and agricultural credit to tolerate both higher input and risk,

and a good cooperative marketing organization, however, are required. Simply improving production technologies is not sufficient to achieve these ends. The market garden described in the AVRDC garden project can be considered a step toward the development of this type of production system.

CHOICE OF PRODUCTION SYSTEM

School and Home Garden Production

In 1980 AVRDC conducted some simple nutrition surveys in Thailand, Indonesia, and the Philippines as an initial effort of a two-year consulting nutritionist position funded under a USAID grant. These surveys consisted of reviews of the literature, interviews with key persons from the ministry to the village level, and field observations. The objective was to identify nutrition problems in these countries, the populations affected, foods--especially vegetables--that would alleviate the problems, and assistance and nutrition intervention offered by national governments and international agencies.

The results of the surveys suggest that people in these countries have varying degrees of deficiencies in vitamin A, calcium, iron, and protein. Those affected most are the rural poor--preschool children, for the most part, and pregnant or lactating women. Some of the foods that could help to alleviate these problems are legumes, leafy green vegetables, and yellow fruits and vegetables. Some of the nutrition interventions undertaken by national governments and international agencies consist of distributing surplus foods from developed countries, food fortification, the development of commercial weaning foods, nutrition education, the operation of nutrition rehabilitation centers, increasing the farm yields of staple crops, and various gardening activities. At the time of the survey, AVRDC was already involved in increasing farm yields but had not ventured into gardening projects. AVRDC was interested in pursuing the gardening idea to generate basic expertise, to develop an economic demand, and to involve women in production and nutrition because not only do garden crops provide vitamins and minerals, but their potential to provide energy and protein is underestimated.

AVRDC's garden program, initiated in 1981, has emphasized nutritionally oriented school, home, and market gardens. The school and home gardens are designed to improve nutrition through direct consumption, while the market garden is designed to improve nutrition indirectly by increasing household income.

School Garden. School children need both energy foods and body-building protein plus the vitamins and minerals found in vegetables. A small serving of cooked vegetables, grown in a school garden and added to the ricebox lunch that many children bring to school, could contribute greatly to a child's daily needs. The objective of this project is to develop a garden that can be grown at a school and that would provide half a cup (approximately 113 grams) of nutritious vegetables to each of 80 children, five days a week, during the school year.

Seasonal gardens were planted during a one-year period in a plot 10 meters by 18 meters consisting of 12 raised beds. During the year, 27 vegetables selected for their nutritional value and cultural acceptability were grown. Low-input agricultural procedures were practiced, including, when possible, hand weeding and hand pest control. Yields were recorded for each vegetable and analyzed for content of protein, calcium, iron, and vitamins A and C.

During the year, the school garden produced an average of 15.18 kilograms of nutritious vegetables a day, totaling 134 113-gram portions. Each 113-gram serving contributed the following percentage to the recommended dietary allowance for a 10-year-old child: protein, 6.39 percent; calcium, 22.69 percent; iron, 59.14 percent; vitamin A, 59.01 percent; and vitamin C, 261 percent.

A 10-by-18 school garden can provide school children with significant amounts of selected nutrients. In this manner, school gardens can serve as a way of increasing both local food production and the availability of vitamins and minerals in the community.

Home Garden. AVRDC scientists recognize that some nutrition-related diseases can be alleviated by increasing consumption of vegetables. The problem is to create a reliable source of vegetables available to the consumer. One way is to show rural populations how to grow their own vegetables in simple home gardens. Gardens that can produce nourishing and culturally acceptable vegetables that are suited to the conditions found in Thailand, Indonesia, and the Philippines have so far been developed.

During a one-year agricultural cycle 16 vegetables were planted on plots 4 meters by 4.5 meters, consisting of three 4-by-1.5-meter raised beds. The vegetables were planted at different times in four seasonal gardens that reflected the slight climatic changes in the AVRDC environment--that is, relatively hot and wet, hot and dry, cool and dry, and cool and wet, respectively. These conditions are similar to those found in the lowland, foothill, and highland areas of Thailand, the Philippines, and Indonesia.

Low-input methods were practiced to simulate actual field conditions. Control of weeds and insects, for example, was carried out by hand whenever possible, and compost was used to save on the cost of fertilizer. Rice-straw mulch was used to minimize erosion during the rainy season and retain moisture in the soil during the dry season.

Collection and analysis of data followed a pattern that enabled the gardens to be evaluated rapidly. Edible yields of each crop in each seasonal garden were recorded, and samples of each were then analyzed for calcium, iron, protein, and vitamins A and C. Data for the five nutrients were multiplied by the edible yield of each crop to give information on nutritional output; these data were then totaled to illustrate the contribution of a seasonal garden to the recommended dietary allowance of a family of five, consisting of father, pregnant mother, and three children, as set by the FAO. Vegetables were harvested at the end of the growing season and yield weight was divided by growing time (in days).

The gardens produced a calculated daily yield ranging from 1.0 gram to 1.8 kilograms. The Thailand home garden, for example, produced a calculated daily yield of 1.5 kilograms. This would provide a family of five with the following percentages of their recommended

dietary allowance: protein, 21.9 percent; calcium, 72 percent; iron, 100 percent; vitamin A, 128 percent; and vitamin C, 500 percent. Detailed data on each of the gardens is available from AVRDC.

Gardens specifically planned to meet nutritional requirements are a valuable way of increasing the availability of vegetables in rural areas. With seeds, hand tools, a small piece of land, and an hour of labor a day, a rural family can produce enough vegetables to supply its basic needs. Such gardens are a cheap investment compared with the costs of administering massive doses of vitamin A, or that of international aid programs that distribute supplementary foods.

Market Garden. Today, the subsistence farm is a rarity. More often than not, small farmers in developing countries practice subsistence farming part-time and purchase goods in nearby towns and villages. In these areas lack of employment opportunities often makes it difficult to earn the necessary cash. An on-farm income-generating scheme is one answer to the employment-cash-subsistence problem.

The objective of the market garden is to increase the incomes of the rural poor--households that exist on approximately U.S. $600-$700 a year--at least 30 percent. This type of garden is designed for small farms located on the peripheries of urban areas. Crops high in demand in nearby town or village markets should be selected for production.

Surveys were first conducted at local markets to determine which vegetables would be low in supply and high in demand and would command good prices in the coming months. The most promising of these were grown in a market garden, consisting of a plot 10 meters by 20 meters containing 13 raised beds 10 meters by 1.5 meters and 25 centimeters high. Standard farming practices were followed using commercial fertilizers and pesticides. A total of 23 crops were grown and at harvest the vegetables were sold wholesale at village markets.

The wholesale price of the yield, the cost of the inputs, and the net profit for each vegetable were recorded throughout the year. The garden produced 2,356 kilograms of vegetables, which were sold in the wholesale market for NT$18,394 (U.S. $460). The costs of the inputs--seed, fertilizer, pesticide--were deducted, leaving a net profit of NT$15,798 (U.S. $394). Labor costs were not calculated, under the assumption that unemployed members of the household would provide the labor.

It was demonstrated that the market garden could increase the annual net income of a poor rural household well over 30 percent, especially if the produce were to be sold at retail instead of at wholesale.

Details on all three types of garden are available from the AVRDC Office of Information Services.

Farming Systems Research. In 1982, with support from the Asia Bureau of the USAID, the AVRDC gardens were incorporated into an on-farm research methodology designed by the University of Missouri and called "Farming/Family Living Systems" (F/FLS). This methodology takes into account the usual cropping and livestock subsystems and, in addition, the household subsystem--including the activities of the women and children of a small-farm family.

F/FLS methodology regards a home or market garden as an economic enterprise of a small-farm family that is in competition with other enterprises that may or may not increase the quality of life of the family. Under F/FLS, baseline data on the three subsystems in a small farm and on possible enterprises that the farm family may undertake are collected. All the necessary inputs and outputs--that is, income over variable costs--of an enterprise and of a particular small farm are collected. An analysis of the results can then assist a farmer in deciding which enterprise best suits his family's needs.

AVRDC will modify the F/FLS methodology to include the nutritional value of a home garden as well as the monetary value. In this manner the contribution of the garden output to a family's daily recommended dietary allowance of selected nutrients can be calculated, and the overall value of a home garden to a family in a developing country can be suitably assessed.

Looking Ahead. AVRDC has transferred its gardening technology and F/FLS methodology to Thailand, where they are being tested and promoted. Transferring them to other countries, such as Indonesia, the Philippines, and Malaysia, is planned, and a training program for extension personnel to demonstrate the linkage between agriculture and nutrition will be included.

CONCLUSIONS

Nutrition is a primary concern of AVRDC. It is reflected in the distribution of the center's resources and in the nature of its research programs. The following constraints limit the effectiveness of nutrition inputs at international agricultural centers and require strengthening:

1. The dietary approach to improvement of nutrition is not receiving sufficient attention from nutritionists and makers of food policy.
2. The results of research conducted at international agricultural research centers are not always used properly by national programs. National programs, moreover, are primarily crop-production institutes, and they promote little interaction between agriculturists and nutritionists in national programs.
3. The position of international centers in the nutrition intervention chain is not clearly defined.

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The Effects of the International Agricultural Research Centers on Human Nutrition — Catalog and Commentary

James G. Ryan

This paper is a summary of the contributions of the thirteen IARCs to the workshop. No center was able to provide precise data on the effects of its research programs on human nutrition except, in some instances, in aggregative form by inference from data on adoption and production combined with estimates of demand parameters. No diet surveys have been conducted by the IARCs with this specific purpose in mind. As a result it is not possible to present a comprehensive picture of the contribution of the IARCs to improvement of human nutrition.

The papers of the centers have been reviewed under eight headings. These include their work in using nutritional considerations in determination of commodity priorities and characteristics, the production systems in which they conduct research, the design characteristics of technologies, the inferred effects of research on nutritional status of producers and consumers, issues that have arisen in the approaches used, and suggestions for future research.

The mandates of ISNAR and ILRAD do not afford them the opportunity to affect directly the nutritional status of people living in developing countries (see Chapters 13 and 15). As a result there is little discussion of these two centers here. Other centers, such as IRRI and CIP, are single-crop centers and therefore have no scope for influencing commodity priorities, so they are not mentioned in the discussion of that subject.

RESEARCH ON COMMODITY CHARACTERISTICS

Nutritional Quality

The quality protein maize program at CIMMYT probably constitutes the most significant attempt by any of the IARCs to modify the nutritional quality of a mandate crop (see Chapter 5). Feeding experiments are cited to support the emphasis on quality protein maize, but there is no discussion of the effects of tannins and other antinutritional factors that may affect the availability of the enhanced protein. The quality protein maize program has led to the establishment of protein-quality laboratories in a number of national agricultural research programs.

CIMMYT maintains that it has now developed cultivars of maize of high lysine content that are stable across environments and that also have desirable kernel characteristics and mean yields. According to IBPGR, however, the newly released CIMMYT cultivar of maize with high-quality protein called Nutrice may not be stable because the quality gene is recessive and maize is a cross-pollinated crop (see Chapter 7). A study in Guatemala has shown that high-quality-protein varieties of maize when fed to children under two years of age improve their nutritional status; the yields of these varieties are equal to those of the local varieties, and they can be as satisfactorily stored and cooked. CIMMYT is now studying the desirability of increasing the energy density of maize by increasing its oil content, but with no sacrifice in yield. Advanced generation materials are to be measured to ensure that their protein content does not fall below minimum acceptable levels.

Wheat and triticale are not bred for protein quality at CIMMYT because it is thought that too great a sacrifice in yield would be the result. This is contradicted by Shivashankar (Chapter 7), who contends that lines with high protein content have been developed without any sacrifice in yield. CIMMYT abandoned its high-protein high-lysine program in barley because of the doubtful nutritional value and the lack of good agronomic characteristics in the germ plasm, although once again the IBPGR maintains that lines have been developed that yield 90-95 percent as well as the parent stock and that protein and lysine content is high.

In its first five years protein-quality analysis for sulphur amino acids was used to select parent breeding materials at CIP in Peru (see Chapter 6). However, the nutritional objectives were not to dominate the attainment of yield or the resistance to insects and disease. It would seem that even though the protein-gap philosophy was known to be under a cloud, CIP continued to include protein quality and quantity as an objective of its applied breeding programs. There was a minimum cutoff of 10 percent crude protein (dry basis), concern for levels of vitamin A, antinutritional factors, and processing and storage techniques in order to maintain the nutritive value of the potato.

In 1978 the physiology laboratory began work on producing potatoes from seed. This new initiative raised questions about the resources tied up in nutritional research that was then seen to be of doubtful value to plant breeders. It was concluded that there was a negative correlation between protein content and yield, and since yield seemed to have the higher priority, it was decided to drop protein content as an objective. As a result the laboratory closed in 1979. CIP now relies on national programs to analyze improved cultivars for their protein content because CIP sees increases in total protein per hectare as the most effective means of realizing nutritional improvements.

The protein content of chick-peas, faba beans, and lentils is tested at ICARDA (see Chapter 8) and was originally included in the cassava and bean breeding programs at CIAT (see Chapter 4) and the rice breeding program at IRRI (see Chapter 14). Emphasis on improving protein content subsequently ceased at these IARCs. Improvement of protein quality of wheat was given priority early in the Cereals Improvement Program at ICARDA and in the coarse-grain and pulse programs of ICRISAT (see Chapter 7). Except for pearl millet at

ICRISAT and wheat at ICARDA the IARCs that instituted breeding programs for protein quality have now ceased focusing on this objective.

ICRISAT's attitude toward quality protein breeding changed because of several reasons. Analysis of secondary and primary data in India showed that protein and amino acids were not the major deficiencies in human diets but rather that energy, calcium, and vitamins A, B-complex, and C were. The emphasis in breeding programs has now shifted more toward breeding for yield and yield stability in order to increase the availability of foodgrains important in the diets of poor people in the semiarid tropics. A study of the impact of the green revolution in wheat in India on the production of nutrients showed that this yield-oriented strategy was significant in increasing the aggregate supplies of all major nutrients, even after allowing for the reduction in pulse production that followed the introduction of high-yielding varieties of wheat. This lent further support to the basic priority of improving yields and yield stability. At ICRISAT there has been an increasing trend toward screening elite breeding lines to ensure only that they do not fall below desirable nutritional levels rather than attempting to incorporate quality traits into the breeding programs. This is the situation in many of the IARCs.

Sorghum and pearl millet were found by ICRISAT to be important sources of vitamin A and some minerals in the diets of rural households in the semiarid tropical zones of India. There also seemed to be sufficient genetic variability in these characteristics to suggest that they might well be included in future breeding programs. More basic research is suggested, however, before vitamin and mineral content are added to applied breeding programs.

Research at ICRISAT also showed that the high-lysine gene in sorghum was relatively unstable because of environment x genotype interactions. This was a further reason for de-emphasizing the high-lysine program. The instability of protein content in chick-pea owing to the same interactions was also the reason for a change in emphasis in the breeding program for that crop. It has been concluded that there is no trade-off between yield and protein content in pearl millet. This relation was derived using advanced generation breeding lines, however, where the inverse relation usually expected among the entire germ plasm may already have been diluted.

Research by IFPRI has been focused upon the implications of dietary deficiencies for research strategies and government policies (see Chapter 3). Work is cited that suggests that the protein content of the diets of the poor is adequate whenever energy requirements are met. As the incomes of calorie-deficient and protein-deficient households rise, protein deficiencies seem to be alleviated before or simultaneously with calorie deficiencies. IFPRI concludes that more food is the primary need in the diets of poor households.

The focus in IRRI's rice breeding program has been on high-yield potential as the most effective way of improving human nutritional status. Subsequently, IRRI began also to focus on disease and pest resistance to help stabilize rice production. Development of the short-duration rice cultivars also allowed cropping intensity to be increased with consequent effects on production, employment, incomes, and rice consumption. IRRI has not bred for high lysine as it was felt that there was little variation in this characteristic in the rice germ plasm. It has endeavored to increase protein content but

because of the inverse relationship to yield, increased susceptibility to diseases and pests, low heritability, and environmental interactions, progress was difficult. Protein is now secondary to achieving increased yields, pest and disease resistance, and tolerance to environmental stresses. As with other IARCs, elite cultivars are checked to ensure that they do not have unacceptably low protein content.

The major breeding strategy at IITA is to rely on yield-enhancing technologies, even if this entails a sacrifice in nutritional quality of the grains in the plant-breeding programs. The notion is that by increasing crop yields in this way total food supplies are increased, thereby reducing consumer prices and allowing increased consumption of staple foodgrains. Cultivars of cowpeas are being examined that allow defoliation of leaves for use as green vegetables without sacrificing grain yield. Vegetable cowpeas are also being developed. Attention is also being given to cassava leaf yield, quality, and protein content and to sweet potatoes. With maize there is little emphasis on achieving increased protein content or quality and none with rice.

The principal breeding strategy at IITA is to rely on yield-enhancing technologies, even if this entails a sacrifice in nutritional quality of the grains in the plant-breeding programs (see Chapter 11). AVRDC aims to maintain oil, protein, and nutritional quality in its vegetable-breeding programs but does not have any programs to enhance these characteristics (see Chapter 16). Until yields have been increased assessment of quality will receive less attention. Depending upon the crop, characteristics such as digestibility, B-carotene content, and fiber content are assessed.

The IBPGR paper stresses the importance of exploiting genetic variability in the nutrient contents of the world's cereal, legume, oilseed, and vegetable germ plasm. The contention is that "breeding crops with improved nutritional quality is one of the cheapest and most reliable means of addressing the nutritional gap in the world" (see Chapter 7). It is difficult to accept this conclusion in the light of the experience of the IARCs responsible for crop improvement. Because of genotype x environment interactions, low heritabilities, and trade-offs in the achievement of nutritional attributes at the expense of others such as yield and disease and pest resistance, most IARCs have decided to de-emphasize the improvement of nutritional quality. Indeed, the IBPGR acknowledges the aforementioned difficulties in breeding for improved nutrient content. Their entreaty thus seems somewhat of a non sequitur.

Acceptability to Consumers

Many IARCs built their programs for increasing acceptability to consumers during the period when they were rationalizing their emphasis on improvements in nutritional quality in their breeding strategies. Given that increasing the total availability of food was seen as the most appropriate research policy at the IARCs for enhancing human nutritional welfare, emphasis on the acceptability of the enlarged food supplies to consumers seems entirely appropriate. The adverse reaction of consumers to some of the early releases of improved cultivars of rice and wheat lends credence to this approach.

At CIP the emphasis has shifted more toward concern for improving

the consumer acceptability of new potato cultivars by selecting, for example, for increased specific gravity to improve transportability, shape, color, eye depth, culinary characteristics, and processing quality. Again, national programs are requested to select from CIP's germ plasm those genotypes that have characteristics preferred by local consumers.

At ICARDA the emphasis in the chick-pea-breeding program is on taste and cooking time as well as on protein content. Kernel weight, hardness, fermentation time, and breadmaking quality are tested in wheat along with genotype x environment interactions for these characteristics. With barley the digestibility of cultivars for livestock is the primary concern. ICARDA plans to do digestibility studies with barley straw in the future.

Starch content is now included by CIAT as a selection criterion to improve acceptance of cassava cultivars by consumers, and storage and handling is a subject of research because of the considerable deterioration of cassava after harvest. CIAT is examining the desirability of mixing cassava with wheat for bread and using it as a substitute for coarse grains in animal feed. There is some concern, though, that diverting cassava to use as animal feed may have an adverse effect on the nutritional status of poor households that rely on cassava for the bulk of their energy needs.

CIAT now includes quality characteristics such as seed size, color, broth thickness, and cooking time, explicitly in its bean-breeding program. Confirming the experience of ICRISAT, CIAT found a great deal of regional variation in the characteristics of grains preferred by consumers and in the markets. IRRI now evaluates all breeding materials for milling percentage, grain size, shape, appearance, and cooking and eating characteristics and plans to give all these qualities greater attention in the future.

Consumer preferences, including large rough seed coats, whiteness, and ease of cooking, are taken into account in the cowpea program of IITA. Priority is given to rice cultivars that satisfy the preferences of local consumers and that do not deteriorate in storage, mill well, and are preferred in the market. This emphasis will be increased in the future along with development of cultivars that are resistant to disease and pests. More attention will be given to processing improvements for roots and tubers to ensure consumption levels are maintained.

Studies of consumers' preferences have always been an important part of the quality-breeding program of ICRISAT. These studies have been conducted by economists and biochemists. Economists have conducted market studies in which price has been used as the primary indicator of consumers' preferences. Both evident and cryptic characteristics of grain quality, such as seed size, color mix, taste, cooking time, and damage by disease and pests have been used to explain price variations. Indexes of quality, which breeders can construct from measurement of these quality characteristics, can be used to screen germ plasm, breeding lines, and elite material. Taste panels have also been employed to assess the preferences of consumers and to validate the findings from market studies. More recently ICRISAT has begun research on processing technologies, including the feasibility of mixing sorghum with maize in the preparation of tortillas in Latin America.

AVRDC aims to maintain oil content and processing quality in its vegetable-breeding programs. It does not have breeding programs specifically devoted to improvement of these characteristics. Depending upon the crop, characteristics such as color and taste are examined.

Antinutritional Factors

The growing emphasis on the part of the IARCs on breeding cultivars that contain lower levels of antinutritional factors, such as tannins, trypsin inhibitors, and the like, seems to be motivated in part by a concern to make them more acceptable to consumers. In some instances, however, the need to avoid undesirable nutritional consequences of such components is explicitly recognized.

IRRI has evaluated the effect of cooking on the digestibility and use of protein, concluding that while digestibility is reduced by cooking, the utilization of protein remains the same. Retention and absorption of protein by both children and rats was found to be the same for both brown rice and milled rice. The energy and fat content of the brown rice were less well used. Parboiling did not reduce protein absorption below that of raw rice.

AVRDC includes measures of flatus, digestibility, and fiber content in a number of its mandate crops in order to avoid unacceptable levels of these factors in improved cultivars. The primary aim in cassava breeding at IITA is the development of lines that are low in HCN. Some sacrifice in yield will even be considered because a low level of HCN is required in cassava flour that is to be mixed with wheat flour for bread in an effort to reduce dependence on imported wheat. ICRISAT is now emphasizing antinutritional factors in its five crops, especially the relation between these and resistance to damage by insects and birds.

RESEARCH ON COMMODITY PRIORITIES

Use of Demand Parameters

At least three IARCs--IFPRI, CIAT, and ICRISAT--have either estimated or used income, direct, and cross-price elasticities of demand to assess the potential effects of technological change on prices and real incomes. The subsequent effect on consumption of market baskets of different socioeconomic groups has also been evaluated. The research done so far by IFPRI suggests that the income and price elasticities of demand of low-income groups are higher than those of more affluent groups. Parameter estimates of this type are now available for a number of countries, including Brazil, Egypt, and Sri Lanka, and will make possible more refined analysis of the commodity balances that would be appropriate in research programs if nutritional objectives are to be achieved.

CIAT has incorporated nutritional priorities in its agricultural research programs from the outset. Commodity priorities were rationalized from a possible 12 to 4 as a result of careful analysis of the probable nutritional implications. It was concluded that rice, oil-

seed, cassava, and potatoes were most effective in increasing supplies of protein. Time-series data have been used to estimate income, direct, and cross-price elasticities for beef, pork, and poultry. Cross-price elasticities among these three commodities were found to be quite high, the implication being that successful technological change in any one of them will enhance its share of the market at the expense of that of the others.

In research recently completed at ICRISAT income and price elasticities of demand for calories and protein in India have been estimated and the prospect of improving the allocation of research resources to various mandate crops to enhance nutritional benefits has been assessed. Poor households have been shown to have large elasticities of demand for calories and protein, and most of the dietary supplies of these nutrients come from sorghum and millet. It thus seems that successful research on sorghum and millet should have a large positive effect on the nutritional well-being of low-income people in the semiarid tropics.

IFPRI is conducting household studies in an effort to understand the relation among production, consumption, time allocation, and ownership rights of the members of a household and the ways in which these affect individual nutritional status. The effects of policies aimed at improving human nutrition, including the effects of cash cropping and food subsidies, are also being examined within this framework.

Analysis of Aggregate Data

Analysis of trends in food supplies in developing countries has helped IFPRI to identify nutritional gaps that may emerge in the future. Studies of food-consumption patterns and the way they are influenced by rural or urban residence, policies, and demographic trends have also been conducted.

Considerable research has been devoted by ICRISAT to the determination of commodity priorities using congruence techniques and a multifactor additive-scoring model that embraces concerns for both efficiency and equity and includes nutritional considerations. In this type of research both commodity priorities and the appropriate regional balance of research effort have been examined.

An attempt was made by CIAT to assess the relative value of emphasizing rice versus cassava research using a multivariable objective function that included nutritional considerations, import substitution, exports, and income distribution. It was recognized, however, that this approach was rather ambitious and depended heavily upon the weights given to the various criteria used.

It is felt by CIMMYT that no change in the balance of its commodity programs could materially affect nutritional status. Instead it is preferable to encourage national programs to formulate appropriate policies that guide their research activities into avenues offering prospects of enhanced human nutritional status.

Use of Surveys

Baseline household surveys were conducted by ILCA before the initiation of livestock research in order to obtain information on diets,

the seasonality of food availability, household incomes and expenditures, the extent of subsistence orientation, and the importance of animal products in consumption (see Chapter 12). Studies of this sort have assisted ILCA in determining that small ruminants will be given high priority in its research because of their particular value to poor households. Milk production looms large in the priorities for the same reason.

IITA makes the important point that commodities that are not part of the plant-breeding mandate of an IARC can be included under the farming-systems research program. IITA sees good scope for such an approach after surveys have been conducted to determine local food preferences and environmental adaptation of different crops and their roles in farming systems. IITA has recently collaborated with ILCA in initiating research on the integration of crop and livestock production in the African context. In this type of research shrub legumes are seen to offer potential for productivity improvement in both crop and livestock enterprises. These can improve the availability of fodder and fuel, which have nutritional significance as they allow meat production to increase and provide more fuel to cook food items such as pigeon peas. They also enhance the nitrogen status of soils thus increasing grain production.

ICARDA believes that because of its mandate for research it will have its principal nutritional effect on staple commodities consumed mainly by the poor of the Middle East--namely, wheat, lentils, chickpeas, and faba beans. The inclusion of barley, livestock, and forage-crop research in its portfolio--crops that primarily benefit livestock--is justified on the grounds that barley is grown mainly in the more arid regions that are not well suited to the production of other food crops and that sheep produce milk and wool and act as a store of wealth, all of which are of special importance to poor households. Surveys conducted as part of the farming-systems approach to research at ICARDA helped lead to this conclusion.

Diet surveys have been conducted from time to time by CIAT to examine such questions as the importance of beef and milk for low-income urban consumers and to estimate income elasticities of demand.

The choice of commodities in the program of AVRDC depends primarily upon their probable contribution to improvement of nutrition and the genetic scope for achieving increases in yields. As a result AVRDC has a veritable fruit-salad approach to its commodity priorities. In the selection process a "relative nutrient cost" calculation is made, and a consulting nutritionist was recently added to the staff. The nutritionist is conducting diet surveys that have already shown that vitamin A, calcium, iron, and protein are the principal deficiencies in diets in Southeast Asia. The conclusion drawn is that research on legumes, leafy green vegetables, and yellow fruits and vegetables can help alleviate these deficiencies.

RESEARCH ON PRODUCTION SYSTEMS

Use of Surveys

IFPRI has found that there are large regional differences in patterns of consumption that seem to be closely associated with differ-

ences in patterns of production, which in turn are determined largely by agroclimatic characteristics, modified by socioeconomic factors. These findings are similar to those of ICRISAT and suggest that in nutrition planning it may be more important to study differences between regions and villages than to understand variations in nutritional status within them. Probably it is primarily at the region or village level that the determinants of nutrition express themselves.

In designing improved technology ICRISAT has always been concerned about incorporating desirable equity features such as employment creation. A prime example is the research on the economics of herbicide use in rainfed regions of India. It was concluded from an analysis of village survey and experimental data that herbicides were not only less cost-effective than traditional animal and human methods of weed control, but also that their use in farming systems would displace large numbers of low-income female laborers. As a result, herbicide research has not been a major priority at ICRISAT in India.

Nutrition planning has not been explicitly incorporated into CIMMYT's programs to date but the potential exists. Considerable emphasis has been placed on on-farm research as a means of identifying target farmers for technology design and nutrition planning purposes. Diet survey information has already been used to help identify crops that can complement the new early-maize varieties from a nutritional perspective.

Analysis of Aggregate Data

Equity and efficiency concerns have been incorporated into decisions about research priorities among irrigated, rainfed wetland, deepwater, and dryland rice-growing regions at IRRI. If the major concern was with efficiency, then less of IRRI's resources would be devoted to rainfed and deepwater environments. However, IRRI believes that equity is important and hence stresses the less well-watered regions with a view to increasing their incomes and nutritional status.

Criteria such as man/land ratios, variances in yield, and nutritional status have been used in determining priorities in the allocation of regional research resources at ICRISAT. Data on agroclimatic and socioeconomic variables have been assembled to characterize environments in which both crop-improvement research and farming-systems research are being conducted. These data have been arrayed in a series of multifactor scoring models to assist in the determination of regional research priorities taking considerations of equity and efficiency appropriately into account. Analyses using both farm and aggregate models have been conducted at ICRISAT to assess the probable effects of these prospective technology choices on farm incomes, employment, food consumption, and nutritional status.

Studies of Farming Systems

The focus at IITA has always been on problems of small farmers. Maintenance of soil fertility, which offers nutritional benefits by improving the nutritional quality of foodgrains, is given high priority in research. Research on cropping systems helps to ensure

diversification of diets and hence better nutrition throughout the year. The aim of agroforestry research on aspects such as alley cropping with Leucena and plantains is to improve production of both crops and livestock, with consequent nutritional benefits.

ICRISAT has found intercropping to be an important practice in traditional farming in the semiarid tropical regions of India and Africa. It provides stability and diversity to the self-provisioning nature of subsistence farming in these regions. The consumption of so-called "protective foods," such as milk, vegetables, fruits, and meat, which provide the necessary vitamins in which diets are usually deficient, has been found to decline significantly during periods of drought. Policy and technology interventions are necessary to alleviate this adverse effect of droughts. In studies at ICRISAT the importance of common property resources in and around villages in semiarid tropical India has been documented and implications for future activities in the Farming Systems Research Program have been identified.

Emphasis is placed upon lowland commercial production systems by AVRDC because these regions offer the best potential for improvement of nutrition through the use of vegetable production and because there are large numbers of small farmers. Attention is also given to the development of household systems of consumption and production that will bring nutritional benefits.

The AVRDC garden project arose out of the nutrition surveys mentioned earlier. The focus of this project is on school, home, and market gardens. Research has been conducted to measure the additional supply of vitamins, minerals, and proteins that can be generated from school and home gardens, and the results are impressive. The potential income from small market gardens near towns and cities, which increase both employment opportunities and supplies of seasonally scarce vegetables, is also attractive.

The development of rice cultivars with a short growing season at IRRI has made possible increases in cropping intensity and diversification of crops grown after rice. Both innovations improve nutritional status and allow a more nearly even seasonal pattern of food availability together with increased income and employment. IRRI will include nutritional concerns in its farming-systems research in the future. It will also examine more closely the deterioration of grain quality in storage.

Considerable research on improving draught power availability has been conducted by ILCA with a view to increasing and stabilizing crop incomes of small farmers. In this way nutrition is expected to improve. In the humid zone of southern Nigeria the strategy is to reduce the disease incidence of dwarf trypanotolerant sheep and goats in order to reduce mortality and improve the availability of animal products for small herders. In the semiarid tropical regions of Mali the role of intercropping legume with millet in order to improve draught power availability at the end of the dry season has been a particular focus. It is expected that this will also increase meat and milk production and hence human nutrition.

Most of the IARCs have increased their emphasis on development of improved cultivars and production systems that enhance the stability of production and thus reduce seasonal and irregular fluctuations in nutritional status.

Mechanization, Processing, and Markets

Research on development of improved grain dryers has been conducted by IRRI. The aim has been to reduce quality deterioration of the short-duration cultivars of rice, which are generally harvested during the rainy season. Cost-effective dryers have been designed as it has been recognized that the market is not prepared to pay a premium for quality rice.

CIP is conducting research on processing of potatoes, including the development of potato-drying technology and mixing dried potatoes with other ingredients for reconstitution into soups that would allow a more balanced diet.

In designing its technologies ICRISAT has endeavored to ensure that employment and hence nutritional status are not adversely affected. In addition to the study on the use of herbicides mentioned earlier, studies of the effects of tractors on employment have also been made and incorporated into the design of agricultural technology.

IFPRI is looking at the effects of technological change on income and nutrient consumption. The effect of expansion of cash cropping on the nutritional status of semisubsistence farmers is not well understood. Earlier studies have given conflicting results. Three case studies are being initiated to understand the relationships between commercialization of crop production and human nutritional status.

IMPACT OF IARC RESEARCH ON NUTRITIONAL WELFARE

Impact on Producers

All the wheat grown on more than 35 million hectares--more than half the area sown with wheat in the developing world--is derived from CIMMYT germ plasm. More than 100 varieties and hybrids of maize based on CIMMYT materials have been released in 25 countries during the past five years alone. CIMMYT has not attempted to measure the nutritional effects of the adoption of high-yielding varieties that have emanated from its collaboration with national research programs, but it is clear that they have been quite significant. A study by ICRISAT has shown that in India the aggregate nutritional effect of the new wheats was such that the availability of energy, proteins, and amino acids during the period since the mid 1960s when the new dwarf wheat cultivars were first released, has been substantially improved.

CIMMYT contends that small farmers in developing countries have benefited as much as have large farmers from the green revolution in wheat and maize. The current emphasis on breeding cultivars that are resistant to the principal stress factors is a further recognition of the importance of developing improved cultivars that will be of value to resource-poor farmers. Because small farmers have adopted the improved cultivars, CIMMYT suggests that their incomes must have risen and hence that their nutrition has "very probably" improved also, since most of those who are malnourished are resource-poor farmers. The example is cited of a tenfold increase in wheat production in Bangladesh as a result of the introduction of high-yielding varieties of winter wheat in that country. Half the new wheat farmers have

holdings of less than one hectare, and 60 percent of these retain for home use all the wheat they produce. The nutritional benefits of this development are presumed to be large.

Several country studies are cited to show that CIP varieties, developed in collaboration with national programs, have increased yields of potatoes significantly. In Rwanda, for example, the additional potato production has been particularly valuable in improving the nutritional status of weaned infants.

More than two-thirds of the rice cultivars developed locally in Asia contain IRRI lines in their parentage. Modern varieties of rice have increased yields between 1.5 and 2.5 tons per hectare in the irrigated and more favorable rainfed rice-growing regions of Asia. Modern varieties have also made possible increases in cropping intensities that have facilitated diversification, with attendant, but unmeasured, nutritional benefits.

Farm size and tenure have apparently had little effect on the final adoption of modern varieties of rice. Adoption seems to be determined primarily by environmental factors, suggesting once more the importance of selection of regions in determining the ultimate welfare effect of research and development, including nutritional improvements.

The modern varieties of rice are scale-neutral and have made possible absolute increases in the incomes of labor and small farm households. Obviously ownership of assets largely determines income shares, but if it is assumed that income affects nutritional status, there must have been an improvement in the nutrition of labor and small farm households in the regions in which the modern varieties of rice have been adopted. As IRRI and other centers point out, however, they have not made any attempt to measure empirically the relations between adoption, employment, income, and nutrition. This remains a subject for considerable research by both social scientists and nutritionists.

Adoption of improved technologies that have emanated from research by IITA is seen as the only proxy from which IITA can infer the likely nutritional effects of its activities. Five varieties of cassava have been released in Nigeria and now occupy an area of 80,000 hectares. Derived varieties and selections of cassava from IITA have also been released in Sierra Leone, Zaire, Gabon, the Congo, Equatorial Guinea, São Tomé, Tanzania, Seychelles, Rwanda, Liberia, and Cameroon. A considerable number of varieties of sweet potato that are resistant to pests and disease have been released in the region. Development of tissue-culture techniques has improved the ability of IITA to spread improved cultivars of sweet potato through Africa.

A 60-day variety of cowpea has been developed and is expected to offer considerable nutritional benefits in those regions having a short rainy season. Improved cowpea cultivars that are resistant to pests and disease and that yield well have been released in nine countries. In Nigeria improved cultivars of maize from the collaborative programs of IITA were sown on an area of 200,000 hectares in 1981. In Cameroon they have been sown on 150,000 hectares and on unknown areas in Benin and São Tome. New lowland varieties of rice were released in 1984 in Nigeria and an improved iron-toxicity-tolerant cultivar was released in Liberia in 1979.

Impact on Consumers

A CIMMYT study showed that consumption of wheat by the rural poor in India increased following the introduction of the improved cultivars. In addition wheat prices rose least among prices of all the cereals in urban areas of India. Wheat and maize contribute significantly to world supplies of calories and proteins, and the contribution of wheat has increased since the mid-1960s. The implication to be drawn is that research on these crops by CIMMYT has had a considerable effect on the nutritional well-being of people living in developing countries.

Research by IFPRI has shown that income elasticities of demand for rice are higher in rural areas than in urban areas of some developing countries because of the generally lower levels of income in the former. Price elasticities of demand for rice and cassava are also generally higher in absolute terms in rural than in urban Indonesia. These findings clearly imply that successful technological change in these crops will offer larger gains in social welfare in rural areas than in urban areas, both from changes in consumers' surpluses and in improvement of human nutritional status.

IFPRI has examined the effects of consumer-oriented food subsidy policies in a number of developing countries from the point of view of both nutrition and welfare, and by integrative analysis it is trying to derive general principles from these studies. The effectiveness of various methods of providing subsidies is being examined through evaluation of food-stamp programs and subsidies for production and consumption and by identification of commodity priorities for subsidization in order to obtain the greatest nutritional effect. Food subsidies have been shown to improve the distribution of income and the nutrition of the poor in developing countries.

A study of import strategies in Egypt has shown that when the prices of imported food rise, food imports decline less than proportionately. This places a burden on imports of industrial products and raw materials that presumably affects the employment and nutrition of the urban poor adversely.

Studies by CIP have shown that the national and international statistics on production and consumption of potatoes have been considerably underestimated in the past. As a result of research by CIP, FAO is considering a revision of its data on potatoes for countries such as China.

A study of potato marketing in Peru conducted by CIP showed that middlemen provide marketing services efficiently and competitively. In studies of demand patterns in developing countries, the income and price elasticities of demand for potatoes have been found to be high, and the consequences of research on potatoes in regions with nutritional deficiencies are likely to be beneficial.

Nutritionists and anthropologists have successfully combined their efforts at CIP in reviewing the literature on the importance of potatoes in human diets in the developing world. These studies have covered aspects such as nutritional value, the effects of cooking, processing, and storage, and toxic components. It has been pointed out that there is a dearth of data available on the use of potatoes, including information on the portions of production used for seed, processing, livestock feed, waste, and fresh food. Research has shown that among the principal food crops, the most rapid rate of increase

in production has been in potatoes: 93 percent in low-income food-deficit countries of Asia and 35 percent in those of Sub-Saharan Africa during the past 10 years. While CIP does not claim credit for this increase the implication is clear that research on potatoes is having a significant effect on nutrition.

Nutrition surveys have been conducted by ICARDA to determine the extent of malnutrition and its causes in urban and rural Jordan. Another study is planned for Syria. Among the children in Jordan the serious deficiencies identified were of calories rather than protein. Bread is the principal item of diet in both rural and urban Jordan, and since subsidies on wheat apply only in urban areas, the rural poor have been shown to suffer accordingly.

CIAT has found that the relative importance of the contribution of various commodities to the total supply of calories and protein differs among the several countries of Latin America. In general research by CIAT indicates that calories rather than protein are the limiting factor in diets, although the variation in adequacy among socioeconomic groups may be greater with respect to protein. Little is known about the intrahousehold distribution of nutrient status.

CIAT has assembled considerable data on the importance of its mandate commodities in diets and how it varies by region and income level in Brazil. This work appears to have been done in collaboration with a nutrition institute. As incomes rise the share of CIAT's mandate crops in consumer expenditures seems to fall, implying that research on beans, cassava, and rice will have a proportionately greater beneficial effect on the nutrition of the poor. This will not necessarily be true of beef because the share of total expenditure that is for beef increases with level of income. The CIAT commodities were shown to provide 30-60 percent of total dietary calories and 39-55 percent of total protein and to account for 20-48 percent of total food expenditures.

A study of the effect of the CIAT rice-breeding program in Colombia has shown that the improved varieties in the lowland regions were of benefit primarily to low-income consumers. CIAT did not undertake a nutrition study to determine the precise effects, however, but relied instead on analysis of consumer and producer surpluses to come to these conclusions. An ex ante analysis of the probable effects of improvements in the productivity of cassava showed that the calorie consumption of the poorest 25 percent of the population of Brazil could be increased 45 calories per capita a day. A similar improvement in the rural Brazilian Northeast could alleviate up to 20 percent of the calorie deficiencies in the diets of the poorest 25 percent of the population in that region.

Other findings at CIAT have suggested that research should be focused on commodities for which expenditure by the poor is high or where the income elasticities of demand by high-income groups are low. The effect of this strategy would be to ensure that growth in income would not put undue upward pressure on prices of commodities that are important in the consumption patterns of the poor.

CIAT has conducted a regional analysis of the importance of cassava as human food in countries outside the region of its primary mandate, namely, Latin America. The study is to be used to set regional priorities and determine appropriate commodity characteristics. It is suggested, for example, that for countries such as Malaysia, the Philippines, and Thailand, the appropriate emphasis

might be on production of cassava for starch and livestock feed, whereas in countries such as India and Indonesia, cassava will still be used primarily as human food. Because of the importance of beans in many African countries and the downward trend in production and consumption per capita, CIAT has now developed an important bean-research program in Africa.

Like CIMMYT, IRRI maintains that it is difficult to isolate its contribution to improvements in production and nutrition from the contribution of collaborating national agricultural research programs. They do cite a figure of 30 million hectares sown with modern varieties of rice in Asia, which represents more than 37 percent of all the rice grown in that region. They have estimated that the modern rice varieties in Asia have contributed 27 million metric tons, or 23 percent of the increase in Asian rice output, during the last 15 years, which is estimated to be worth 4.5 billion dollars annually. The rate of growth in rice production in countries planting more of the modern varieties has generally been higher than in those in which adoption has been at lower levels. This is true both in total production and in production per capita.

IRRI's studies suggest that consumers have in general gained more from the introduction of modern varieties of rice in Asia than have farmers. Returns to labor and to landowners, however, have increased in absolute terms. Because of the high income and price elasticities of demand for rice among low-income groups, IRRI concludes that the consumption of rice must have increased more among poor households. One of the reasons is that real prices of rice have declined 20 percent in Indonesia and 30 percent in the Philippines during the past several years. It is estimated that such a reduction in real prices would have caused an increase of 26 percent in consumption by the poor in Indonesia and 21 percent in the Philippines. The latter increase would have allowed the poor to meet their minimum calorie requirements.

ICRISAT has conducted extensive reviews of secondary data on nutritional status in the semiarid tropical regions of India and Africa to assist in determining the nutritional status of target populations. This has been supplemented by the collection of primary data in collaboration with nutritionists and home scientists for its village-level studies.

As mentioned earlier the research by ICRISAT on the demand for primary nutrients suggests that the income and price elasticities are high among the poor households in India that have been studied, implying clearly that whatever gains in productivity may be made in its mandate crops will be translated into a proportionately greater improvement in the nutritional welfare of the lowest income groups.

The studies by ICRISAT of consumers' preferences in India have indicated that the market does recognize differences both in cryptic and evident quality characteristics of the principal foodgrains consumed by the people living in the semiarid tropical regions. It appears, for example, that a premium is paid for sorghum cultivars that have a high protein content.

SOME ISSUES IN RESEARCH ON NUTRITION

Lack of Information

There seems to be a general lack of precise information on the actual nutritional effects of research conducted by the IARCs. Most have assumed that through the adoption of improved technologies emanating from research at the centers in collaboration with national agricultural research programs, incomes will have been increased and that part of the increase will have been spent to increase food consumption, with consequent improvement in nutritional status. CIMMYT recognizes that such aggregative analysis is insufficient to assess the actual nutritional effectiveness of its work. The need is for more disaggregated data such as that provided by IRRI (see Chapter 14), but CIMMYT does not think that it has the expertise to assemble such information. An additional sentiment voiced by a number of IARCs is reluctance to attribute increased food production and nutritional welfare entirely or directly to their own activities. Herein lies a dilemma for the CGIAR system.

Crop Replacement

It seems that the taste for wheat is increasing in nontraditional consuming regions such as Southeast Asia and West Africa. This is leading to greater demand for research to be conducted on adapting wheat to the tropical environments that these regions represent. The question arises as to the economic value of introducing wheat into these nontraditional producing areas, especially if wheat is going to be grown only in place of other crops. Assessment needs to be made of the probable nutritional consequences of replacing crops such as sorghum, millet, and chick-peas with wheat where this seems to be implied. Similar issues arise in assessing the value and desirability of introducing potatoes into more humid tropical environments where diseases, pests, and other problems will only ensure that far more research will be required if production is to be viable.

Seasonality in Nutritional Status

Schofield, Longhurst and Payne, and Chambers contend that it is generally the rainy season in developing countries when malnutrition and morbidity are greatest.[1] This may well be the case when the two

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[1] Sue Schofield, "Seasonal Factors Affecting Nutrition in Different Age Groups and Especially Pre-School Children," Journal of Development Studies 11 (October 1974): 44-47; Richard Longhurst and Philip Payne, Seasonal Aspects of Nutrition: Review of Evidence and Policy Implications, IDS Discussion Paper 145 (Sussex, England: Institute of Development Studies, University of Sussex, 1979); Robert Chambers, "Health, Agriculture, and Rural Poverty: Why Seasons Matter," Journal of Development Studies 18 (January 1982): 217-238.

principals in diets, energy and protein, and the incidence of respiratory ailments and other illnesses caused by wet conditions are considered. Major foodgrain staples are generally not harvested until the end of the rains, so during the few months before the harvest grain stocks and food consumption are often low. Even though the availability of foodgrains may be better in the seasons of surplus--the dry seasons--the availability of "protective" foods such as leafy vegetables in nonirrigated regions is much more restricted than during the rainy season. Since diets are primarily deficient in vitamins and minerals, at least in South and Southeast Asia, directing nutrition programs to the wet seasons may address only half the problem. Ryan et al. conclude that much more research on vitamin and mineral nutrition is required as part of the effort to enhance their availability, especially during the dry seasons.[2] It is in this effort that further development of common property resources (CPRs) such as village forests and fallow lands could be of great value. Jodha has found that CPRs contribute significantly to the income and nutrition of low-income groups in the Indian villages in the semiarid tropics that he studied.[3] If sources of vitamins and minerals that became freely available in the dry season and that could be grown on CPRs could be developed, a serious nutritional problem might be alleviated. Tree crops probably offer the best prospect for such an effort. During the wet season annual crops grown on private fields could doubtless provide the answer. The advantage of providing foods high in vitamins and minerals from CPRs is that poor people would be the principal beneficiaries. Further research is required to quantify the seasonal patterns of availability of nutrients derived from village CPRs more precisely. Then research and policy strategies to fill the nutritional gaps can be devised.

The inferences of Chambers and Longhurst and Payne that improved technologies should not exaggerate labor peaks during the wet season lest energy balances be adversely affected may be a non sequitur.[4] To advocate appropriate mechanization, the use of chemical weed control, and the growing of high-yielding varieties that are less time-constrained during the wet seasons, when energy balance is apparently negative, as Longhurst and Payne do, is to ignore a basic factor.[5] The creation of labor peaks is one of the few avenues by which laborers can expect to increase their wage rates and employment. With expenditure elasticities of demand for calories estimated by

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[2] J. G. Ryan et al., The Determinants of Individual Diets and Nutritional Status in Six Villages of South India, Research Bulletin No. 7 (Patancheru, Andhra Pradesh, India: ICRISAT, 1984).

[3] N. S. Jodha, "Market Forces and Erosion of Common Property Resources," paper presented at the International Workshop on Agricultural Markets in the Semi-Arid Tropics, ICRISAT, Patancheru, Andhra Pradesh, India, October 24-28, 1983.

[4] Chambers, "Health, Agriculture and Rural Poverty;" Longhurst and Payne, Seasonal Aspects of Nutrition.

[5] Longhurst and Payne, Seasonal Aspects, p. 31.

Radakrishna and Shah and by Murthy to be about 1.0 for low-income groups in rural India, the creation of wet-season labor peaks might bring about a net improvement in nutritional status.[6] This is an empirical question, however, that can be answered only after further research has been done. It is the landless and small-farm families who rely on wage labor for their sustenance who would benefit from the creation of labor peaks.

Consumer Studies

An important issue is the interpretation of the results of consumer-panel and market studies the aim of which is to define preferred quality characteristics that breeders could include in their programs. If, for example, small red beans are judged from market studies to be an inferior good, as CIAT found in Colombia, should breeders try to increase production of this type of bean, which presumably represents a considerable share of the food consumed by poor households? Or should priority be given to increasing the productivity of large red beans, which are consumed principally by high-income households? If the latter course were taken it might well be that poor consumers would be made better off by increasing the availability of a "superior" type of grain.

Postharvest Technology

How much emphasis should be given by the IARCs to postharvest technological improvements? IITA, for example, has concluded that because of the low elasticity of demand for roots and tubers, improvements in processing techniques must accompany increases in production if levels of consumption are to be maintained as incomes rise. In addition, improvements in processing to make probable future surpluses of roots and tubers usable as animal feed after human needs have been satisfied are being planned.

SUGGESTED TOPICS FOR RESEARCH

The suggestion made by CIMMYT that a panel of nutritionists be assembled for the CGIAR system as a whole is one that deserves close attention. CIMMYT also suggested that there be closer collaboration between the national agricultural research programs and their respective national institutes of nutrition, particularly in on-farm research.

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[6] R. Radakrishna and N. C. Shah, "Calorie Demand Function, Price Indices, and Some Distributional Implications," ANVESAK 11 (June 1981): 177-202; K. N. Murthy, Consumption and Nutritional Patterns of ICRISAT Mandate Crops in India, Economics Program Progress Report 53 (Patancheru, Andhra Pradesh, India: ICRISAT, 1983).

Demand Parameters

As a number of centers have suggested, there is a need for disaggregation of the benefits of IARC research from the nutritional point of view. Perhaps IFPRI is the appropriate institution to coordinate this type of activity. If such an institution as IFPRI can develop quick methods of estimating price elasticities of demand for food items consumed by the poor on the basis of national estimates, we will be in a much better position to employ the models developed by Freebairn et al. and Pinstrup-Andersen et al. to assess the distributional and nutritional consequences of successful technological change.[7]

Household Studies

An important subject for future research is the way intrahousehold patterns of income earning affect the nutritional status of the household and its individual members. Of concern here are questions such as the relative importance of the earnings of women and those of men, of food stamps and wages in cash or in kind, and so on. Such an approach could profitably make use of the framework of the new household economics and embrace questions such as the linkage between population, nutrition, agriculture, and technological change. Both the effects of income on nutrition and the reverse effect of nutrition on income-earning capabilities should be included.

Food Subsidies

Research is required on the design of food-subsidy policies that will ensure nutritional benefits to both the urban and the rural poor while avoiding disincentives to production. It appears that in the past a significant share of the benefits of food subsidies have accrued only to the urban poor, though what happened in Egypt may be an exception (see Chapter 10).

Vitamins and Minerals

Nutrients other than calories and proteins should be examined to determine whether there is scope for altering the content of nutrients such as vitamins and minerals, in crop-breeding programs.

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[7] J. W. Freebairn, J. S. Davis, and G. W. Edwards, "Distribution of Research Gains in Multistage Production Systems," American Journal of Agricultural Economics 64 (February 1982): 39-46; Per Pinstrup-Andersen, N. R. de Londoño, and Edward Hoover, "The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy," American Journal of Agricultural Economics 58 (May 1976): 131-142.

Collaboration with National Programs

ISNAR has raised the question whether it is desirable to include nutritional goals in the research, training, and communications programs of national agricultural research institutions in developing countries. Also, techniques for obtaining measures of the combined nutritional effects of research activities by both national and international agricultural research programs are needed. As has been mentioned earlier, most of the IARCs are reluctant to attribute nutritional benefits solely to their own activities. They need to collaborate with national agricultural research programs to help identify target groups for research and their needs. As ICARDA suggests, more knowledge of demand projections at the disaggregate level will be required to assist in this process.

Cropping Systems and Seasonality

Most centers point out that the new cultivars being developed in their breeding programs have a shorter growing season than the traditional cultivars. This has made possible increases in cropping intensity, and it would be desirable if more studies could be made of the effect of greater cropping intensity on the seasonality of labor supplies, income, consumption, and nutritional status. Greater emphasis could be given to cropping-systems research that aims to increase the productivity of crops with nutritional contents complementary to those of the mandate crops of the IARCs. Vegetables should be explicitly examined in this context because they are important sources of limiting vitamins and minerals.

Biotechnology

IITA has suggested that biotechnology, which could make possible wide crosses among root and tuber crops with those crops that have high protein content could improve the nutritional quality of the former. Techniques such as tissue culture and genetic engineering are suggested. It would be wise to assess the probable effect of such an approach on nutrition before making it part of any applied breeding program.

Import Replacement

The effect of diverting starchy foodstuffs into mixtures with wheat to make composite flours so as to save on the costs of imported wheat needs to be evaluated. The evaluation should include both the domestic resource costs of such a strategy and the probable effect on the nutritional status of various socioeconomic groups in the communities that are likely to be affected.

CONCLUSION

More and more the IARCs seem to have made higher yields and improved yield stability of the commodities in their mandates their

primary strategy for improving human nutrition in developing countries. The varied diets of the populations of developing countries have dictated a change in the attitude away from incorporation of improvements in nutritional quality that are centered on protein content and protein quality in the plant-breeding programs of the centers. Other factors that have influenced this change include growing evidence of a food gap rather than a protein gap, the difficulties encountered in achieving improvements in nutritional quality because of low heritabilities and genotype x environment interactions, and the high opportunity costs of enhancing nutritional quality while sacrificing other desired characteristics.

There is growing emphasis in crop-breeding programs on the improvement of evident quality characteristics preferred by consumers to ensure that the additional food supplies will be acceptable in the marketplace. Greater attention is also being paid to nutrients other than protein, such as vitamins and minerals, in recognition of the constraints on improvement of the nutritional status of the poor in developing countries that deficiencies in vitamins and minerals represent.

Increasing food production by developing cost-reducing technology is seen by the IARCs as the most effective mechanism for improving human nutritional status. This approach allows the incomes of farmers to be increased, the real prices of food to be reduced, or both. Since most of the commodities included in IARC mandates have income and price elasticities of demand that are inversely related to per capita incomes, it appears that most of the nutritional benefits of successful research will accrue to low-income households.

To enable more refined estimates of the effects of IARC research to be made in the future, additional studies are needed to measure income and price elasticities of demand for basic food commodities in the developing countries. These estimates should be disaggregated by region and by socioeconomic group within a region in order to examine the nutritional effect in an ex post framework as well as providing a basis for further ex ante assessment. Good estimates of this type are already available for countries such as Brazil, India, the Philippines, and Indonesia. It might be valuable for IFPRI to include coordination of further country studies in its future research.

To complement these parameter estimates additional data on the adoption of improved technologies that emanate directly or indirectly from activities of the IARCs plus estimates of the incremental yields attributable to the technology are required. These data can then be translated into supply shifts and by use of the demand parameters the nutritional effects can be assessed by inference. The disadvantage of this inferential approach to assessment of the nutritional benefits of research is that estimates can only be obtained on a household or consumption-unit basis. It is not possible to derive the nutritional effects on individual members of the households. Diet surveys conducted before and after the improved technologies have been adopted and with and without them are the only means of eliciting such effects.

Various IARCs have collaborated effectively in the past, but more emphasis could profitably be given to these efforts in the future to help ensure that a diverse array of crops is embraced in research programs of the centers, thus making it possible to increase the production of commodities that have complementary nutritional contents.

Good examples of such collaboration in the past include that between IRRI and IITA to improve the productivity of cowpea in rice-based cropping systems, that between IRRI and CIMMYT in the production of wheat after rice, and that between IRRI and IFPRI on policies having to do with rice in Asia. If vitamin and mineral deficiencies are as large as the accumulating evidence suggests, the collaborative assistance of AVRDC might be vital in the future. Many centers have mandates to conduct farming-systems research in which they could include nonmandate commodities of nutritional value to their target populations. Some possible examples are collaboration between CIP and ILCA to test the scope for potatoes in the Eastern African highlands and cooperation between ICRISAT and ILCA to improve Vertisol management in Ethiopia.

High returns on further collaboration between IARCs and national and international institutions concerned with nutrition and health in developing countries are clearly possible. The suggestion that a panel of nutritionists be formed to help the CGIAR system articulate broad research strategies to take nutritional goals appropriately into account is a good one. It may even be time to consider recruiting nutrition scientists to more of the IARCs so that nutritional concerns can be incorporated into on-station and on-farm research. Inclusion of a nutritionist on the staff of a center such as ISNAR might make it possible to incorporate nutritional considerations into its training, research, and communication activities with national programs in developing countries. As ISNAR correctly points out, taking such a step must be in part a response to an induced demand for nutritional planning by developing countries. The evidence presented by the centers in the papers that they prepared for this workshop suggests that there may be sufficient material on which to begin developing training programs with this effort in mind.

Finally, it seems clear that there is little hard evidence on the actual nutritional effects of research conducted by the IARCs. On the other hand, there is convincing evidence that most IARCs have explicitly or implicitly incorporated nutritional concerns into the design of their programs and the determination of their priorities. No center has attempted to measure the nutritional effects of its research, and one reason this may not be a desirable thing to do is the close interaction between research activities of the centers and those of national agricultural research programs in developing countries. All that can be hoped for is that with additional information on the economic parameters required for such an assessment, a synthesis of the probable effect can be made using data on the adoption of new technologies that may arise from joint activities of IARCs and national programs. This synthesis could be supplemented by a number of case studies, perhaps making use of diet surveys.

Discussion

Kutlu Somel

I would like to commend James Ryan for presenting a most coherent synthesis of the papers of the various centers.

At ICARDA, even though it was founded in 1977 and began operations at its headquarters in Aleppo, Syria, in 1979, we are involved in nutrition, our research does have nutritional dimensions, and we consider it to be of great importance.

Centers have a multitude of goals. For those that concentrate on production, the underlying goal, through which they can contribute to the solution of nutritional problems, is to increase the profitability, productivity, and stability of the farming systems. As indicated by many participants in this workshop, there are other factors that affect nutritional problems. Production-oriented centers, however, cannot be expected to delve actively into these dimensions of nutrition by virtue of their immediate tasks and also because there are other agencies and organizations--IFPRI, WHO, and FAO, for example--that have competence and comparative advantage in such matters.

The problem then is to develop a synthesis of procedures, based on the experience of the centers, for three aspects of nutrition-related research.

The first has to do with methods of establishing the priority of nutrition research at the centers, both at the center level and at the collaborative-outreach, on-farm level. There is much research related to nutrition being done at the centers. One example is quality research; at this meeting the parameters of such research can be discussed. At the field-research level, activities have involved research on the acceptability of crops and their characteristics, the identification of vulnerable groups and their needs, and selective research aimed at the needs of specific groups. During this meeting it will be necessary to scrutinize these activities to increase their effectiveness in answering nutritional issues.

It has been suggested that nutritional expertise must be enhanced in the IARCs. This recommendation must be balanced against the budgetary constraints faced by the centers because of the scarcity of resources.

The second aspect is the incorporation of nutritional dimensions into research. The IARCs are already involved in nutrition research that is of immediate relevance to their activities. Research on the quality characteristics of crops has been mentioned. Increasing production through appropriate technologies is another way in which international centers contribute to the solution of nutritional

problems. It has been suggested that the IARCs look into those commodities that are most often consumed by the poor; it is my contention that this is exactly what the centers, by definition, are doing. We do not conduct research on exotic commodities; we emphasize those commodities that are staples and are consumed primarily by the masses.

We do face a restriction, as far as commodities are concerned, in our mandates. The primary purpose of having well-defined mandates is to intensify the focus and increase the efficiency of research. Some centers have specific crop mandates. Yet, when we go to the "real world" of the farmers, we invariably have to work in farming systems that involve many crops and livestock. I have always wondered why my colleagues--in CIMMYT, for example--have not surreptitiously started research on beans that in many instances are found intercropped with maize. At ICARDA we are fortunate to have a farming-systems research perspective and we are actively involved in, for example, research on crop rotation and livestock. Through this research we expect to contribute to an increase in the profitability and stability of farming systems by introducing crops that may reduce the incidence of diseases and other problems that arise due to dependence on monoculture.

In this respect it must be emphasized that of the 13 centers in the CGIAR system, some that have quite long histories have been able to develop, through time, sound biological bases for their research. Subsequently, they have gradually been able to incorporate into their research other dimensions that have come into being because of constraints in, for example, social, economic, and nutritional aspects.

Those centers such as ICARDA that are just getting started can benefit from the experiences of the older centers. An example is the incorporation of the farming-systems research perspective into our activities. What is necessary is to assess thoroughly and establish priorities among the various aspects of our research activities. The development of a sound biological basis of research, however, must have the highest priority.

This is necessary because we are working in "difficult" environments--difficult in climatic conditions, in soils, and in social and economic conditions. In this situation nutritional concerns are competing with other objectives in the face of pressures to produce results. If we can find in this meeting or through other channels, avenues through which nutritional concerns will facilitate the achievement of results and increase the effectiveness of our research efforts, we will be ready to take the necessary measures to incorporate nutritional dimensions into our research.

Finally, the most important area for discussion in this meeting should be the development of techniques, methods, and approaches for assessing the effect of our research on nutrition. We hope that nutrition scientists will be able to contribute significantly to this exercise.

In this connection I would like to alert participants to some problems that may arise in the case of resource-poor areas. The environmental, biological, social, and economic stresses that are felt by rural farm households in the resource-poor areas invariably call for solutions that go outside agriculture. These may produce efficient results in improving the welfare of the family--for example, by diversifying family labor resources among on-farm, off-farm, and urban employment. Some of these solutions, however, also imply a reduction in the importance and income-generating capacity of agricultural

production. Hence, when considering nutritional problems and their solutions, we must decide whether we should look only to agriculture or should look into the larger entity from which solutions emanate.

This requires that we overcome the bias toward local agricultural production as the only source of food and cast a critical eye at the potential and actual contribution to nutrition of processed foods and purchased foods. While our activities may not in every instance bring about increases in food production, they may create or release resources with which more food can be purchased.

At this point general measures of the effects of the centers on nutrition through the spread of varieties and related technologies, the area they cover, the yield and production effects, and so on provide workable evidence for assessment. It is clear, however, that this approach lacks the specificity that nutritional measurements may require.

On the other hand, some of our location-specific activities produce more solid evidence, such as "in a given location, covering around 100,000 hectares and involving 30,000 families, we increased the production of commodities a, b, and c by x percent and had such and such an effect on nutrition." The value of such results is undeniable. Many studies project the number of malnourished at the turn of the millenium to be in the hundreds of millions, however. When we work on such a small scale, therefore, we should anticipate some criticism and be prepared to produce counterarguments.

In conclusion, the centers are involved in research activities that impinge directly or indirectly on nutrition. We expect that the deliberations of this workshop will show us the way to do a better job.

18
Incorporating Nutritional Concerns into the Establishment of Commodity Priorities in International Agricultural Research

Eugenia Muchnik de Rubinstein

During the past few decades agricultural research has undergone criticism because, some argue, it has contributed to a growing inequity in the distribution of income in many countries of the Third World. Others have maintained instead that by providing more and cheaper food it has benefited society as a whole, since in the absence of these technological changes food shortages would have been more severe, which presumably would have meant higher food prices, more imports of food, and lower real incomes for everyone, but particularly for the poor, who spend a large share of their budgets on food.[1]

One important aspect of the distributional effect of new technology is its effect on nutrition.

As Shah has observed, consumption is the final goal of all production activities.[2] Because food is one of the basic consumption goods, a basic necessity of life, it can be contended that economic growth should enable even the poor to have adequate food. Food consumption is linked to poverty in such a way that the "poverty line" is determined by the level of income or expenditure at which the observed daily intake of calories is equal to the recommended daily calorie allowance.

The decision to incorporate nutritional goals into the objective function of the international agricultural research centers (IARCs) is a typical problem of policy evaluation, the response to which should be guided by the benefits to society. Complications arise since the existing goals tend to be multifaceted and are often in conflict with one another. Commodity priorities, for example, set for the purpose of improving the balance of payments may be different from those indicated by the effort to realize large increases in the value of agricultural production or to increase the employment of rural labor. An additional complexity is the link between international research and

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[1] Per Pinstrup-Andersen, "Modern Agricultural Technology and Income Distribution: The Market Price Effect," European Review of Agricultural Economics 6 (No. 1, 1979): 17-46.

[2] C. H. Shah, "Food Preferences and Nutrition: A Perspective on Poverty in Less Developed Countries," Indian Journal of Agricultural Economics 35 (No. 1, 1979): 1-38.

national research; support for international research can either be concentrated in areas not covered by national research or seek to exploit complementary relations.[3]

If better human nutrition is a goal of the IARCs, it must be explicitly stated and steps must be taken to identify the places and the ways in which they can make significant contributions. This is not a simple task. Malnutrition is present in various forms, population groups, geographical locations, and economic activities, and its causes may be many. It may be a result of deficiencies in a number of factors, not only in the amounts and kinds of food available in the marketplace or on the farm.

The purpose of this paper is to synthesize the views of social scientists in the several centers of the CGIAR and others on whether and how nutritional goals figure in the setting of commodity priorities and to offer a brief survey of the activities that have been undertaken toward this end. Suggestions as to future activities and the information that is needed to incorporate nutritional concerns more effectively into the establishment of commodity priorities will also be made.

THE GENERAL FRAMEWORK

Pinstrup-Andersen has provided a brief overview of the linkages between agricultural research and human nutrition and has suggested ways in which nutritional concerns can be incorporated into decision-making regarding agricultural research priorities (see Chapter 3). He has, in fact, presented a tight summary of a systematic research effort in which he and others have been involved for almost a decade and which they have ably documented in their writings.

The nutritional effects of expansions of food supplies are seen to depend on the distribution of the increase between the malnourished population or those at risk of malnutrition and well-nourished groups, and it will vary significantly, depending on, among other factors, the crop or commodity that is expanded.

Different commodities are produced under different production systems, labor intensities, and types of farmers; have different compositions of nutrients and different prices; and represent different shares of the budgets of households in which some members are malnourished. The distribution among consumers, producers, and landless laborers of the economic surplus that comes about from the adoption of cost-reducing technologies will also be determined by decisions regarding commodity priorities, although more important perhaps will be the economic policies and the preexistent distribution of assets, which are outside the reach of agricultural researchers. Within each of the three groups: consumers, producers, and landless laborers, the distribution of benefits between the malnourished and the rest will again be influenced by decisions on commodity priorities.

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[3] Hans Jahnke and Dieter Kirschke, Quantitative Indicators for Priorities in International Agricultural Research (Rome: Food and Agriculture Organization of the United Nations, September 1983).

Information is needed on the likely effects of technological change on the global availability and market prices of commodities and on the incomes of producers. Undernourished groups and the foods that they produce and consume must be clearly identified, and the way they would adjust their food intakes in response to changes in the prices of individual commodities and incomes, the commodity-related employment of the rural landless poor, and the way food is allocated within the household must all be understood.

Additional information on other factors, particularly food, foreign trade, and price policies, is also needed. If free trade is maintained, an increase in the supply of a traded crop will probably not cause significant price reductions, so the effect on nutrition in the urban sectors will be negligible.[4] The opposite will come about if domestic prices are insulated from international prices and are permitted to adjust in response to changes in domestic supply.

To obtain quantitative data on all the relations discussed above would probably demand an excessive amount of time and resources. Pinstrup-Andersen has suggested both short cuts and the use of parameters that are not project-specific.[5] According to him from a nutritionally ideal point of view priority should be given to commodities that occupy a large share of the budgets of households that have malnourished members and for which the price elasticity of demand for calories and protein is high;[6] that require a large share of the resources in land and labor owned or controlled by producing households that have malnourished members; and that generate employment and incomes for the landless poor. Conflicts will arise, however, since the relative importance of malnutrition of consumers and that of producers differs from one country to another.

These criteria are even more difficult to apply in large countries in which there may be important regional differences or to the work of centers that have mandates across countries that differ in resource endowment, stage of development, and so on. Precisely one of the arguments of those who think that nutritional goals should not be considered in the setting of commodity priorities in their centers is that "while a global problem, malnutrition needs location-specific solutions" and that "although malnutrition is generally correlated

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[4] Alberto Valdés, "Integrating Nutrition into Agricultural Policy," in Nutrition Intervention Strategies in National Development, ed. Barbara Underwood (New York: Academic Press, 1983).

[5] Per Pinstrup-Andersen, Nutritional Consequences of Agricultural Projects: Conceptual Relationships and Assessment Approaches, World Bank Staff Working Paper 456 (Washington, D.C.: World Bank, April 1981).

[6] The condition that the income elasticities of demand in the high-income strata should be low or negative is also included in Douglas Pachico and J. K. Lynam, "Food Supply and Malnutrition in Latin American Agriculture," in Trends in CIAT Commodities, Internal Documents in Economics 1.6 (Cali, Colombia: Centro Internacional de Agricultura Tropical, May 1981).

with poverty, the specific causality varies from area to area" (see Chapter 5).

COMMODITY PRIORITIES IN THE RESEARCH CENTERS

Insofar as the selection of crops for agricultural research by the IARCs is concerned, commodity priorities were in general determined by mandate at the time that each of them was founded. Some, like CIP and IRRI have global mandates for single crops, and commodity priorities are therefore not a central issue. Others, ISNAR and IFPRI, do not engage directly in agricultural research, although they do assist other IARCs or national research institutions in a number of activities, the former on issues having to do with the planning, organization, and management of agricultural research; the latter undertakes research on the relations among technological change, food policy, agricultural growth, overall economic growth, and social welfare. The remaining centers in the CGIAR have global mandates to do work on several commodities and sometimes have additional responsibilities for research on other crops at regional levels.

Although the commodity portfolio of the third category of centers is predetermined for each of them, it is possible to modify in time the budget allocation to each of the commodities in the system as a whole and within each center. Also, the relative allocation of research funds for individual commodities within the CGIAR may change over time, as illustrated in Figure 18.1.

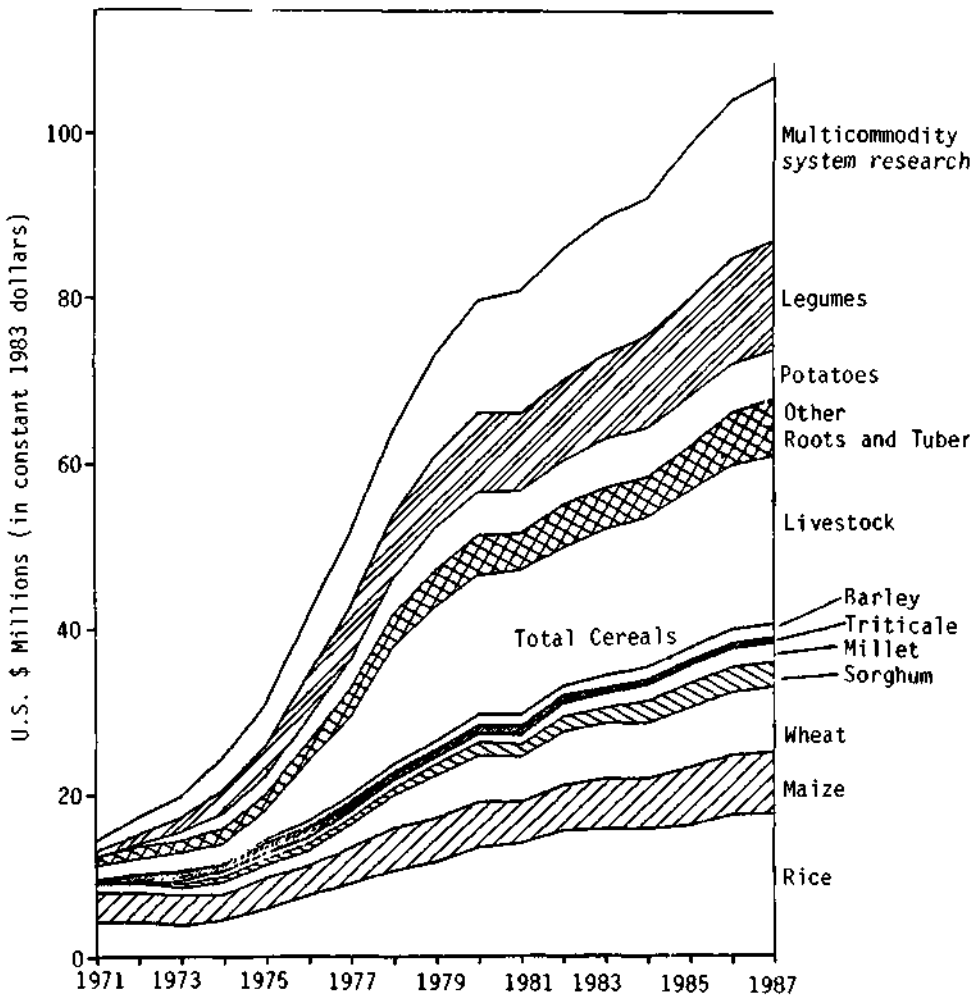
On the basis of the papers prepared by social scientists from the several centers, it is possible to infer the degree to which decisions made on commodity priorities have been associated with nutritional goals.

In general, the mandates of the various centers as they pertain to commodity priorities are considered to have built-in nutritional concerns in the sense that the commodities that were selected in each instance represented the main sources of calories or protein for the bulk of the population in the target regions. But most of the social scientists do not interpret nutritional concern as a specific preoccupation with the malnourished population or with those at risk. The implicit assumption is that expanding the food supply will mean better nutrition for everyone, including the poor and the malnourished, who spend larger shares of their budgets on food. This assumption, as mentioned earlier, may prove to be incorrect in some circumstances.

One center, for example, indicated that nutrition was a primary goal in the setting of commodity priorities because of the specific nutrient content of the commodities and the importance of their contribution to the average diet of the population--not specifically to those of the malnourished. Another center considered nutritional concern to be reflected in the composition of its portfolio of commodities, as it sought to achieve a dietary balance at the farm level by including certain crops or livestock products for their high calorie content and others for their high protein content.

Only two centers, CIAT and ILCA, stated that nutritional concern, in the form of observation of the patterns of food consumption of the low-income strata of the population, was present when commodity priorities were determined. In neither instance was a formal methodology or procedure used in decisionmaking. Nutritional goals were

Figure 18.1--Annual research and research support expenditures of the CGIAR, by commodity, 1971-87



Source: Consultative Group for International Agricultural Research (CGIAR), "Statistics on Expenditures by International Agricultural Research Centers, 1960-1987," CGIAR Secretariat, Washington, D.C., August 1983 (mimeographed).

Note: The data are actual for 1971-82, estimated for 1983, and projected for 1984-87.

[a] This includes farming systems, food policy, genetic resource conservation, and assistance to national research programs.

said to have been considered along with other socioeconomic objectives without the attachment of explicit weights to different objectives.

None of the centers has mentioned that nutritional considerations have been incorporated into cross-commodity comparisons within its portfolio. An exception is an exercise carried out at CIAT not too long ago, when the anticipated positive or negative effects on nutrition of new cassava and rice technologies were compared as part of a multiobjective function.

Finally, only two of the centers, CIMMYT and ICARDA, explicitly stated that nutritional goals are not considered relevant to the realignment of priorities by the IARCs. In general, the arguments in favor of their position are that the international centers are producers of intermediate goods, so it is the job of national centers to choose the products that are the most convenient, nutritionally or otherwise, according to the specific problems of each country, and that, in the case of CIMMYT, world consumption of bread wheat and maize is so high and variations in its use are subject to so many factors as to make nutritional concerns of little use in the establishment of commodity priorities. It is best, in their view, to encourage countries to formulate and articulate development policies to help them guide their own research.

In this respect current efforts to incorporate nutritional goals into agricultural research at the national level are not encouraging. According to ISNAR it has not yet been explicitly asked by any country to assist with the establishment of a nutritional program or to take nutritional goals into consideration. The expectations of IFPRI are also negative in its present attempt to help strengthen the capabilities of national institutions to deal with the interactions among agriculture, public policy, and nutrition; and IFPRI has observed that several factors tend to oppose success in this respect.

OVERVIEW OF CURRENT RESEARCH EFFORTS OF THE IARCs

The IARCs have undertaken a series of research activities and actions that are directed toward the gathering and understanding of empirical evidence on present nutritional issues and problems. The degree of incorporation of nutrition-related activities, which are useful for setting commodity priorities, into the normal work of social scientists within the IARCs varies widely from one center to another. Some of the centers acknowledge that they are in the very early stages of such efforts.

Activities have been arbitrarily grouped according to the main type of information provided by a study or program. Only those activities that are directly relevant to the establishment of commodity priorities have been included in the following list.

Contribution of Commodities to the Diet

Attempting to deal with the food sector of a country as a whole, collecting data on and analyzing the contribution of various commodities to average per capita consumption of calories and protein, is a widespread activity within the IARC network. Information is usually obtained from national or FAO statistics, except in some regions such

as tropical Africa and the Middle East where there is a lack of reliable statistical data, and except for commodities such as potatoes and vegetables, data concerning which are usually consolidated with statistics on other similar crops in secondary sources. In such instances, baseline surveys at the household level have been either specifically undertaken or obtained from national sources.

Trends and Ex Ante Analysis

Information on current supply of, demand for, and trade in food and on the future food needs of a country or region is useful for the establishment of commodity priorities because it provides some idea of the magnitude and location of anticipated shortages of food. This type of analysis requires estimates of future growth in income and income elasticities of demand for each commodity.

Research activities of this nature have been reported by IFPRI, CIMMYT, CIAT, and CIP. IFPRI has studied the situation in a large number of developing countries. Another effort in this area is the work by Jahnke and Kirschke, which is the result of a request by the CGIAR to FAO to update and broaden the quantitative indicators that can be used by the CGIAR as guides in the setting of priorities.[7]

Consumption Patterns and Food Acquisition Behavior of Low-Income and Malnourished Groups

Present knowledge of the food-acquisition behavior of the poor and malnourished is insufficient for predicting the consumption and nutrition effects of agricultural research or food policies.[8] To begin with, a functional classification of the nutritionally deficient population is needed. Who are these people? Where are they located? Are they within or outside the agricultural sector? What is the composition of their diets and what are the reasons for their nutritional deficiencies? It is important to find out which is the most vulnerable group: poor urban consumers, the landless rural poor, small semisubsistence farmers, or mothers and young children.

Most social scientists working in this field identify the malnourished with the poor because low income is often the main cause of malnutrition. But this is not always so.[9] If malnutrition is confined primarily to small farmers, moreover, cost-reducing technologies that reduce the prices of demand-inelastic commodities will not favor nutritional goals unless the sectors under study are self-sufficient,

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[7] Jahnke and Kirschke, Quantitative Indicators.

[8] Per Pinstrup-Andersen, "Incorporating Nutritional Goals into the Design of International Agricultural Research," paper presented at the meeting of directors of the international agricultural research centers, Washington, D.C., June 1983.

[9] Cheryl Williamson Gray, Food Consumption Parameters for Brazil and Their Application to Food Policy, Research Report 32 (Washington, D.C.: International Food Policy Research Institute, 1982).

but they will do so if malnutrition is instead located primarily within the urban sector.

Even inside the low-income stratum the diets of urban and rural consumers have been shown to vary greatly from one another, at least in Latin America, particularly in large countries. Information obtained from low-income urban consumers will not be appropriate for use in planning agricultural research when the vulnerable groups are found primarily among the rural population.

Finally, if malnutrition is concentrated in the population of mothers and young children of low-income families, there may be considerable leakage from programs that seek to reduce commodity prices as a means of transferring income to these families and thereby to improve their nutrition. The decisions that are made within the family group may seem rational to the head of the household yet not be optimal from the point of view of nutrition. Also, the household may choose to spend only a fraction of the income transfer on low-cost calories or may spend it on food for well-nourished members, thereby reducing the effectiveness of funds spent for agricultural research or of any other policy for the achievement of nutritional goals.[10]

Thus, information on intrahousehold distribution of income control and allocation of the time of the individual members is also of particular importance. In the case of semisubsistence farm households with malnourished members, information is needed on the integrated process of making decisions concerning production and consumption. Households may consider it necessary to allocate more food to income-earning members at the cost of malnutrition of the economically inactive members, such as small children.

Cross-sectional data on household expenditures have been widely used at the centers to describe the consumption patterns of low-income consumers and to derive elasticities of demand for individual commodities. But price elasticities are not usually available for functional classes or income strata because they are difficult to derive from cross-sectional data.

Six of the Centers--CIAT, CIP, CIMMYT, IFPRI, ICRISAT, and IRRI--have reported activities the purpose of which is to estimate commodity-specific income elasticities of demand by income stratum. Using data on household consumption collected by the Program of Joint Studies on Latin American Economic Integration (ECIEL), CIAT has estimated income elasticities by income stratum for various foods and food groups for a number of Latin American cities.[11] CIP has also recently examined the importance of potatoes in the diets of various population

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[10] It has been shown that as their incomes rise people purchase foods that cost more per unit of energy; see Shlomo Reutlinger and Jay Katona-Apte, "The Nutritional Impact of Food Aid: Criteria for the Selection of Cost-Effective Foods," discussion paper, Agricultural Research Unit, World Bank, Washington, D.C., September 1983.

[11] Eugenia Muchnik de Rubinstein and G. A. Nores, "Gasto en carne de res y productos lacteos por estrato en doce ciudades de América Latina" Centro Internacional de Agricultura Tropical, Cali, Colombia, 1980 (mimeographed); Pachico and Lynam, "Food Supply and Nutrition."

According to the description provided by ILCA, these studies provided the kind of information that is useful in planning research in that it helped to identify and rank the priority of component research studies.

Ex Ante Analysis of the Effect of Technological Change on Market Prices and the Incomes of Producers

The incorporation of nutritional goals into agricultural research planning makes it necessary to consider the probable effects of alternative strategies both on food supplies and prices and on the generation and distribution of income.

From a nutritional point of view it is clearly insufficient to use the amount of additional food produced as an indicator of the nutritional effect that can be expected. The effect of a given increase in supply on the incomes of malnourished rural families will depend on the way the supply increase is brought about--through what commodity, what technology, and so on. Research technology that brings about an increase in the supply of one commodity may cause reductions in the production of other commodities because of some scarce fixed resource, and the nutritional implications may even be negative.

Ex ante analysis is a difficult and time-consuming activity. In fact, only two institutions, ICRISAT and CIAT, report having undertaken some type of ex ante exercises, and these only recently. ICRISAT reports having developed during 1983 indexes of commodity priorities for different groups of countries involving considerations of efficiency and equity. Actual allocation of resources among the center's portfolio of commodities was compared with the allocation suggested by the different indexes. It became evident that the actual pattern of allocation of research resources to crops and regions within the center was similar to the allocation suggested by an index that had an implicit preference for considerations of efficiency.

At CIAT nutritional goals have recently been analyzed for planning allocation of resources between cassava and rice as part also of a multivariable objective function. According to the center, optimal strategies were not identified, partly because of a lack of explicit policy weights for different objectives and partly because of the lack of quantifiable data for many of the variables. Other socioeconomic goals besides improved nutrition were to increase agricultural production, foreign exchange, and agricultural incomes.

Adjustment of Nutrient Intake by the Malnourished to Changes in Commodity Prices and Income

It is by now well documented that certain commodities that have a high potential for producing large quantities of energy per unit of area and that are now consumed in relatively large quantities by the poor are often regarded by the poor as inferior goods. This means that when confronted with lower prices or higher income, consumers, including the malnourished, may adjust by reducing rather than increasing their intake of nutrients from some of these commodities. Therefore, the adjustment in the consumption of foods other than those

groups, under a variety of agroecological, cultural, and socioeconomic conditions.[12]

IFPRI has estimated parameters of income elasticity by income stratum for a considerable number of countries including Brazil, Egypt, and Thailand. The Institute recently initiated comparative analyses of estimates of price and income parameters of the demand for food by low-income groups in various countries. Present efforts of IFPRI to develop and test methods of estimating or approximating price elasticities for the poor on the basis of estimates for society as a whole would, as Pinstrup-Andersen suggests, significantly reduce the amount of data required for estimation (see Chapter 10).

On the basis of existing data, CIMMYT undertook an analysis of the importance of maize and wheat in the diets of the poor and the way these are affected by various policy measures.[13] IRRI has produced income-group-specific price elasticities for rice in the Philippines and Indonesia, but the basic data were obtained during the early 1970s. ICRISAT has estimated elasticities of price and income specific to the poor or malnourished for India.[14]

In general, activities devoted to obtaining and understanding empirical evidence on other aspects of food-acquisition behavior and consumption patterns of the malnourished have represented isolated efforts or case studies covering only a few aspects and those not fully.

In my view the collaborative project of ICRISAT, the National Institute of Nutrition, and the Home Science College of Andhra Pradesh Agricultural University, conducted in 1976-78, which involved daily dietary recalls by about 1,200 people during four seasons in six Indian villages, is the ideal type of activity for providing this kind of information. Besides consumption figures, the data collected include anthropometric measurements, clinical assessment of symptoms of morbidity, and a study of time-allocation patterns within the household.

Other activities worth mentioning are the studies made by ILCA in Kenya and Mali in which an effort was made to identify variables related to nutritional status and behavior of the local people.

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[12] Susan V. Poats and Gelia T. Castillo, "Beyond the Farmer: Potato Consumption in the Tropics," paper presented at the CIP Decennial Anniversary, Lima, Peru, February 22-26, 1982; Susan V. Poats, "Potato Nutrition and Consumption Research at the CIP," Centro Internacional de la Papa, Lima, Peru, 1982 (mimeographed; circulation restricted).

[13] Derek Byerlee and Larry Harrington, "New Wheat Varieties, Poor Producers, and Poor Consumers," paper presented at the Eighteenth International Conference of Agricultural Economics, Jakarta, Indonesia, September 1982.

[14] K. N. Murty and R. Radakrishna, "Agricultural Prices, Income Distribution, and Demand Patterns in a Low Income Country," paper presented at the First International Working Conference on Computer Applications in Food Production and Agricultural Engineering, Havana, Cuba, October 26-30, 1981.

the supply of which has increased and the price changed is of great importance in determining the final change in intake of a given nutrient.

Explicit estimates of price and income elasticities for calories and proteins, derived from elasticities of demand for several commodities in Cali, Colombia, were first obtained by CIAT during the early 1970s from elasticities of demand for 11 commodities.[15] Estimates of elasticities of demand for certain nutrients have also been made by IFPRI for Brazil and by ICRISAT for India.[16]

Commodity-Related Employment of the Rural Landless Poor and the Malnourished

The agricultural sector sometimes provides income for large proportions of landless laborers, usually including a large number of the malnourished in rural areas. Changes in commodity priorities may have significant implications for the incomes of these families and thus for their nutritional status. A conflict may then arise on account of research planning that is aimed at the provision of cheap food for the urban malnourished, for it may reduce the incomes of malnourished workers in the agricultural sector. On the other hand, to the extent that new agricultural technology creates additional employment and increases the incomes of the agricultural labor force, the result for nutrition may be positive. The adoption of high-yielding or yield-stabilizing technology that is highly responsive to the use of fertilizer--that is, technology of the biological-chemical type--is fortunately not of the labor-displacing type. But if it requires irrigation, the existing distribution of irrigated land, usually quite uneven, may mean that better-off farmers will benefit more from technological change than will the poorer ones. Thus, knowledge of the probable effect of new technology on commodity-related employment is needed if significant numbers of the vulnerable groups belong to the landless labor class.

Only ICRISAT seems to have been involved in research to examine the effects of the adoption of modern technology on the employment and

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15 Later in the literature it was realized that the want-independence assumption used in that study to derive the price elasticities from cross-sectional data is violated for individual commodities; see Jon A. Brandt and Joseph B. Goodwin, "The Impact of Increasing Food Supply on Human Nutrition--Implications for Commodity Priorities in Agricultural Research and Policy: Comment," American Journal of Agricultural Economics 62 (August 1980): 588-591; Pinstrup-Andersen, Nutritional Consequences of Agricultural Projects.

16 K. N. Murty, Elasticities of Demand for Nutrients Derived from Commodity Demand Elasticities (Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 1983).

incomes of laborers.[17] But none of the centers has reported gathering data on the generation of employment by commodity.

Ex Post Evaluations of the Results of Past Agricultural Research

Evaluations of the effects on specific commodities of investments in agricultural research made in the past can be quite useful in indicating what worked and what did not work, the constraints that impeded wider adoption of successful technology, and--for present purposes--what the consequences for nutritional goals were.

A study by ICRISAT of the effect of shifting from pulses to wheat in India on the production of protein and essential amino acids per unit of land made an important contribution in refuting the belief that new technology for wheat had reduced the availability of protein and amino acids.

Since this is a subject that will be covered in another paper, ex post evaluations made by the centers will not be reviewed here, but one comment may be timely: in very few of these analyses, within or outside the CGIAR, has the distribution of benefits from new technology by income group within the larger groups of consumers or producers been considered. This would probably be the closest it would be possible to get to estimating past effects on nutrition, unless specific data on nutritional status were to be gathered for a considerable period and used instead.

Price Policies and the General Socioeconomic Environment

In most countries in which there are IARCs, decisions concerning production and consumption are made by a large number of economic units influenced by varying degrees of market intervention by the government and of integration with world markets. Some economies are close enough to free trade that prices are determined by world prices, in which case actions to increase supply will have a negligible effect, by way of lower prices, on the nutrition of urban consumers. In others prices are determined locally, particularly where rates of inflation are high and where price controls, particularly of food prices, are typically used.

Given the fact that price effects are one of the main channels through which agricultural technology can influence nutrition--at least among consumers--information is needed on the mechanisms--particularly the existing food and price policies--by which commodity prices are determined within each country. IFPRI is indeed the center within the CGIAR that has done most of the research in this field. Initially, three country case studies were completed; but today, studies in at least nine other countries of Africa, Asia, the Middle East, and Latin America are under way.

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[17] Hans Binswanger, The Economics of Tractors in South Asia: An Analytical Review, ADC-ICRISAT Monograph (Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 1977).

Beyond the provision of useful policy information for the countries involved, the ultimate research objective of IFPRI is to contribute to the existing body of knowledge that can be applied to policy-making in other situations. Such integrative analyses are now being initiated with at least two well-specified objectives: to increase knowledge of the performance of various types of consumer-oriented food-subsidy programs and to increase knowledge of the underlying processes and relations. One of the issues to be dealt with is the effects of these programs on real incomes and the nutritional status of the poor and malnourished.

Research by IFPRI on food-price and food-subsidy policies is thus particularly valuable when decisions about commodity priorities are being made, in view of the small amount of analysis done by the countries themselves.

Development of Methodology

The study carried out for CIAT by Pinstrup-Andersen, Londoño, and Hoover is already a classic of the literature.[18] It was based on estimates of direct and cross-price elasticity for various income strata within the consumer group and related final adjustments in total consumption of nutrients--both calories and proteins--by income stratum, to the increase in supply of each of 22 commodities. More recent publications by Pinstrup-Andersen illustrate the way this model can be extended to incorporate the distribution of benefits from technological change among commercial producers and semisubsistence farmers.[19] If benefits to producers are expressed as income transfers and the income and price elasticities of nutrient intakes are known, it is probably possible to estimate the implied changes in the nutritional status of producers. More complete or more sophisticated models will obviously demand more and better data.

Collaboration with Other National and International Institutions

Several collaborative projects and workshops with national and other international institutes on nutritional issues have been undertaken by the centers. IRRI has sponsored or cosponsored four workshops that offer guidance for the setting of commodity priorities. The first one, in 1976, was organized to examine the socioeconomic consequences of new rice technology at a time when modern varieties of rice had already been adopted in several tropical and subtropical Asian nations. A year later IRRI cosponsored with the United Nations

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[18] Per Pinstrup-Andersen, Norha Ruiz de Londoño, and Edward Hoover, "The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy," *American Journal of Agricultural Economics* 58 (1976): 131-142.

[19] Pinstrup-Andersen, "Modern Agricultural Technology."

University a workshop to explore the nutritional considerations inherent in production, processing, and distribution of food. A third workshop, cosponsored by IFPRI, was held in the Philippines to examine, in collaboration with researchers from academic and government agencies, the need for more research on food and nutrition policy in the country. Finally, a workshop was held by IRRI on women in rice-farming systems for explicit consideration on the effect of new rice technology on women; issues concerning rural labor markets and intra-household allocation of income were also considered.

ICRISAT is another center in which seminars and workshops related to nutrition are held regularly. During 1981 it sponsored, jointly with the National Institute of Nutrition at Hyderabad and the United Nations University, a workshop on the interfaces between agriculture, nutrition, and food science. In AVRDC a workshop was held in 1975 on the roles of vegetables and legumes in Asian diets. A workshop on economics and the design of small-farmer technology held at CIAT in 1975 is also worth mentioning. One of the problems considered was the function of technology as a vehicle for inducing social change.

The few existing collaborative research projects have been joint efforts with national institutes of nutrition or university departments of agriculture and food sciences, undertaken by ICRISAT and ICARDA to carry out nutrition surveys at the household level and by CIP to evaluate the effects of including potatoes in infant nutrition.

SUGGESTIONS FOR FUTURE WORK

Several activities and research topics can be suggested that would involve social scientists and nutritionists and that would help to introduce nutritional goals, together with other goals, in the process of setting future research priorities.

Filling Gaps in Needed Information

As mentioned earlier, the introduction of nutritional considerations into research planning demands a great deal of data. Nevertheless, the centers can draw on information that is already available either from their own past work or from national or other international institutions. It is thus suggested that the centers keep in close contact with other international organizations, such as FAO, the World Health Organization (WHO), the World Bank, the United Nations Sub-Committee on Nutrition (SCN), the Institute of Nutrition for Central America and Panama (INCAP), and others working on nutrition-related activities, and that they collaborate with national institutions on research or other activities for which the centers do not have adequate resources or comparative advantage. Gathering data on food consumption in collaboration with other institutions to estimate income and price elasticities by income group has been specifically proposed by CIAT's social scientists. Another type of collaboration has been suggested by CIMMYT for on-farm research activities. I shall return to this proposal later.

It has also been suggested that each center have at least one staff member who has a basic understanding of nutritional issues in

order to facilitate communication with other organizations and to keep nutrition-related activities in focus within the center.

The sort of gaps in information that can be filled in collaboration with outside organizations are, for example, projections of demand for the IARCs' commodities; more disaggregated data and trends in the use of crops; and identification of target groups of the malnourished and their needs. The last is, in my view, fundamental because the parameters of consumption of these groups may differ significantly from average parameters for the country or region as a whole.

Analysis of the Adjustment of Nutrient-Intake by the Malnourished

More information is needed at the national and regional levels to estimate the responsiveness of the malnourished to changes in food prices, incomes, and other variables. As shown earlier, separate estimations for the malnourished are definitely scarce at present.

Improved Analytical Tools for Looking at the Intrahousehold Decisionmaking Processes

Activities to increase our knowledge of the decisionmaking processes that take place within households, particularly farm households, with malnourished members are lacking.

Introduction of Nutritional Dimensions into Work on the Consequences of the Introduction of New Technology

Previous analyses of the consequences of the introduction of new technology were seldom focused on its effects on nutrition, the distribution of income among rural households, and employment links. Future work in selected crops and countries would facilitate the assessment of nutritional effects.

Introduction of Nutritional Concerns into On-Farm Research

On-farm research is an approach to agricultural research now being used by a number of centers. Work by CIMMYT in Ecuador has provided useful insights on the way dietary information can be obtained in this type of research and how it can be used to guide the selection of research priorities. It is suggested that participation by local agricultural research scientists and nutritionists from national institutions in one or more on-farm research activities in selected countries would be of mutual benefit.

Enhancing the Capacities of National Research Institutions with Respect to Nutritional Concerns

The IARCs are apparently ahead of national research institutes and other public entities in using nutrition-related information for decisionmaking; this means that the centers are in a position to

transfer methodologies to these other organizations. Activities with this purpose would be of benefit to both because of their interdependence.

ISNAR has proposed construction of a typology of national approaches to the achievement of nutritional goals. In doing so, it would collect and analyze information that would be useful to the IARCs.

Macroeconomic Work, Particularly on Food and Pricing Policies

The need to generate better data and understanding of macroeconomic questions such as the effects of pricing and subsidy policies on human nutrition has already been emphasized. Some of the centers have shown an interest in collaborating with IFPRI in research activities of this type. IFPRI's recent undertaking to consolidate the results of earlier case studies so that they can be extrapolated to other countries or situations should prove quite useful in setting priorities and policies beyond the cases studied.

Discussion

Prasarn Trairatvorakul

Eugenia Rubinstein has made a broad summary of the individual center papers and has offered a long list of recommendations. It would be difficult for me to comment adequately on all the points she has made, so I would like to make a summary interpretation of her paper and make comments following it.

The essence of what Dr. Rubinstein has said is that direct nutrition intervention tends to be costly and difficult to sustain. In the long run, therefore, nutrition should be incorporated into the strategy of agricultural development. As I see it, there are four groups that enter into the policy-decisionmaking process, namely, the malnourished members of the population; the national institutions, both research institutions and institutions that carry out policies; the international research institutions; and the national policymakers.

Dr. Rubinstein has emphasized a number of areas that should be considered in order to understand the malnourished members of the population. Some indicators, such as patterns of food consumption and the disaggregated parameters of food consumption, are useful in this task. In the context of setting commodity priorities, she mentioned the short-cut suggested by Per Pinstrup-Andersen, namely, that to be given priority a commodity should meet the following three criteria: it occupies a large share of the budget of a household, some of whose members are malnourished and for which price elasticity of demand for calories and protein is high; it occupies a large share of the resources, both land and labor, owned or controlled by producing households with malnourished members; and it generates employment and incomes for the landless poor.

I agree that these are among the tools for the setting of nutrition targets, but I would like to add mention of the need for awareness of the possibility that these parameters will change in time. For example, when the incomes of the poor rise, their food-consumption patterns may also change. Once a policy decision has been made, however, time is required before the results can be seen, and frequent change or modification of these policies is usually costly. What changes will take place with the passage of time? The second criterion for selecting a commodity priority, that is, the distribution of the ownership of resources among producing households of different income classes and the potential changes in it, must also be carefully examined. If this is not done, the original aim of targeting the benefits to the malnourished people may not be fulfilled.

At present the analytical tools for trying to understand the behavior of individual malnourished members of a household are quite limited. Tools are available for analysis at the household level but not at the individual level. Further studies in this area are therefore needed.

The last three groups that figure in the policymaking process must somehow be interrelated with one another. The limitations of the international organizations usually prevent their work from being location-specific. How should the functions of the national and international organizations in setting research priorities be divided? If policy criteria are in conflict, should the international organizations try to find a framework for ascertaining the net effect in both the short run and the long run? Should they also help in finding the trade-off schemes for policymakers?

The last group--the national policymakers--are usually interested only in the macro implications. Dr. Rubinstein mentioned that there should be macro studies. But her suggestion is more in the direction of discovering the effects of present and potential macro policies, such as trade and price policies, on nutrition. I would like to suggest that in order to understand why the national policymakers agree or do not agree to do something, it is necessary to know the possible implications of the establishment of commodity priorities for macro policies such as the improvement of the health of a section of the population or a production policy that shifts from one crop to another.

Discussion

N. S. Jodha

Eugenia Rubinstein has aptly summarized the situation of CGIAR centers regarding their failure to incorporate human nutrition as an explicit concern in the determination of commodity priorities. CIAT--and to some extent ILCA and AVRDC--are exceptions: for various reasons nutrition is an explicit part of their mandates. The concern of other centers for nutrition emerges largely as a post facto rationalization of work that they have done. In fact most of the papers from these centers are useful attempts to screen their research efforts with reference to nutritional effects.

It is quite surprising, though, that even without the improvement of nutrition as an explicit mandate, most centers, while addressing the problem only indirectly, have given it ample coverage. I am more sympathetic than Dr. Rubinstein to the present approach of the centers to commodity priorities. The commodity priorities of the centers were determined as part of their research mandates. In most instances, at the time research mandates were established there was hardly any systematic noise about interfaces between agricultural research and nutrition. Pragmatism was the guide. "Poor" was equated with "malnourished" or "undernourished"; increases in the production of their staple food and development of technologies to increase and stabilize their income and employment were considered appropriate means of helping the undernourished. Though accomplished in successive stages, the CGIAR research has covered practically all regions inhabited by the poor and the less poor. Food crops researched by the centers probably account for more than 90 percent of the staple foods of the human population. The implicit assumption was that production of more food means that more food is available for everyone, including the undernourished. Thus the CGIAR centers did address nutritional issues without explicitly incorporating them into their mandates.

I am not sure whether more would have been achieved by explicit incorporation of nutrition into the research mandate than has been accomplished with the present approach to commodity priorities on the basis of a broader view of the world--that is, of the regional distribution of the poor, their staples, their income and employment, and so on.

The largest question about the approach of the centers has to do with the implicit assumption equating food production with food availability. For a variety of reasons, a state of surplus food production may coexist with its scarcity for particular groups. These persistent gaps between production and availability are, however--

especially to the poor--the product of complex socioeconomic factors. These gaps obviously cannot be offset by explicit incorporation of nutrition of the poor into commodity priorities. A different strategy involving greater awareness of the problem on the part of the policy-makers is required. Some centers, such as IFPRI, are better equipped to facilitate this task. Greater possibilities for the generation of income, created by prospective technologies of the centers, will also help in bridging the gap between the production of food and its availability.

There are also a few other practical considerations. The idea of increased food production in various regions--brought about as one of the fruits of research--is much easier to sell to funding agencies and governments of developing countries than is pure strategy for promotion of nutrition. Similarly, increased grain yield is a stronger incentive to the breeders than improvements in the nutritional quality of grain. The strength of these constraints should not be underestimated.

My last point, not closely related to what I have already said, has to do with the considerable degree of imbalance in the gathering and analysis of information that is supposed to serve as the basis for fixing commodity priorities. While most centers have done work on the trends in production, the prices, and the elasticities of demand for and supply of their mandate crops, they have done much less work on patterns of consumption and their instability and variability at the household level. Research on food consumption at the household level may clarify several issues relating to nutrition and in the process sensitize the research policies to them. In this connection the suggestion made in Chapter 5 to incorporate nutritional criteria in on-farm research should be given serious attention.

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Incorporating Nutritional Concerns into the Specification of Desired Changes in Commodity Characteristics in International Agricultural Research

Ricardo Bressani

During the past 20 or 30 years, significant advances have been made in developing and implementing ways of providing the world population, particularly the undernourished, with adequate diets, whether in the form of simple foods or of processed foods. Statistics from nutritional surveys, however, are a constant reminder that the world food situation is serious, particularly in the developing countries.

Although the solutions that have been developed are technically sound and many have been implemented, the complexity of the nutrition problem is such that by themselves they cannot produce satisfactory results. It is clear that a satisfactory solution will come about if concerted efforts are made throughout the nutrition chain, beginning with efforts to ensure an adequate food supply, followed by those on the factors that determine the effective demand for food, favorable environmental conditions, and finally, the complex factors associated with allocation and consumption of food in the household. Each link is characterized and influenced by its own specific chain, and the reactions between links or areas commonly run both ways rather than straight forward. The efficiency of the whole system depends to a large extent on the efficiency achieved within each area and in the interfaces between areas. It is at the interface level where there is much misunderstanding and where more research is needed. Interventions in certain areas may be unsuccessful because of lack of knowledge at the interface level. The events begin in the agricultural sector, where the food required for improving human nutrition, whether from vegetable or animal sources, is produced.

In this paper, the main purpose of which is to synthesize the activities of the IARCs in incorporating nutritional concerns into the specification of desired changes in commodity characteristics, the principal nutritional deficiencies that affect the world population will be described briefly; the nutrition problems of the specific population groups most afflicted by the problem will serve as background information. This will be followed by a brief description of the nutritional concerns that it may be desirable to incorporate into research on various commodities as reference criteria for the synthesis of the activities of the agricultural research centers. The paper will conclude with a series of suggestions for action by the

centers that may be useful in the effort to increase the nutritional effects of the research done by the IARCs.

THE MAIN NUTRITIONAL DEFICIENCIES AND THE MORE SUSCEPTIBLE POPULATION GROUPS

It is accepted by now that malnutrition has significant functional consequences for the individual. From the point of view of nutrition the overall intake of nutrients in the diets of populations at risk is generally low and varies greatly. Those deficiencies to which attention has been given include the much discussed protein-calorie deficiencies that afflict the majority of preschool children, interferes with growth and development, and reduces immunity to infection. When these deficiencies become severe, they lead in young children to the diseases known as kwashiorkor (protein deficiency) and marasmus (protein/calorie deficiency), which have been associated with adverse effects on learning and behavior. Protein-calorie deficiency has been defined in broad terms since the quality of each nutrient, particularly of protein, is far more important than the absolute amount consumed. The quality factors are more important for young children and pregnant and lactating women than for adults, particularly when the total intake is of a single food of vegetable origin and the absolute amount is low, whether because of limited availability or because of bulkiness. A second nutritional deficiency of importance to all age groups is the nutritional anemia caused mainly by iron deficiency, in which other nutrients such as vitamin C and folic acid figure, as does the chemical structure in which iron is present in foods. This deficiency has functional consequences such as reduced physical capacity and performance and increased susceptibility to infection.

A third significant category of nutritional deficiency includes avitaminosis A, which when prolonged may lead to blindness, and iodine deficiency, which is responsible for endemic goiter, and in pregnant women can cause feeblemindness and sometimes cretinism in their offspring. The best approach to this problem is through analysis of the overall nutritional quality of the diet and the quantity, frequency, diversity, and possible monotony of intake.

Although these deficiencies arise primarily from the quality and amount of food consumed, it must be understood that other factors enter into their final manifestation. The most significant is infection, which reduces intake and absorption of nutrients and induces metabolic losses in urine and internal diversion of nutrients as part of the immune response. Furthermore, the specific deficiencies do not take place individually but are related since most metabolic functions are based on a complete intake of all required nutrients. These relations must be considered by the IARCs as they attempt to measure the effects of their research. It is unfortunate that the malnutrition problem has been described in terms of nutrients--first protein, now calories--when in fact diet should have been the indicator used and should have been described in terms of quantity, quality, wholesomeness, acceptability, and variety.

AREAS OF INFLUENCE ASSOCIATED WITH NUTRITIONAL CONCERNS OF THE CENTERS

The following discussion is presented as a means of arriving at a synthesis of the activities carried out by the IARCs in incorporating nutritional concerns into the specification of desired changes in commodity characteristics.

Using as a frame of reference the world food situation and the nutritional condition of people in developing countries as well as some of the reasons underlying this condition, the IARCs work in five broad areas in trying to find a solution to the food and nutrition problem and in interacting with scientists in biochemistry and nutrition, in food science and technology, and in other agricultural sciences. These areas include research on individual food commodities, on harvest and postharvest technology, on diversification of use and industrialization of commodities--in animal-production systems and the food and other industries--on the development of efficient farming systems, and on the development of human resources and their influence on national agricultural programs.

Specific Commodities

With respect to specific commodities two approaches have been taken to help solve the problems of nutrition and food supplies. One, the most common, is to increase total production of the kinds of food that sustain the world population--cereal grains, food legumes, and roots and tubers. Through the organized and efficient use of resources it has been possible to increase agricultural productivity--more biomass per unit of land--at the lowest possible cost. This is a significant advance in itself since it makes more food available. Production is only one aspect since it must be processed and distributed, and it must be consumed and the nutrients that it contains absorbed by the malnourished members of the population if increased production is to help solve the problem of malnutrition.

The second approach has to do with the quality of the commodities produced, which must be taken into consideration both to see that the resources used in increasing production are used efficiently and to maximize the biological use of the biomass produced, which in essence is the final objective of the whole process. Two indexes of quality are important. One, called "technological value," refers to attributes that determine consumer acceptance, including storage, distribution, processing, milling, cooking, and eating characteristics. The second is the nutritive value, which includes quality and quantity of protein content and the biological availability of other nutrients. The chemical composition of the biomass is influenced by the resources and methods used in its production, the conditions under which it is distributed and processed, and its biological use by the individual. Changes that can be induced in the chemical composition of the commodity may influence the efficiency of biological use of the nutrients in it when it is tested by itself and when it is tested as a component of a diet. An example of each case will be presented by way of illustration.

Nutrients in Food Crops and Their Nutritive Value. From an analysis of the documents prepared by the centers and of scientific publications by scientists from the centers, it becomes evident that all these institutions have been concerned with the world nutrition problem as reflected by the incorporation of analysis of the nutrient composition of the food crops in their several mandates. This kind of analysis is the basis for assessment of nutritional value and quality and it is a component of the nutrition strategies of the centers. The centers seem to be more concerned with the socionutritional problem, however, which is highly complex and not necessarily dependent on the centers for its solution. This has led the scientists in the centers to analyze the nutrient relations in their particular crops lightly, and they have chosen nutritional objectives represented by chemical contents that are not related to the efficiency with which the nutrients are used. As the protein content of the potato, for example, increases from 7.6 percent to 11.6 percent, the quality of the protein decreases; a variety of potato that contains 10 percent protein offers a lower efficiency of use than one containing 8 percent protein. This relation, which is common in food crops, is caused by the fact that smaller amounts of the limiting amino acid are present, expressed on a per protein basis, as protein content increases. It can be argued that higher protein content is better even if efficiency drops because absolute protein intake is greater. While this is true, it is achieved at a lower efficiency. Better quality with lower protein content is superior to higher content of low-quality protein. It is recognized, however, that these trade-offs must be analyzed separately for each commodity and in the context of the total diet. Efficiency of use is seen as better performance at lower cost, which has implications for the amount of land used, the total input of energy required for production of a crop, and the efficiency with which that energy is used in a complete biological system. People may survive on a single food, and if that food is of a high quality they may be fairly well nourished until other foods become available. If the single food is common maize, for example, a larger intake of the grain is required than if it is a maize of higher quality. Nutrition situations in which children are fed only one food are often found in developing countries, particularly during episodes of diarrhea. In such cases higher quality foods would be of significant value.

All this is not to say that greater protein content is not a desirable feature. It certainly is desirable when the higher-protein variety of a commodity is part of the diet, where advantages result from the higher level of protein and of the limiting amino acid on a weight basis, complementing more efficiently the protein of the other components of the diet.

Nutrients in Food Crops as Consumed and Their Nutritive Value. Consideration must also be given to the influence of a change in the nutrient content of a commodity when it is incorporated into a diet, since metabolic relations among nutrients in the total diet must be taken into account. The point is illustrated in the following example: protein content, protein quality, and vitamin A are all metabolically related. If intake of vitamin A is low the ingestion of a protein or diet that does not contain vitamin A will promote vitamin-A deficiency. In one experiment rats were fed vitamin A-

deficient diets of maize alone, maize and beans, high-quality maize, and high-quality maize and beans. At the outset all the rats had adequate hepatic levels of vitamin A. Their hepatic reserves of vitamin A dropped more and faster when they were fed diets high in protein content and quality (high-quality maize and beans, high-quality maize) than when their diets were common maize and beans and common maize. Although much can be accomplished by incorporating the desired nutrients into the food itself through fortification schemes, economic factors and the preferences of consumers in the foods they eat make it unlikely that such an approach will succeed.

Harvest and Postharvest Technologies

Harvest and postharvest technologies are also of concern to agricultural research centers; if through agronomic technologies, for example, more food is produced, the problems of handling it and preserving it must be dealt with. Field losses must be reduced so that the farmer and the rural working population will be assured of a satisfactory income, foods will be available to urban groups and in areas where they cannot be produced, and the characteristics that make them wholesome and acceptable for home and industrial processing will be preserved.

Diversification of Use

Diversification of the use of a commodity in industry is important in maintaining the income of the producer and a stable supply of food to the consumer that is of good quality, available all year, and convenient to prepare. High-yielding varieties of a commodity that are not acceptable for direct consumption may be of great value as raw material for processed food products or for industrial use.

Agroindustrial development is acquiring ever increasing importance in the food and nutrition systems of developing countries, though it varies according to the degree of economic and urban development of the country. The transformation of a highly rural society into one that is mainly urban means among other things that the population is moving farther away from the sources of its food supply. It also means that the crops must be transported, stored, and transformed into foods that are acceptable to a population whose patterns of preference for certain types and qualities of food are changing. These changes must be taken into account in agricultural research.

A striking fact is that of the maize used in Guatemala, for example, only 0.36 percent is used industrially, whereas losses account for 5.2 percent; 82.3 percent goes to feed the human population, and 6.1 percent to feed animals. The use of main commodities to increase animal productivity on the farm or in the household may be controversial. It is quite common, however, to find small animals kept in rural homes and on small farms--an integral activity that has not been developed or improved. About 90 percent of the swine in Latin America are of the native type, for example, and do not necessarily survive on grains. One of the concepts incorporated into on-farm research is to take "full account of the circumstances under

which farmers operate," and the raising of small animals at a low level of productivity is part of the farm operation.

Farming Systems

Agricultural research strategies, which include farming-systems research or on-farm research, offer sound opportunities for a more effective interaction between agricultural scientists and nutritionists for the benefit of the population. One is the possibility of improving the nutritional quality of the diet by providing high-quality diets at minimum cost through integrated and diversified systems of agricultural production.

Human Resources and National Agricultural Research Centers

There are two other interrelated areas of influence of the centers. One is the development of human resources through advanced training in the various aspects of agricultural research for production and productivity. This type of training should include concepts of food and nutrition--nutritional value, consumption, and use--that will contribute significantly to the interaction between agriculture, food science and technology, and nutrition. The other area is the development of national agricultural research centers not only for training scientists but for adapting the philosophy of research and the activities and interests of the centers to nutritional concerns.

NUTRITIONAL CONCERNS IN THE CGIAR

As a first step in the synthesis of the contents of the documents prepared by the centers for this workshop, a general statement in each document was selected as representing the activity and general interest of that center in incorporating nutritional concerns into its mandate for agricultural research. Analysis of these statements indicated that the highest priority is given by all the centers to increasing and stabilizing the production and productivity of their mandate crops. The rationale is the assumption that greater production will lead to greater availability and consumption of food. If the caloric intake of the population increases, their intake of unqualified protein and other nutrients will also increase. Increased production may also represent increases in income, which together with a greater intake of food will mean better nutrition. Some centers indicate that their final objective is to improve nutrition; in some instances this is convincingly stated as nutrition is stressed in documents presented by centers involving animal research, while in others interest in improving nutritional quality in their specific commodity is no longer considered. The concept of diet as an attractive and potentially effective means of translating agricultural research into better nutrition is well stated by some centers. The statements also show some inconsistencies with one another, particularly the statements of the centers that are dedicated to animal research with those of the centers that work with vegetable crops. In

the former the beneficial nutritional effects of animal products is indicated, while in the latter protein quality is no longer of interest to most of the centers.

Areas of Influence

The second step in the synthesis was to acertain the types of nutritional activity being engaged in. The areas identified are shown in Table 19.1 and include the food commodity itself, harvest and post-harvest technology, diversification of use, farming systems, training, and activities undertaken in collaboration with national agricultural research centers.

Table 19.1--General activities of the IARCs that have nutritional purposes

Area	Activity	Nutritional Purpose
In the food commodity itself	Production research; food technology value; nutrient analysis; food-consumption surveys	Increase intake of calories and other nutrients; ascertain acceptability and use; assess nutrition value and function in diet
Harvest and postharvest technology	Development of technology for harvest and storage	Reduce losses; retain acceptability, processing qualities, and nutritive value
Diversification of use	[Processing, feed formulation, and feeding]	Increase income; develop new food products; production of animal foods; home and industrial
Farming systems	Increasing diversified agricultural production, including animals	Diversification of food basket and a more nutritionally balanced diet; interaction with nutritionists
Training	Agricultural research only	[Integrated solution to the nutrition problem]
National agricultural research programs	Transfer of technology	[Adoption by national centers of nutritional concerns in agricultural research]

Note: Brackets indicate an act not being carried out or purpose not being fulfilled at present.

All centers are obviously developing technology to increase production of the food crop or commodity. As already indicated, this is associated with increased consumption or a greater intake of calories. All centers, particularly those that work on food crops, have shown concern for the indexes that are used to express characteristics of acceptability or use of food. These indexes for wheat and rice are well known, but those for maize, sorghum, and most food legumes are less well known. More research in this area, particularly on the last group of food crops mentioned, is needed. There is also concern for evaluation of grains that are used primarily as processed flour. At one time many of the centers were concerned with specific nutrients that limit nutritive value, particularly the amino acids. Although publications on this subject are being issued by the centers, all indicate that this is no longer given high priority, so the activity has been dropped. It is assumed wrongly in some instances that crops of high nutritional quality will cost more to produce. While it is recognized that such crops will not be produced by farmers or purchased by the population because of their high quality, it should be the objective of agricultural research to overcome the constraints that are responsible for the higher cost so that the cost of production of high-quality crops will be the same as that of others, such as is true of maize that contains high-quality protein. Many of the centers have participated in food-consumption surveys, which are useful for ascertaining the nutritional function of a commodity in the diet and the interaction of nutrition with other disciplines.

Not much was found in the various documents about postharvest technology and diversification of use of a commodity except the research activities of some centers on food storage and agro-industrialization. The diversification of use of a crop into animal-production systems, industrialization, and food-product development can increase the income of the farmer and provide foods for nonfarm and urban populations. The question can be asked how far into the food chain agricultural research should go; if this is not in the mandate of the centers, strong collaboration between them and other institutions should be established. Some centers have indicated their interest in postharvest technology, however. All centers are doing farming-systems research and on-farm research, the advantages of which are well defined, as a means of developing and transferring agricultural technology; but any system developed should be based not only on economic factors but also on other factors, such as the components of the diet or the food basket. It is an ideal subject for interaction with nutrition scientists in a number of activities. Training, another area of interest and activity in the centers, could well be extended, although not in a specialized form, into the areas of food science and technology as well as nutrition. Agriculture is more than production, and knowledge of the purposes of production will facilitate the interaction and collaboration of the centers with other institutions. Although the centers are showing interest in nutrition, they do not have nutrition scientists on their staffs, although they have chemists, biochemists, and food scientists. Only one center has a nutrition panel.

Both through training and through direct contacts the IARCs share activities with national agricultural research institutes. As indicated earlier, the example and interest of the IARCs may significantly influence the national centers, which are most of the time completely

dissociated from institutes of nutrition and food science and technology.

Specific Activities

The last series of considerations in the synthesis of the documents is shown in Tables 19.2, 19.3, 19.4, and 19.5. In Table 19.2, eight activities associated with consumption patterns and diets are

Table 19.2--Activities associated with consumption patterns and diets

Subject	Activities Undertaken
1. The function of the particular food commodity as a source of nutrients: (a) Quantitative (b) Qualitative	Food consumption surveys; estimations of calorie and protein contribution of commodity to the total based on chemical composition disregarding biological utilization; not all nutrients have have been considered; no corrections have been made
2. Relation to other components of the diet; frequency of intake	Not generally considered
3. Methods of preparation and form of consumption	Only some centers have considered this subject; important in relation to 1; related to 4
4. Preferences of consumers (color, size, cooking quality, texture, functionality)	Have been assessed mainly for cereal grains; limited assessment or none for food legumes; good opportunities for collaborative studies
5. Potential nutritional effects of change on other limiting nutrients in diet	Not considered Opportunity for collaboration
6. Confirmation of nutritional change to improve quality of	Not done directly--if considered, it is estimated as in 1
7. Cooperative activities with other institutions	Should be increased, particularly cooperation with national institutions
8. Nutritionists on staff, or relation to nutrition consultants	Only one center has; conferences on agriculture and nutrition have been held

presented. All the centers, through food-consumption surveys or other statistics, are aware of the quantitative functions of the various commodities in various societies; but the qualitative nutritional functions are not clearly understood. No attention has been given to other nutrients besides calories and protein, but good nutrition consists of more than just calories and total protein. Methods of preparation and forms of consumption are known in a general way--information that is useful, since most foods are not consumed raw--but calculations of nutrient intake from the nutrient content of raw foods may lead to erroneous conclusions. Processing may also reduce the availability of nutrients; in particular, it may decrease the total biologically available protein. In recent years all centers have been concerned with consumers' preferences, many of which are not well defined and have not been quantified. Because there seems to be a strong feeling for calories in all centers--which is convenient, since calories are strongly associated with yield--no concern is expressed for the possible effects of a change in nutrient content on other nutrients at the metabolic level. A case in point is the relation presented earlier between protein quality and vitamin A. Except for the assumption that increased production may signify greater intake, no attempts have apparently been made by means of actual tests in controlled intervention studies to measure the effects of increased production. This whole area may not pertain to the mandates of the centers, or it may not be their responsibility; cooperative activities with other institutions, however, have been and should be carried out in all these areas.

In Table 19.3, four elements of the subjects of harvest, storage, marketing, and distribution are shown. Some centers have been devel-

Table 19.3--Harvest, storage, marketing, and distribution

Item for Analysis	Research Undertaken
1. Harvest and postharvest handling (threshing, dehydration)	Not by all centers
2. Stability in storage:	
(a) Insects and molds (b) Cooking quality (c) Acceptability (d) Processing (e) Physical deterioration	Not studied by all centers; activity should be increased
3. Distribution	Carried out in a limited way; should be considered--affords opportunities for collaboration
4. Cooperative activities with other institutions	Not considered; offers opportunities for collaboration

oping technologies to improve harvest efficiency and to stabilize the changes that take place in storage. The latter may directly affect acceptability to consumers as does extended cooking time for food legumes, for example, and indirectly as does the development of off-flavor or even incomplete destruction of toxic compounds. Poor storage influences the processing efficiency of a commodity that is to be used at home or industrially. Distribution and marketing are also of interest, as are the cooperative activities undertaken by some of the centers.

Table 19.4 is concerned with research on the effects of processing on nutrient content. It contains 7 items for analysis. As indicated earlier, they are important because what has been gained in production may be easily lost in processing. Wheat, for example, is consumed as flour, but flour and unprocessed wheat are nutritionally different; and high-quality maize consumed without the germ is of significantly lower nutritional value than whole maize. Many other processes destroy vitamins, amino acids, and other nutrients. Processing also catalyzes reactions, such as that of tannins with protein. These effects are not considered by the centers; and although it is agreed that it is not their responsibility, their collaboration with other institutions that do research on them is highly recom-

Table 19.4--Effects of processing on nutrient content and use

Item for Analysis	What Has Been Done
1. Processing technologies used in food preparation	Only for some commodities, mainly cereals
(a) Industrial	Not much for cereal grains
(b) Home	Some for roots and tubers
2. Effects on nutrient content and bioavailability	Not considered
3. Effects on functionality and acceptability	Not for all commodities; research has been limited to cereal grains
4. Effect of nutritional limiting factors (inhibitory factors)	For some commodities, by some centers; food legumes, mainly sorghum, have been studied
5. Industrial use	Not considered, but it should be
Food-product development	Some research has been done
6. Cooperative activities with other institutions	Only by some centers
7. Food scientist or biochemist on staff	Various centers have them

mended. Processing also affects the functionality of a commodity and its acceptability to the consumer. The centers should be aware, however, of the industrial use of high-yielding commodities that may not by themselves be altogether acceptable to consumers. IR8, for example, could be used in food products that contain rice flour, thereby benefiting both the farmer and the consumer.

Table 19.5 is concerned with five aspects related to production. All the centers have been interested in knowing the variability, both genetic and environmental, of the nutrients that limit the efficient use of food commodities. Various centers indicate that this subject was of interest to them at one time but is no longer being considered. Various centers have also studied extensively the relations between yield and nutrient content but have not made the final evaluation of nutritive value. Studies of the biochemical relations among nutrients have also been considered by many centers as have the effects of environmental factors and cultural practices on nutrient content, best exemplified by the work on rice. As in other areas, cooperative studies with other research centers have been and are being conducted at both the national and the international level.

There is no doubt that the centers have shown interest in incorporating nutritional concerns into their research on the commodities for which they are responsible and that this interest is growing. Cooperative efforts have been weak, however, not because they have not been carried out with institutions in developed countries but because they have. The purpose of the IARCs is, of course, thereby well

Table 19.5--Production-related aspects

Aspect	What Has Been Done
1. Genetic variation in the particular nutrition-related characteristics or factors that affect nutritive value	Studied by most centers that work with food crops; nutrients analyzed include protein, limiting amino acids and CHO; Others include HCN, antiphysiological substances in potatoes but not in food legumes generally
2. Relations among yield, nutrient content, and nutritive value	Some work has been done, mainly with rice
3. Biochemical nutrient relations in commodity	Information has been obtained but has not often been analyzed
4. Effects of environment and cultural practices on nutrient of interest	Some research has been done, particularly with rice
5. Cooperative activities with other institutions	Most centers are cooperating with other institutions

served; but a significant opportunity for collaboration is lost as is the transfer of the nutritional interest at the local level. Closer ties and networks with competent local institutions should be established where the food and nutrition problem exists. If those institutions do not exist, they should be developed.

The Past, the Present, and the Future

In this section I shall describe the changes that have taken place in nutrition-related activities of the IARCs since their creation. Since I am not a part of any of the centers, it was difficult for me to be exact and true; the changes that I shall describe, however, reflect a careful reading of the available documents and of world events having to do with the problem of food supplies and the causes of malnutrition.

At first the objective was to increase the production of the various foods consumed in the developing countries. There was little concern about nutrition, and it is even possible to think that the centers did not know of the malnutrition problem--a problem that was brought to the attention of the world by the medical profession. Soon malnutrition was associated with the lack of protein of good quality. Much attention was being given to the rapid increase in the world population and to the much slower increases in agricultural production, which meant that production per capita was declining. This motivated the centers to intensify their research in agricultural production, thereby giving origin to the green revolution--a significant achievement. Their efforts were criticized, however, because increasing income was their main concern and they disregarded certain foods such as legumes, the chosen protein supplement of rural diets.

At that time protein as the main nutrient that was deficient was at the height of its scientific popularity, but it was not merely protein, but protein quality, that was the object of attention. It was the protein problem that made the centers take the next step, and research on protein content, the limiting amino acids, and some biological testing was initiated. More than discouraging results in protein quantity and quality, nutrition opinion and criticism induced the next change: the object of increasing production was to increase the intake of energy, now the favorite dietary component. Results showed levels of protein intake to be in most instances adequate or above the needed levels, and the concept of protein quality was somehow lost.

In the meantime world opinion from the food technologists was now increasing, and postharvest losses became the subject of a great deal of interest. Somehow this moved the centers to take a closer look at this problem, and at the same time they became aware that some of the products of their research were little accepted by the farmer and the consumer. This gave them the impetus to introduce acceptability factors as a component of their research, though as far as food legumes are concerned it is a problem still to be researched. Their own experience moved them to do farming-systems research and, more recently, on-farm research. This effort should be exploited for better and more efficient interaction with nutrition.

With the establishment of centers that deal with animal production and with the findings of on-farm research, it looks as if more of such research will be incorporated into the strategies of the centers,

and it is almost certain that production will be diversified and transformed industrially. Somehow, I believe that concern with the quality of protein will return, simply because this concept implies a greater efficiency in the use of world resources from production of the commodity to its utilization by the individual. More interaction between disciplines is also likely to take place.

THE VALUE OF THE CONCEPT OF DIET IN AGRICULTURAL RESEARCH STRATEGIES

Although in many food crops genetic variability in specific nutrients that limits nutritional value has been shown to exist, it would not be practical, for various reasons, to attempt to perfect each of such foods nutritionally, mainly because several individual foods are consumed together in a diet, so some mutual supplementation takes place.

A Method of Establishing Goals for the Nutrient Content of Food Crops

Mutual supplementation offers the possibility of establishing goals for the nutrient content of food crops lower than they would need to be if the individual food were to be optimized to the ideal level; goals that would be easier to achieve in breeding and selection programs. An example of this is given by analysis of the protein quality of mixtures of cereal grains such as common maize and food legumes such as black beans, a system of consumption that prevails in many countries where there is malnutrition. The results show a point of maximum mutual supplementation which, although better in quality than single components, is still deficient in lysine and methionine, on the basis of both theoretical figures and actual experimental studies with amino acid supplementation. The point of maximum quality improves significantly when both lysine and methionine are added. Calculations have been made to obtain the best concentrations of limiting amino acids in both components to achieve higher quality. On the basis of the food-consumption system of common maize and beans, lysine content in maize should be around 225 milligrams per gram of nitrogen, while total content of sulfur amino acids in beans should be 242 milligrams per gram of nitrogen. This figure is almost twice as high as present levels in beans, and easy attainment of it may not be possible. The alternative is to split or distribute the needed level into the two components. If this were done, maize should have 227 milligrams per gram of nitrogen and beans 213 milligrams per gram of nitrogen of total sulfur-containing amino acids for a 30 percent and 70 percent distribution. A further alternative exists, if foods high in these amino acids were included in the diet consumed. A bean containing 242 milligrams of total sulfur amino acids per gram of nitrogen would be of benefit to diets that were based on root crops such as cassava and yam and included potatoes.

The mutual complementation effect described for maize and beans is also to be found in many other combinations of the cereal grains and the food legumes. Thus by applying the same type of analysis, goals for nutrient concentration in other individual crops could be established that might be easier to achieve without interfering with

productivity, acceptability, functionality, and cost of the particular commodity concerned.

The food-consumption system has other applications. One has to do with selection programs for nutritional value. If a cereal grain is fixed in the system, cultivars of beans can be screened for supplementary value. Obviously, cereal grains can also be screened by testing selections against a common food legume. A second application has to do with agricultural production systems, farming systems, or on-farm research, either of intercropping, relay, or integrated type. It may be desirable to use this application to evaluate the effects of agricultural research on the malnourished sector of the rural population.

Farming Systems and Food-Consumption Systems

Although the definition of farming-systems research is not clear, its title to anyone outside agricultural research implies research on the sequential production of agricultural products, possibly integrated with other production activities and using resources as efficiently as possible. Farming-systems research is here defined as the strategy by which the farmer will use his land and resources as a means of producing the foods for an improved diet for himself and his family and an excess for the purpose of increasing his income, thereby feeding other groups with high-quality foods. On the other hand, the term "food-consumption systems" implies the consumption of the two main food crops in a quantitative blend for highest absorption of protein in combination with other foods to maximize efficiency in nutrient use and bring about better nutrition for the consumer. The two concepts are therefore complementary and could be combined so as to associate agricultural research with nutrition.

As indicated earlier, most people in the developing world base their diets on two staple foods. These are often a cereal grain and a legume or a starchy food and a leguminous grain. The rest of the diet generally consists of small amounts of other foods sometimes including animal food products. In any case the two main items provide most of the energy and a good part of the protein needed by the individual, with protein of relatively high quality and variable amounts of the other nutrients. The overall quality of the diet is, however, not the best, particularly for those population groups who need to increase their intake of nutrients. The difference in nutrient intake, however, can be met with other foods produced on the farm, not only for members of the family but for others as well. Thus the ideal diet can be obtained by means of a farm-production system designed for such a purpose. The model for farming systems is therefore a diverse diet of high nutritive value.

In order to translate the nutritional information of food-consumption systems to that of farm-production systems, the weight distribution and the amounts of food required to optimize the consumption system can be translated into units of cultivated land, animal units, and food required to feed a family or a certain number of individuals. Thus farming-systems research can be linked to the need for nutrients in a better approach to improve nutrition. In other words, such food-consumption systems and the means to supplement them with other foods could be the basis for agricultural research strategies in farming systems research or in on-farm research.

The Importance of Agricultural Research in Increasing the Efficiency of Biological Use of the Nutrients in Food Crops

The main objective of all the disciplines included in agricultural research is to achieve maximum production per unit of land. Maximum production can be achieved through a number of actions, however, that may finally not really mean much in benefits to those who produce, consume, or use whatever was produced. The true objective of agricultural research, therefore, is to realize maximum production with productivity. The last term is taken as an efficiency term, in which the cost of the calories used to achieve maximum production is the lowest that will ensure greater acceptance of the technology by the producer at the lower possible cost to the consumer. It may be observed that productivity is also the parameter used in animal-production systems, as measured by the minimum amount of feed needed--thus the cost--to produce one unit of edible animal food. Such an approach, however, seems to have been forgotten in the study of human nutrition, although the human biological system is not too much different from that of plants and animals; the sociological nature of man, moreover, makes it easy to solve the whole difficult problem. The universal need of plants and animals, including man, for calories is obvious. In the first instance calories are obtained through photosynthesis. In the second they must be obtained from plants. The plant obtains other essential elements from the soil, while animals obtain them again from the plant. But the plants consumed by the animals are blended in such a way as to achieve maximum efficiency of use, because the system has a cost. The same principle is applicable to man, and the system now used to feed him is wasteful and of poor efficiency of use, even if more of the same is used to feed him.

There are various means of achieving greater efficiency in the use of food and nutrients by man. One is to increase the intake of animal protein, an approach believed to be too costly for developing societies if it is patterned after developed societies. The required intakes are in fact small. A second approach is through technological fortification of foods, an approach essentially similar to that used in the animal industry. A third is to improve the nutrient content of the vegetable food, and a fourth is through diet, to which agricultural research can make significant contributions, and if productivity of the whole system, from production to use, is achieved, the term will have its true meaning.

To demonstrate the point, one example, which has to do with the problem of the low digestibility of the protein in common beans, will be given. Table 19.6 shows human values for digestibility of the protein in common beans fed at a physiologically adequate level of protein and energy intake with the addition of other nutrients. The table also shows the metabolic efficiency of use of bean protein and the average protein content of beans.

The digestibility of the protein by human beings is about 52 percent. This means that of the 42 grams of protein ingested from beans--for an individual weighing 65 kilograms x 0.65 grams of protein per kilogram a day--only 22 grams were absorbed and 20 grams were lost in excretion. In other words, of the 24 percent protein content of beans, only 12.5 percent was absorbed. The metabolic efficiency of use of the protein absorbed is 63.5 percent; therefore, only 7.9

percent was used. If the yield per hectare and the cost of production are expressed as protein per hectare, the calculation without the biological parameters may look attractive, but if the calcultion is based on the amount actually used, the effective yield of protein is low and the cost is very high. Productivity is, therefore, actually low. This is what is now being achieved to a variable degree in agricultural research by following the assumption that more production means greater intake of food, calories, and nutrients.

Hunger must of course be satisfied first, which is not strange since "bulk is the principal desired characteristic of the diet among the poor"; bulk, however, is easier to provide than quality. The IARCs have the means to achieve quality, and their development shows that this will finally be the direction they will take.

Table 19.6--Low digestibility of the protein in common beans

Item	Average
	(percent)
Apparent digestibility of common bean protein by an adult human being	52.0
Protein content of common beans	24.0
Absorbed protein	12.5
Biological value of bean protein to human beings	63.5
Net usable protein	7.9
Apparent digestibility of the protein in maize	82.0
Apparent digestibility of the protein in maize and beans, in a maize/bean ratio of 7 to 3	61.0

SOME RECOMMENDATIONS TO ENHANCE THE EFFECTS OF AGRICULTURAL RESEARCH ON NUTRITION

1. Increase collaborative work with national institutions in food and nutrition.
2. Increase farming-systems research or on-farm research that is based on the concept of diet; diversify production of food commodities; incorporate animal-production systems when possible; include increased income as an objective.
3. Associate agroindustrial development with crop production, including harvest technology, storage, distribution, marketing, processing, and diversification of use of commodities.

4. Promote the concepts of food and nutrition in training programs and in national agricultural research centers.
5. Increase the content of the limiting nutrients in commodities without decreasing yield or increasing costs by using the diet concept.
6. Establish goals for nutrient content in specific commodities with respect to diet.

Discussion

Doris Howes Calloway

Six commodity characteristics are important in the context of this meeting:

1. Nutrient content and bioavailability.
2. Nutrient density.
3. Palatability.
4. Preparation requirements.
5. Storage characteristics.
6. Affordability.

Dr. Bressani notes the increasing risk of deficiency of essential nutrients if the diet is based heavily on a single food, especially if it is a plant food. This is a point on which all nutritionists agree. A minimum array of foods that will provide a nutritionally adequate diet consists of a cereal or potato, a legume, a dark green leafy vegetable, and, of course, salt and water. (A bacterial mold or other source of vitamin B-12--such as insect fragments--is assumed). The diet would be improved by the inclusion of eggs, milk, or meat.

The volume of food required may be a limitation on the attainment of adequate levels of intake. This is especially true for very young children and, perhaps, for pregnant women, whose needs for essential nutrients are greater in proportion to their needs for energy than are those of physically active adults. The main commodity characteristics that affect bulkiness are water-binding capacity, content of indigestible fibrous matter, and fat content. Bulkiness can be reduced by complementing the diet with energy-dense foods such as meat, eggs, and nuts or fats and sugar. If, however, density is increased by the addition of separated fat or sugar, the content of essential nutrients in the basic foods become more important.

Nutritional characteristics of commodities should therefore be examined in the light of their place in a total diet and the age and condition of the users most at risk of malnutrition. A principal goal is to assure diversity and complementarity. The need for greater energy density suggests the need for attention to fats and oils, and special attention should be given to nutritious foods such as eggs, oilseeds, and nuts, of which fat is an integral part and a carrier of fat-soluble vitamins including vitamin A.

Palatability may also be a barrier to adequate consumption. Human beings appreciate sensory stimulation and novelty. There is a limit to how much bland food a person <u>will</u> eat--as opposed to what he <u>can</u> eat. Palatability of the food <u>itself</u> is the first limitation; its <u>ability</u> to be presented in varied forms, textures, or shapes is

another. Fat enhances both energy density and palatability. Condiments are important to assure sufficient consumption of the staple food and often contribute important nutrients; examples are vitamins contained in chili and minerals in crude salt.

Cookability is a central issue because of its relation to fuel requirements and the amount of time demanded of women and children. This is also a concern of the food-processing industry.

Removal of toxicants and antinutritional components is a significant variable in preparation for consumption. To the extent that antinutritional substances are critical to the ability of a plant to withstand stress, some trade-off may be necessary; but preparation needs must be taken into account in reaching decisions. There are also public health risks--cancer, for example--that are difficult to quantify for cost-benefit analysis.

The supply of nutrients must be stabilized across regions and time. Some sacrifice in initial nutrient content may be warranted to achieve the goal of storability.

Energy can be stored to some extent in vivo as accumulated fat tissue, at a loss of about 10 percent in overall efficiency of energy use. Some fat-soluble nutrients and trace elements may also be stored in tissues.

The costs of storage in external stores must be taken into account and may be associated with health hazards the costs of which are assignable.

In my opinion the international agricultural research centers should appraise the probable effects of changes in commodity characteristics according to the total cost of the produce delivered to the mouths of the household members most at risk of malnutrition. Costs include production costs--seed, fertilizer, water, and so on and the time of women and children as well as that of men; preparation costs--fuel, equipment, time, necessary additives; and storage costs--loss of product, loss of nutrients, costs of processing, contaminants, use of storage facility, use of time; and, in the case of urban consumers, the costs of transportation and marketing.

The poor may pay more per unit of product for a number of reasons. The point raised by Mr. Ryan as to who will buy what--that is, the preferences of consumers at different nutritional and, presumably, income levels--is important and has to do with such product characteristics as color, size, and flavor.

Valuable byproducts that are consumable or marketable should also be taken into account in assessing the desirable characteristics of commodities.

20
Incorporating Nutritional Concerns into the Specification of Desired Technology Characteristics in International Agricultural Research

Omawale

NUTRITION AND AGRICULTURAL TECHNOLOGY

In this paper it will be assumed that international agricultural research will most often be addressing situations in which free enterprise is dominant in the economy and state control is limited. In such situations the relatively free marketplace, however imperfect it may be, will determine nutrition outcome and related factors. Furthermore, in these circumstances changes can be expected to come about through modest incremental improvements rather than through radical action.

In this context the possibilities for including nutritional concerns in the specification of technology characteristics in agricultural research arise principally from two conditions that affect most of those who are at risk of malnutrition: they are either rural dwellers, whose livelihood is dependent on agricultural production, or urban residents, the adequacy of whose diets is dependent on the availability of low-cost food. Consequently, the nutritional implications of proposed agricultural technology are perhaps best evaluated by the way in which the technology can address the following problems that confront many poor households:

1. Low incomes of agricultural producers that are related to low productivity and to the prevailing unfavorable pattern of the distribution of assets.
2. The seasonality of food harvests and consequent fluctuations in the levels of food consumption of producers.
3. High food costs as a result of low agricultural productivity and seasonality of food supplies.[1]
4. Inadequacy of the food intakes of young children, which is related to the extent of control that adult males exercise over household income and income-earning resources.
5. Inadequacy of the intakes of energy and nutrients, accounted for in part by the low density of these factors in primary food commodities.

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[1] Sometimes the burden is borne by the state in order to protect the poor consumer to some extent, but at some definite opportunity cost.

6. Dietary imbalance caused by limitations on the variety of food produced and consumed, related in turn to low cropping intensity and low productivity of nonstaples.

These problems are not of equal importance for the nutrition of the poor. Consequently, technology can be judged to be more or less important nutritionally to the extent that the problems it addresses are more or less important.

Although a number of constraints will subsequently be identified, the possibilities are more likely to be realized, at least in part, if the objects of research are clearly identified. Research should benefit especially persons who are at risk nutritionally and who are, or can be, engaged in production and other persons who are at risk whose consumption can be improved by local agricultural production. In the first instance significant increases and stability in employment, incomes, and the amount of food available from the consumer's farm should lead to improvements in diet. In the second, consumption of food by nonproducers should increase when the prices of price-elastic commodities decline as productivity increases. Research is usually helpful to the extent that it introduces technology that favors at-risk groups more than others (see Chapter 3).

Constraints

One general constraint that all centers face is the fact that each of them serves a range of national political systems, with possibilities that vary, so a particular technological package may be appropriate for one country and inappropriate for another. Within a project, for example, the creation of short-run employment is often seen to be in conflict with increases in productivity, whereas both are regarded as essential for the elimination of poverty. In a highly redistributive and state-controlled economy, however, social accounting should render the same intervention free of such a contradiction. There is therefore a need for country-specific and location-specific research that some international institutions may find restrictive and impractical. Even within the same political system, the specificity of farm-related problems requires careful identification of targets and on-farm research. But such activity can be accomplished only through creative collaboration among several national and local groups--a novel approach for some centers.

Traditionally, the responsibility of international agricultural research has apparently been considered to stop short of implementation and even monitoring and evaluation of technological intervention. On-farm research does offer possibilities for extending work in this direction, but many factors that influence its effect on nutrition may be beyond the control of agricultural research and yet be limiting factors in the nutrition system (see Chapter 3). Intensely political factors, for example, and health and sanitation factors may be so important in certain situations as to render new agricultural research largely irrelevant to nutrition.[2] To compound the problem,

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[2] See Omawale, "Political Constraints to Nutritional Improvement: The Case of Guyana," International Journal of Health Services 12

evaluation of the effects of a particular technological intervention is extremely difficult. This is because of the simultaneous existence of several other confounding factors that pose serious threats to the validity of interpretations of any observed nutritional change.[3] But the lack of sure knowledge of its effects reduces the likelihood that the research will be useful.

Furthermore, policy decisions regarding research priorities and boundaries, while essentially political decisions and not usually made by researchers, do constrain research activities. Thus the policy decisions and administrative mandate of a center may limit the extent and type of on-farm research that can be undertaken (see Chapter 13). On the other hand, the mandate may be interpreted simply as a requirement to do that, and only that, which is requested by the countries served (see Chapter 15); or it may propel research in directions dictated by certain efficiency criteria as opposed to activity influenced by considerations of equity or nutrition (see Chapter 7). Similarly, the fact that the economies of most countries served by the centers are essentially free enterprise leads to the probability that research will tend to develop in favor of areas in which profits are likely to be large and the pressure on prices is great because the demand for food is high. But these situations are not likely to include those most at risk of malnourishment.

Another constraint is the fact that in the past the primary concern of most agricultural research has been production; it was concerned with consumption only in the aggregate. Perception of the ways in which nutrition can be improved by agricultural technology might thus be limited by tradition and the scarcity of in-house expertise in nutrition or useful collaborative opportunities. To the extent that this is true, the research may not benefit from adequate insights into its potential for improvement of nutrition.[4]

Perhaps the most serious constraint arises from the extensive landlessness of most of the people in the world who are nutritionally at risk. Agricultural research will, in most situations, affect their lives only indirectly, if at all. The indirect effect may come through the creation of employment and increases in real income, but it can only be small in relation to the magnitude of the problem.

Finally, on the issue of constraints, scale-neutral technology, an important development since the early interventions of the green revolution, may still help to reinforce the status quo or even

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(1982): 231-247; Robert Tripp, "On-Farm Research and Nutrition: Some Suggestions for Collaboration between National Institutes of Agricultural Research and Nutrition," CIMMYT, Mexico City, 1983 (mimeographed), p. 7.

[3] See Marjorie F. Fruin and Mark L. Davison, "Some Considerations in the Measurement of Change," Journal of the American Dietetic Association 73 (July 1978): 15-19.

[4] Omawale, "Nutrition Problem Identification and Development Policy Implications," Ecology of Food and Nutrition 9 (1980): 113-122.

exacerbate poor nutrition if the redistribution of incomes, assets, and power are the key to improvement.[5] In a study made in Bangladesh, for example, it was concluded that a scale-neutral dairy-development project, that brought some small immediate consumption benefits to the poor, would in the long-run redound to the disadvantage of resource-poor households since it presented a new opportunity for their exploitation, given the existing social relationships.[6] On the other hand, it was found in the same study that a rural cooperative development project exclusively for the landless did confer a degree of independence on the participants in addition to immediate improvements in consumption. In other words, scale-neutral technology, although a welcomed advance, may still be inadequate in situations in which the poorest need to be given special advantages.

PAST ACTIVITIES

In reviews of the past activities of the centers, it was noted that they vary considerably both in the length of time during which they have been in operation and in the nature of their mandates and constitution. These factors make for differences in approach, in the acquisition and assessment of nutrition information, and consequently in apparent response to nutrition considerations. Additionally, the issues of location-specific research and research for the benefit of specific groups are of particular relevance to nutrition. The information that is available is not always conclusive, but there also appears to be variation in the extent to which the several centers practice on-farm research and research that is directed toward specific target groups. In any event some centers seem to have developed an interest in nutrition despite their having been established without specific mandates for the improvement of nutrition. Several activities of other centers, embarked upon for other reasons, are regarded as having implications for nutrition merely because of their relation to food in general or to the alleviation of rural poverty in

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[5] See Keith Griffin, The Political Economy of Agrarian Change: An Essay on the Green Revolution (London: Macmillan, 1974), for one of several critical considerations of this topic.

[6] See Omawale, Olga Stavrakis, and D. L. Bocobo, Nutrition Considerations in Agricultural and Rural Development Projects: Report on a Study in Bangladesh (Rome: Food and Agriculture Organization of the United Nations, 1978). The landless were dependent on relatively large landowners, for example, for straw to feed their animals. This they obtained through a semifeudal system that left more feed for the landowner, without his making any effort or incurring any additional cost. The large landowner was thus able to produce more milk, earn more profits, and accumulate more funds to lend at usurious rates to the very landless who, through the medium of the project, made all this possible. But this very moneylending was one of the principal causes of the frequent demise and malnourishment of the landless and the smallholders in that area of Bangladesh.

particular. Research of this type, however, is best assumed to have little, if any, potential for the improvement of nutrition.[7]

In general activities that had some significance for nutrition fell into three broad categories: primarily agricultural research that has led to the introduction of new materials--varieties, chemicals, and machinery; primarily agricultural research that has dealt with new management practices; and primarily socioeconomic research that has led to recommendations for public policies and for agricultural research itself.

New Materials

The introduction of new disease-resistant or drought-tolerant breeds into the systems of those producers believed to be most at risk of malnutrition was the subject of research by several centers. This activity had the aim of increasing productivity and promoting stability of yield--factors of considerable importance to the poor rural producer.

Thus, CIAT worked on disease-resistant breeds of beans and cassava for small farmers in Colombia and on varieties of cassava that are tolerant of drought and the poor soils that are typical of such systems. IITA collaborated in this work, with emphasis on African farming systems. CIP, for its part, pursued research into disease- and pest-resistant potato cultivation, while CIMMYT did similar work on wheat and maize, IRRI on rice, and AVRDC on vegetables. In addition research on the introduction of drought-resistant varieties was done by CIMMYT and AVRDC. CIMMYT also did research on the introduction of varieties of maize and wheat that are tolerant of aluminum-toxic soils, while IITA worked on rice that is tolerant of iron toxicity. It might be expected that only the poorest farmers would be dependent on such soils, but the truth of such an assumption is not clearly demonstrated in the available reports.

Other work with new materials, although related to management practices, included that by CIMMYT on reduced-lodging varieties of maize for low-management situations and on early-maturing wheat, which makes a winter crop possible in Bangladesh. Similar work was that of IRRI with rice in the Philippines, where there was reported to be an increase of 140 percent in the value of village crops without loss of employment and with only small increases in variable costs (see Chapter 14). Another consequence was less fluctuation in prices, but the net effect on nutrition of this scale-neutral technology has not yet been assessed.

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[7] See Mercedes Hernandez et al., "Effect of Economic Growth on Nutrition in a Tropical Community," Ecology of Food and Nutrition 3 (1974): 283-291; Omawale, "Towards Criteria and Practical Procedures for the Systematic Introduction of Nutrition Considerations in the Preparation and Appraisal of Agricultural Projects," paper prepared for the ACC Sub-Committee on Nutrition of the United Nations meeting on Nutritional Implications of Agriculture and Rural Development Projects, Food and Agriculture Organization of the United Nations, Rome, 1978.

Systems that include livestock received similar attention through the activity of ILCA with high-productivity cows in Ethiopia and that of ILRAD on disease-resistant cattle and embryo-transfer technology. With respect to the latter, the implications for nutrition of this new technology can be truly determined only through appropriate socioeconomic investigation.

Other work involving livestock was done by ILCA in relation to the development of the single-ox plow. This is of particular importance to poor farmers who had until then been constrained in the amount of cropping they could undertake because of the lack of sufficient cattle for traction.

Less closely aimed was the activity of ILCA with ox-drawn scoops for making water ponds and dams. This intervention is unique in its direct relation to health. It serves a fairly wide community, however, which probably includes some persons who are not seriously at risk of malnutrition.

Research by IRRI into warehouse drying of modern varieties of rice offers the possibility of reducing postharvest losses of rice that matures in the wet season. It has been suggested that this will contribute to increases in incomes, food supplies, or both among farm households that are at risk of malnutrition and may therefore improve nutrition. Similarly, research done by CIP into intermediate technology for the processing of such traditional Andean products as Papa seca appear to have direct influence on nutrition. Such a conclusion cannot be confidently drawn, however, without further socio-economic study.

Research done by CIAT on improved varieties of pop bean is of particular significance for the poor Andean farmer who is faced with a shortage of fuel at high altitudes. Under these circumstances, cooking pop beans has proved to be economically preferable to boiling "normal" varieties of bean.

New Management

Research on management practices, necessarily pursued on a small scale in particular localities, engaged the attention of many centers.

CIAT did research on new pasture technology for dual-purpose livestock of "relatively small" ranches, while ILCA was concerned to improve Ethiopian forage-management practices and cropping systems for agropastoralists in Mali. The latter efforts are considered important because they may lead to increases in animal production without jeopardizing food production. This in turn implies greater potential income through the raising of cattle and through their use for traction in the rest of the production system. IITA also cooperated in this work.

On-farm research done by CIMMYT in Ecuador helped identify for development other crops that could be grown in rotation within the existing small-farm systems. ICARDA did testing of livestock feed. CIP developed true potato seed with a view to reducing production cost and releasing traditional seed potato for direct consumption. Clearly, the implication of this promising intervention for nutrition can be determined only when the consequent socioeconomic changes in the system have become well known or predictable. IRRI was involved with other agencies in research on rice-based cropping systems,

primarily with the aim of improving dry-land crops. IITA did research on alley cropping, which reduces the requirement that large land areas lie fallow and facilitates production of fuel wood, stakes, and fodder--all economically beneficial to small-farm systems.

In agricultural processing CIMMYT did research on milling and baking with blends of wheat flour with other flours. This opens possibilities for foreign-exchange savings in countries where wheat does not grow readily. Whether those at risk of malnutrition will benefit from such developments, however, depends largely on socioeconomic and political factors such as those that will determine the disposition of any foreign exchange saved.[8] ICARDA also engaged in research on the suitability of new varieties of wheat for breadmaking. Meanwhile, CIP developed a scale-neutral multimix convenience food, and IRRI investigated the effects of using parboiled rice with added oil in the preparation of gruels for young children. While the work by ICARDA is subject to the same limitations on interpretation as the bread research done by CIMMYT, the gruel research done by IRRI for small children may be more readily presumed to have had positive nutritional consequences.

Socioeconomic Research

As indicated earlier, several centers have undertaken limited socioeconomic studies as part of their efforts to evaluate the effects of new interventions. Somewhat more comprehensive research was undertaken by CIP on consumption and marketing of potatoes. But the most active in socioeconomic research was IFPRI whose mandate appears to point exclusively in this direction.

The activities of IFPRI have been described well by Pinstrup-Andersen (see Chapter 10) and need only to be summarized here for easy reference. They covered:

1. Studies of the effects of technological changes on consumption, including the introduction of new varieties and the irrigation and double cropping of rice, as was promoted by several centers.
2. Studies of the effects on nutrition of shifts from subsistence cropping to cash cropping--to dairy development in India, for example, and production of sugarcane in the Philippines.
3. Studies of the sources of instability in production of foodgrains in order to inform action to reduce these and their supposed ill effects on nutrition.
4. Studies in Nigeria and Malaysia on the links between household consumption and employment on the one hand and between technological change and agricultural development on the other.
5. Studies in West Africa on the effects of price changes that arise from market forces on consumption by the producing and nonproducing poor.

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[8] Detlef Schwefel, Who Benefits from Production and Employment? Six Criteria to Measure the Impact of Development Projects on Poverty and Satisfaction of Basic Needs, Occasional Paper 29 (Berlin: German Development Institute, 1976).

SUGGESTIONS FOR THE FUTURE

Influence of the Centers

It is impossible to judge the influence of the efforts of the centers to make decisions regarding agricultural technology solely on the basis of the available reports. Clearly some of the technologies developed by the centers have been adopted successfully; Tripp, for example, reported in Chapter 5 that

> in less than a decade after the introduction of short-seasoned wheats, ... Bangladesh experienced a tenfold increase in wheat production. Surveys have shown that half these new wheat farmers own less than one hectare, and 60 percent keep all their wheat for home use.

But more research and analysis are needed to evaluate the real effect of these and similar efforts. In some instances, furthermore, it will probably be impossible to separate the effects of a center's intervention from the results of other simultaneous events.

Conflicting Demands

It has often been said that agriculture and agricultural research must serve demands other than those of nutrition. In this context it is frequently argued that while some consideration can and should be given to nutrition, it must be weighed against other competing demands. The suggestion then usually follows that there will be some, perhaps many, situations in which adverse effects or no effects at all on nutrition will have to be tolerated.

Such arguments were more prevalent and more to the point earlier, when agriculture and agricultural research primarily and unapologetically served the interests of those who were not nutritionally at risk and was concentrated on aggregate production or increased productivity of modern or progressive farmers. Many debates ensued about the possibilities, not to mention the desirability, of achieving goals for aggregate growth while ignoring resource-poor farmers. It was argued with particular fervor that increased production was likely to be short-lived if effective demand did not grow substantially. And since the latter was to be achieved principally in the marketplace, the large mass of small producers and the unemployed would have to be included in strategies to increase income. What better way, or how else, to do this than by involving them in agricultural development.

But apart from these salvos at the scientists who were preoccupied with production, the specter of widespread hunger in the midst of the green revolution suggested even to the most conservative professionals that something had gone wrong. Consequently, to address poverty became one of the more frequent objectives of agricultural research. Following this change, which was simultaneous with the spread of mature understanding of the causes of malnutrition, the stage was set for less grudging acceptance of nutrition considerations in agriculture and agricultural research.

The reports from the centers that belong to the CGIAR bear testimony to a significant evolution in the perception of the ways in which agriculture, and therefore agricultural research, could influence nutrition. Thus there are noteworthy observations that early work stressing protein content gave way to emphasis on means of removing constraints to increasing consumption of food by increasing and stabilizing farm production and income, for example, while reducing the costs of food to nonproducers.

This important development has made it easier to argue that there is really no conflict between the goals of improved nutrition and other goals commonly set for international agricultural research. An examination of the mandates of the centers (Table 20.1) reveals that the overwhelming majority are required to address poverty as a priority. This involves the centers in research the aim of which is to remove the constraints to greater and more stable production and productivity of resource-poor farmers, potential farmers, and farm workers. But these are, in fact, the primary constraints to adequate consumption of food and good nutrition. Consequently, it now seems that taking nutrition into account does not imply an opportunity cost in relation to fulfillment of other explicit goals of the centers.

If nutrition were to be ignored simply because responses to concern for nutrition would inhibit the attainment of objectives in aggregate production or growth, it would mean that such objectives were seen not to be in the interest of the poor. Therefore, it seems entirely justifiable now to include consideration of nutrition explicitly in the mandates of the centers.

Table 20.1--Selected elements of the mandates of international agricultural research institutes

Center	Increasing Agricultural Productivity	Improving Commodity Quality	Increasing Food Production	Increasing Farm Incomes	Improving Nutrition
AVRDC	Yes	Yes	No	No ?	No
CIAT	No	No	Yes	Yes	Yes
CIMMYT	Yes	No	No	No	No
CIP	Yes	Yes	Yes	No ?	No
ICARDA	Yes	No	Yes	?	Yes
ICRISAT	Yes	Yes	Yes ?	Yes ?	Yes
IFPRI	Yes	No	Yes	Yes	Yes
IITA	Yes	No	Yes	Yes ?	Yes
ILCA	Yes	No	Yes	No	Yes
ILRAD	Yes	No	No	No	Yes ?
IRRI	Yes	Yes	Yes ?	No	Yes
ISNAR	--	--	--	--	--
Total	10	4	6-8	2-7	7-8

? means not known or doubtful.
-- means not applicable.

Strengthening the Effectiveness of the Centers

As observed earlier, the center reports in the main indicate a decisive trend away from preoccupation with the content of protein and other nutrients in food commodities. Indeed, there is evidently a keen, widespread awareness of the multiple causes of malnutrition and a movement toward concern for its underlying causes rather than its immediate causes.[9] This is to be commended and encouraged. The workshop will undoubtedly further this process through discussion and interchange among the centers, some of which are more experienced than others in this part of the work.

The way forward seems to demand:

1. Avoidance of activity that will lead to interventions which have already been widely demonstrated to have negative effects on nutrition.
2. More socioeconomic research in order to determine and concentrate on the specific problems of the poor, who are the ones most at risk of being malnourished.
3. Intensification of the search for technologies that not only serve the interests of the resource-poor and the nutritionally strategic--women, for example--but actually confer on them a particular advantage.

What is needed additionally, then, is a move toward addressing the more fundamental causes of malnutrition. Because some of these invite consideration of political or semipolitical issues, it will be difficult or impossible for some centers to hurl themselves into this arena. More socioeconomic research is required, however, if our understanding of the constraints to improvement of nutrition through attacks on the underlying cause is to be increased and the effectiveness, or lack of effect, of certain interventions is to be demonstrated in clearly defined circumstances. For one thing, socioeconomic research will expose to decisionmakers the extent to which their policies can help or hinder the achievement of depauperization and the improvement of nutrition, given the technical possibilities developed by the application of science.

The possibilities for advocacy will also then become greater, and some centers may even engage in this exercise to the advancement of the nutrition interests of the poor.

The following are a few practical measures that might aid in such a development:

1. Each center might contribute its experience and information to the development--by the Administrative Committee on Co-ordination-Sub-Committee on Nutrition of the United Nations, for example--of country agronutrition profiles. These profiles would summarize the salient features that are thought to determine the state of nutrition in each country. They would need to be somewhat disaggregated in order to be at all useful but they

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[9] Urban Jonsson, "The Causes of Hunger," Food and Nutrition Bulletin 3 (July 1981): 1-9; Leonard Joy, "Food and Nutrition Planning," Journal of Agricultural Economics 24 (1973): 165-192.

would still be organized in relation to the nation-state.[10] The profiles, if regularly updated, would represent a valuable base of information for any researcher--international, national, or individual--who wished to contribute to the achievement of better nutrition through agricultural research.

2. Centers might include consideration of nutrition in their research by using personnel sensitive to and informed about the interrelations between nutrition and agriculture. In some instances the available funds and the organizational structure might permit the establishment of a post for such a person. In others the resource could be tapped through consultancies or collaboration with other national or international agencies. In yet other instances, it might be appropriate to rely on the latter in conjunction with the retention of the services of a nutrition advisory panel such as CIMMYT has (see Chapter 5).
3. All centers might include a statement of the anticipated effect on nutrition with any recommended intervention. Such a statement might even have to admit the possibility of neutral or negative effects, but it would indicate the reasons and suggest some compensatory measures. By way of illustration, consider the proposal for the introduction of scale-neutral technology in circumstances where the existing distribution of assets would cause the percentage gains to be similar, in the short run, for all strata connected with the production process. Such an instance was the introduction of modern rice varieties in the Philippines, where, according to Ranade and Herdt, the benefits of new technology were distributed roughly in proportion to ownership of resources.[11] The researcher may be unable to change this outcome, but the technology recommendation should carry with it a clear statement of possible or likely effects of certain policies that are beyond the researcher's control. IFPRI, because of its mandate, its experience, and its current research program, appears to be a particularly useful resource for identification of the implications of public policies for nutrition.

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[10] Leonard Joy and Philip R. Payne, Food and Nutrition Planning, Nutrition Consultants Reports Series No. 35 (Rome: Food and Agriculture Organization of the United Nations, 1974).

[11] Chandrashekhar G. Ranade and R. W. Herdt, "Shares of Farm Earnings from Rice Production," in Economic Consequences of the New Rice Technology. (Los Baños, Philippines: International Rice Research Institute, 1978), pp. 87-104.

Discussion: Agricultural Science Planning — A Strategy to Eradicate Malnutrition?

Najwa Makhoul

NUTRITIONALLY CONCERNED AGRICULTURAL RESEARCH OR ERADICATION OF MALNUTRITION

The incorporation of nutritional concerns into international agricultural research, the central theme of this workshop, can take many forms--such as increasing the protein content of luxury fruits, for example--that may have nothing to do with improving the nutritional status of the malnourished. Incorporating nutritional concerns into agricultural research, therefore, cannot in itself be a decisive factor in the eradication of the mass malnutrition that prevails in parts of the capitalist world today. The two processes--advances in nutrition-oriented research and changes in the nutritional status of vulnerable population groups--are determined in entirely separate spheres, and improvements in the one do not necessarily lead to improvements in the other.

The material presented in this workshop is a testimony to the boundless combination of factors that agricultural research can provide toward improvement of human nutrition. Technically, agricultural science can vastly enhance the possibilities for improving nutrition, for example, by breeding potentially low-cost, high-yielding varieties with greater nutrient content. At the same time that such advances in research are being applied in a particular country, however, the nutritional status of the public in that country may be deteriorating.

These twin observations point to the existence of structural barriers to the translation of research advances into actual improvements in the nutritional status of socially oppressed groups. Some of these barriers are inherent in the nature of commodity production and the uniqueness of the commodity labor power while others have to do with the role and class nature of the state.

Mass malnutrition persists today, not where agricultural productivity is low--as illustrated by the examples of Brazil and Mali--but where social relations of production and exchange of a particular type prevail. Enhancement of nutritional possibilities through agricultural research in the context of these relations is quite a different matter from eradication of mass malnutrition, and the attempt to eradicate it in this context is perhaps even counterproductive. Only specific social groups--not the entire population--are the victims of modern malnutrition. Variations in nutritional status among groups

and in time are functions primarily of state intervention in the reproduction of the population as a social structure.

In this sense I am in full agreement with the point so far made only by Mr. Omawale that improvements in nutritional status are primarily a function of changes in the nature of government. An important empirical study by Peter Hakim and Giorgio Solimano of nutritional programs in Chile illustrates this point clearly. Hakim and Solimano found that only under the Allende government did a forty-year-long nutrition program effect significant changes in the nutritional status of urban and rural groups that were persistently malnourished--and this even in the absence of agricultural research planning.

The theme of this workshop--the incorporation of nutritional concerns into international agricultural research--opens two possible avenues of thought: on the one hand, it may advance the misleading assumption that nutritional status is a function of science planning and, by implication, place the responsibility for malnutrition and its eradication on agricultural researchers. On the other hand, it invites us to problematize the assumed interrelations among agricultural science, agriculture, and the state of public nutrition, which would render this workshop invaluable scientifically.

AUTONOMOUS RESEARCH: UTOPIA OR REALITY?

Let us imagine a utopian situation free of the barriers embedded in commodity production as a way of problematizing the relation of agricultural science to agriculture. In this utopian situation we would have a production system that would take the form of an autonomous transnational farm, with emphasis on nutrition, parallel to our international research system, at the disposal of agricultural scientists. This farm would produce food for use, not for profit; and its produce would be distributed according to need, not through the market. The choices of optimal technology, moreover, would be based on productivity per unit of land and on the nutritional content of varieties.

This utopian transnational farm is probably the only situation in which agricultural research would lead agricultural production, yet that agricultural research leads agricultural production is one of the underlying assumptions of our workshop. I have deliberately used a utopian conception in order to illustrate precisely how misleading this assumption is. Only under these utopian conditions could it be assumed that the incorporation of nutritional concerns into international agricultural research would lead to more accessible, nutritionally better food, without changes in the basic social structure of the underdeveloped countries. In other words, assuming that all social conditions remained constant, only in a utopian situation could our workshop's stated goals be fulfilled.

In reality agricultural research does not lead agriculture. The findings of a comparative field study of national agricultural research systems, in which I took part as a member of the World Agricultural Research Project at Harvard University, are quite instructive on this point. Regardless of the level of economic development or type of social structure of a country, in no case was agricultural research found to be autonomous or to lead agriculture. The course of agricul-

tural research was found instead to be shaped by the social organization of production in society at large. In fact, only in Israel and Cuba--although for different reasons--was agricultural research found to be led by agriculture per se. In Cuba this was because of the system of economic and science planning; in Israel it was because of the special role of agriculture in Zionism.

In the other countries we studied, the course of agricultural research was not even shaped by agriculture but by industry. In the United States priorities in agricultural research were found to be determined primarily by the agricultural inputs industry. Plant breeders, for example, select for early maturity to make possible the maximum use of pesticides. In underdeveloped countries such as Brazil, priorities in agricultural research and the direction taken by it were found to be shaped by a combination of the needs of the international agricultural inputs and postharvest processing industries of the advanced industrial countries.

International agricultural research, however, is not bound by the same limitations observed in our study of country-specific research systems and is not led by the needs of the agriculture or industry of any particular country. It is, in this sense, an autonomous agency in which science planning can more easily be directed toward social objectives and in which scientists can be decisive in determining its value orientation. Herein lies both the strength and the weakness of our workshop.

CONTRADICTIONS IN AGRICULTURAL SCIENCE PLANNING

Because of the relative autonomy that international agricultural research enjoys, it is easier to incorporate nutritional concerns into research, but the very attempt to design technological solutions to basic social problems--independent of the intentions of the scientists--turns international agricultural research into ideology. Offsetting capitalism's crisis of legitimation caused by the persistence of mass hunger and malnutrition becomes the primary function of international agricultural research.

Incongruities arise, moreover, when agricultural research is directed toward social objectives while agriculture is the object of private appropriation and while agricultural research is planned but agriculture itself is subject to market fluctuations. These incongruities are sharply revealed when scientists are expected, as they are in Israel, or want, as they do in this workshop, to serve the collective social interest while the direct beneficiaries of their work are not required to abandon the profit motive. Incongruence between the value orientation of agricultural science and the value orientation of agriculture reaches a peak when scientists become missionaries while agriculturalists remain maximizers of profit.

AGRICULTURAL RESEARCHERS: AGENTS OF LEGITIMATION OR FORCES OF CHANGE

As agricultural scientists we cannot claim the task of changing the world. Agricultural researchers concerned with the eradication of malnutrition can address this problem directly, but only in the realm

of the political. A common approach, dictated by the desire to show immediate, measurable improvements in nutritional status, is to circumvent the problem of malnutrition by arbitrarily confining its conceptualization to a technologically manageable scope. The pointed avoidance of urban malnutrition and the constant focus on the small-scale subsistence farm in this workshop illustrate the type of distortion that is the result of this approach; it imposes limits on science itself, compromising its basic function of expanding the horizons of social possibilities.

When put forward as a substitute for the social change that will be necessary if mass malnutrition is to be eradicated, the incorporation of nutritional concerns into international agricultural research is counterproductive. It only sharpens the instruments of social oppression--of which mass malnutrition is one expression. Under these conditions, it may be that truly concerned international agricultural researchers can do nothing more effective than to stop doing agricultural research.

Alternatively, agricultural scientists can define their task as one of exploring scientific possibilities for use in social situations in which structural barriers have been transcended. Only then can scientific agricultural advances become decisive in the eradication of mass malnutrition.

Discussion

Guido Gryseels

First of all I would like to point out that the assumption made by Mr. Omawale that all CGIAR centers are located in market economies is not entirely correct. The headquarters of ILCA are located in a socialist country, and the government here occasionally looks over our shoulder and asks whether we are incorporating their political concerns into the specification of technology characteristics.

More important, however, Mr. Omawale's paper highlights the need to make human nutrition an integral part of baseline studies. What do households, some of whose members are malnourished, eat and what do they produce? How are they likely to change their consumption in response to changes in prices and income that are caused by technological change? What are the time lags involved in this process and what about intrahousehold distribution?

Two important problems are associated with this approach. First there is the need to identify the target population clearly. Who are the likely recipients of the technology and what will its effect on them be? Related to this is the fact that alternative technologies are adopted at different rates.

The second problem is that of the location specificity of nutritional problems. The CGIAR institutes have an international mandate and will focus on research activities for which they have a comparative advantage to the national centers. This highlights one of the problems that I hope will be discussed in the forum of this workshop. It is a straightforward matter for a national research institution to incorporate nutritional concerns into the specification of desired technology characteristics. The problem is very different, however, for an institution with an international mandate. CIMMYT cannot be expected to breed 10,000 different varieties of wheat, for example, each in response to a different nutritional problem.

Another problem arises from the change in marketing organization associated with a change in technology; careful consideration must be given to the implications for the function of women in the farming system. In developing countries, for example, women traditionally take care of cows of local breeds that yield one or two liters of milk a day. When crossbred cows that produce five times this amount are introduced, however, the marketing of the milk may be taken over by the men. This may have implications for nutrition. The change from local cows to crossbred cows will also involve changes in the

allocation of labor and time, which might also affect nutrition. A careful monitoring of all these effects is therefore necessary.

The paper highlights the need for further research on the effect on human nutrition of an increase in income of farmers. The work of IFPRI in undertaking this research in cooperation with other international research centers is particularly important.

Finally, Mr. Omawale asks for a change in the mandate of international centers. I am not thoroughly familiar with the mandates of the other centers, but the mandate of ILCA is to improve the welfare of its target population. The word welfare includes nutrition, so a change in the mandate of ILCA would not be necessary.

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Production Research at the International Agricultural Research Centers and Nutritional Goals

Robert Tripp

This paper is an attempt to summarize the nutritional aspects of production research carried out by the IARCs and to propose an agenda of issues for discussion. It is meant to address only the nutritional problems in rural areas, so only the nutritional relevance of IARC research to farmers and farm laborers will be examined. Information on production research directed toward nutrition is derived from papers prepared for this workshop.

PRODUCTIVITY, INCOME, AND NUTRITION OF SMALL FARMERS

A common theme throughout the IARC papers is that the nutritional element of production research is either closely linked to or synonymous with the effort to improve the productivity and incomes of resource-poor farmers. This not only includes improvements in the production of mandated crops or animals but also involves work on intensification of cropping systems and contributions to postharvest technologies. The assumption that improving farm productivity and income can be an important means of resolving nutritional problems is a valid one. Because the IARCs have established a solid record for reaching resource-poor farmers, they have undoubtedly had a positive effect on nutrition.

The issue of directing gains in productivity to those most in need is a crucial one and will be discussed in greater detail later. The IARCs are conscious of this issue and try to make sure that their technologies are scale-neutral, that their research is carried out with small farmers, and that on-farm research is directed toward well-defined target groups. To bring about gains in productivity for resource-poor farmers requires attention to a number of factors, including a consideration of the complementarity of genetic and agronomic innovations, attention to the availability of rural labor, sensitivity to risk, organization of location-specific research, and understanding the circumstances of farmers.

That IARCs are concerned with reaching resource-poor farmers and that through their efforts productivity, income, and nutrition have been improved is beyond question. But is this enough? Is a strategy that aims production research at the rural poor the best that the IARCs can do by way of ameliorating the problems of global malnutrition? Should the IARCs simply redouble their efforts at bringing

gains in productivity to the poor, or are there more specific activities that would increase the nutritional effectiveness of their work?

There are several issues that must be addressed in consideration of an expanded concern for nutrition in production research. First, it must be borne in mind that better nutrition is one of several goals of the research carried out by the IARCs. If giving more attention to nutrition jeopardized the effectiveness of work by the IARCs in other areas, some choices would have to be made. Although goals such as greater productivity, income, and equity are obviously related to nutrition, there would undoubtedly be trade-offs to be considered in some instances.

Second, it is well known that the nutrition problems of the rural poor are often brought on by a complex of factors. Problems of sanitation, lack of health-care facilities, poor education, and inadequate rural infrastructure may all contribute to malnutrition. When these are the causes of malnutrition, attempts to improve nutrition through agricultural intervention may fall far short of expectations. There is only a certain amount that production research can do by itself to solve nutritional problems, and an overemphasis in this direction may compromise the attainment of other equally legitimate objectives.

Finally, consideration of the nutritional value of a change in production practices is of little use without an assurance of changes in productivity or income that the farmer can appreciate. Farmers have little interest in nutrition per se, and references to the nutritional benefits of a particular technology will rarely persuade farmers to adopt it. More traditional criteria for evaluating a proposed agricultural recommendation must therefore be retained.

With these qualifications in mind, however, it is possible to consider the possibilities for developing a stronger nutritional component for production research. The consequences of changes in production systems that may have serious nutritional implications must be examined, and this is the subject of the following section.

Other Factors Related to Malnutrition

In recent years there have been a number of reminders that improvements in productivity or incomes do not always lead to positive changes in nutrition.[1] What other factors must be considered in order to ensure that production research will have an effect on nutrition? In the following discussion I shall examine the issues of specific nutritional deficiencies and crop diversity, women in agricultural change, cash cropping, and rural labor markets.

The past two decades have seen considerable debate over the nature of nutritional deficiencies. Early criticism of the work of the IARCs was focused on its concentration on basic staples, but both studies of its effects and of current nutritional knowledge seem to

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[1] K.G. Dewey, "Agricultural Development, Diet, and Nutrition," Ecology of Food and Nutrition 8 (1979): 265-273; Patrick Fleuret and Anne Fleuret, "Nutrition, Consumption, and Agricultural Change," Human Organization 39 (Fall 1980): 250-260.

support this approach.[2] The assumption is that calorie-protein malnutrition is the principal problem and that provision of greater quantities of the local dietary staples is what is needed.

It is certainly true, however, that calorie-protein malnutrition is not the only problem and that production research has the potential for affecting the balance of nutrients available to farm families. There are several examples of this in work by the IARCs. A specific focus on broader availability of nutrients is provided by AVRDC, whose mandate includes improving the availability of protein, vitamins, and minerals, and by ILCA and ILRAD, whose work on animal productivity has implications for a wide range of nutrients.

An example of using management for improving access to specific nutrients is the work of IRRI in increasing the protein content of rice through timing and placement of the application of fertilizer (see Chapter 14). A more common strategy for increasing dietary diversity is through the intensification of production systems with early-maturing varieties thereby providing an opportunity for planting a wider variety of crops (see Chapters 5 and 14).

The importance of women in agricultural development has also been the subject of attention recently.[3] The issue is complex and includes the consideration of the time spent by women in agricultural production--which may prejudice child care and nutrition--and the contribution of women to production and the generation of income, for which there is substantial evidence of a positive effect on nutrition. A few of the IARCs are beginning to explore these issues. ILCA is examining the possible effects on women's income of encouraging a shift from milk production to meat production and is also looking at the contribution of women to the labor requirements for livestock management. IRRI recently sponsored a conference on women in rice-farming systems in which the effects of new rice technologies on the labor and income of women were examined. In research done by ICRISAT, the effect of chemical weed control on the wages of female laborers was examined.

A closely related issue is that of the intrahousehold distribution of income, food, and labor responsibilities. The issue has received a great deal of attention, but more information is needed

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[2] Ingrid Palmer, Food and the New Agricultural Technology (Geneva: United Nations Research Institute for Social Development, 1972); James Ryan and Muthiah Asokan, Effects of Green Revolution in Wheat on Production of Pulses and Nutrients in India, Economics Program Occasional Paper 18 (Patancheru, Andhra Pradesh, India: International Crop Research Institute for the Semi-Arid Tropics, 1977); George H. Beaton and L. D. Swiss, "Evaluation of the Nutritional Quality of Food Supplies: Prediction of 'Desirable' or 'Safe' Protein:Calorie Ratios," American Journal of Clinical Nutrition 27 (1974): 485-504; and J. C. Waterlow and P. R. Payne, "The Protein Gap," Nature 258 (1975): 113-117.

[3] See, for example, Irene Tinker, New Technologies for Food Chain Activities: The Imperative of Equity for Women (Washington, D.C.: Office of Women in Development, U.S. Agency for International Development, 1979).

before its relevance to production research can be judged (see Chapter 8). ICRISAT has studied the relations of participation in the village labor market and the wage rates of males and females and related this to nutritional status (see Chapter 9).

Criticism of the negative nutritional effects of agricultural change has often been centered on commercial agriculture. Although the problems are encountered most frequently with export crops,[4] a similar type of analysis is valid for considering some of the changes associated with expansion for the market of the production of staple crops. From the standpoint of nutrition, the success of such projects depends upon the assurance that the income from crop sales is sufficient to cover any dietary deficits, that the income is spent wisely, that the markets are adequate, and that shifts in household allocation of labor to meet the demands of commercial agriculture are not prejudicial to child care or nutrition. Although it has been suggested that a household's subsistence-production capacity should be a focus for farming-systems research, it is not yet clear to what degree these considerations should enter into the production research carried out by the IARCs.[5]

Since a considerable share of malnutrition is found among the rural landless or near landless, it is also important to examine the effect of changes in production systems on opportunities for rural labor. Several of the IARCs in Asia include this in their production research. IRRI is examining the possibilities for increasing rural employment opportunities in rice-based systems, and AVRDC assumes that labor for the market gardens they are testing will be drawn from unemployed members of the households (see Chapters 14 and 16). ICARDA, on the other hand, faces the opposite problem and seeks to develop technologies appropriate for the scarcities of labor that are characteristic of its region (see Chapter 8).

Finally, it might be asked whether there is anything that production research can do with respect to the other causes of malnutrition including poor rural infrastructure, inadequate education, and problems of health and sanitation (see Chapter 8). On a general level it can be argued that successful production programs provide a stimulus for more comprehensive rural development efforts. A more specific example is provided by the work of ILCA on the use of animal power in the Ethiopian highlands for improving water supplies (see Chapter 12).

RESEARCH STRATEGIES

In summary the basic strategy that relates IARC production research to nutrition goals is an emphasis on bringing gains in productivity and income to resource-poor farmers. The IARCs are also

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[4] Per Pinstrup-Andersen, Export Crop Production and Malnutrition, Occasional Paper Series 11 (Chapel Hill: Institute of Nutrition, University of North Carolina, 1983).

[5] W. P. Whelan, The Nutritional Component of Farming Systems Research Research (New Brunswick, N.J.: International Agricultural and Food Program, Rutgers University, 1982); see also Chapter 11.

cognizant of the other factors that are related to changes in production systems and that may influence nutritional status. There is no consensus, however, on the relative importance of these factors, nor on how--or whether--to include them in production-research programs.

There is another distinction that is important in defining appropriate procedures for including nutritional concerns in production research. This is the level of disaggregation at which the research is carried out. A thorough examination of this topic would lead to a discussion of the methodologies of farming-systems research, and that is not my purpose here.[6] Suffice it to say that most IARCs carry out both production research for broad agroecological zones, taking advantage of economies of scale in centrally located research projects on general problems, and location-specific research tailored to the variability that is characteristic of individual production systems. For the purposes of this discussion, these two approaches can be referred to as "upstream" and "downstream," respectively. Thus, the focus "of 'upstream' FSR programs is to find out how to overcome major constraints common to a range of farming systems extending across one or more geographic zones," while these results "must be further adapted by 'downstream' FSR programs to specific local conditions."[7]

There are thus two dichotomies: a focus on gains in productivity to small farmers versus a broader, multifactored approach, and upstream versus downstream research. It is obvious that, at least as a first approximation, there are four possible ways of doing production research in conjunction with nutritional concerns. The IARC papers present examples of all of these approaches.

1. The most common strategy seems to be that of upstream research bringing gains in productivity to resource-poor farmers. IRRI, for instance, has placed considerable emphasis on rainfed and deepwater environments for growing rice, with the knowledge that these represent areas of particularly serious poverty and malnutrition (see Chapter 14). IITA's mandate includes development of alternative production systems for the humid and subhumid tropics. ILCA has identified five ecological zones for work in Africa. Research priorities vary from one zone to another and reflect nutritional concerns (see Chapter 12). CIP has been examining possible uses for the potato in tropical and subtropical

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[6] For recent reviews of the subject, see W. W. Shaner, P. F. Philipp, and W. R. Schmehl, Farming Systems Research and Development: Guidelines for Developing Countries (Boulder, Colo.: Westview Press, 1982); and N. W. Simmonds, "Farming Systems Research: The State of the Art," paper presented to the Agriculture and Rural Development Department of the World Bank, Washington, D.C., 1983 (draft).

[7] The terms are introduced here with some trepidation, for they have been used with various interpretations. They are used here only to indicate the difference between two equally legitimate types of production research, each of which is undertaken from a systems perspective. See E. H. Gilbert, D. W. Norman, and F. E. Winch, Farming Systems Research: A Critical Appraisal, Rural Development Paper 6 (East Lansing: Michigan State University, 1980), p. 23.

cropping systems (see Chapter 6). Similarly, the focus of ICRISAT is on developing farming systems relevant to the semiarid tropics, and CIAT emphasizes technology characteristics for beans and cassava that are appropriate for resource-poor farmers (see Chapters 4 and 9). Of particular interest is the work of AVRDC on market gardens to provide low-priced vegetables for the urban poor, an example of a system in which attention is focused on urban consumers rather than rural producers (see Chapter 16).

2. Much of the work described in the preceding paragraphs is extended into downstream, location-specific research. IRRI uses the Asian Farming Systems Network in order to evaluate local suitability of new cultivars, and IITA uses the West Africa Farming Systems Network (see Chapters 11 and 14). The on-farm research procedures of CIMMYT serve to focus production research on well-defined target groups of farmers (see Chapter 5). CIP, CIAT, and ICARDA all emphasize location-specific research as well (see Chapters 4, 6, and 8).
3. Examples of the broader approach to malnutrition are less common, whether in upstream or downstream research. Of the former, some work done by the IARCs on the function of women in different farming systems and on providing benefits for farm laborers has already been mentioned. In addition AVRDC uses information on nutrient deficiencies in Asia to help plan its research, and ICRISAT has looked at access to "common property resources" as a source of various nutrients in the semiarid tropics (see Chapters 9 and 16). Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) has also considered correlating nutrition problems with various production systems.[8]
4. Downstream, location-specific work in which a multifactored approach to nutrition is taken is not described in detail in any of the IARC papers. There are certainly opportunities for this sort of approach, but the work of CIMMYT in Ecuador was only a first attempt at including a broader range of factors having to do with nutrition in on-farm research.[9]

This is not the place to debate the merits of the upstream and downstream approaches to production research, but it should be noted that there are certain types of problems to which each is best suited. It is possible, for instance, to consider cultivars of specific maturity or tolerance for specific diseases or management of certain types of soil that are appropriate for an entire agroecological zone. On the other hand, the management of soil fertility or weed control or consideration of particular rotations or associations is often best handled through location-specific research.

This difference is also evident in research with an emphasis on nutrition. Certain problems, such as vitamin-A deficiency in certain

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[8] C. F. Burgos, "Sistemas integrados de cultivos alimenticios como medio para proveer una dieta adecuada," paper presented at the conference on Interacción entre Agricultura, Ciencia y Technología de Alimentos y Nutrición," Guatemala City, November 6-10, 1978.

[9] Robert Tripp, "On-Farm Research and Applied Nutrition," draft, Mexico City, 1983; see also Chapter 5.

parts of Asia, seasonal hunger in parts of West Africa, and rural landlessness in various regions, can be studied with an agroecological approach, but other nutrition problems require a location-specific focus. The relation of the situation of women to the nutritional effects of changes in production often depends upon cultural factors or others that are quite location-specific.[10] Similarly, intrahousehold distribution of food and labor and responsiveness to marketing opportunities are also likely to be influenced by local factors.

The problems of choosing an appropriate set of research procedures are obviously compounded when the dual goals of increasing productivity and improving nutrition are considered. Any method in applied nutrition must identify both the nature of the nutritional problem and the population groups affected.[11] Production research, of course, requires similar activities of diagnosis and direction.

The upstream-downstream dichotomy thus has important implications for the methods that might be employed in a nutrition-oriented production research effort (see Chapter 15). A number of the IARCs have carried out investigations of dietary preferences, dietary and nutritional surveys, and case studies in order to focus production research more clearly on nutritional concerns. The level of disaggregation employed in these studies varies greatly, providing examples of the choices that must be made in selecting appropriate methods of collecting data.

Perhaps the best illustration can be found in the studies of dietary preferences. Many of the IARCs try to determine the preferences of consumers among their crops in order to ensure that breeding is directed toward characteristics that are acceptable to target groups. The level at which this type of investigation has been done varies by commodity; rice with certain cooking qualities may be preferred throughout wide areas of Asia, while preferences among various kinds of bean may vary within a single country in Latin America according to regional or ethnic factors or income (see Chapter 4). The IARCs have thus attempted to study consumer preferences at an appropriate level of disaggregation.

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[10] Compare, for example, the fact that a significant proportion of the malnourished children in one region of Malawi come from woman-headed households with the fact that no greater risk of malnutrition in children from similar households was revealed in a study undertaken in Zambia; see H. Burgess et al., "Nutritional Status of Children at Namitambo, Malawi," Journal of Tropical Medicine and Hygiene 75 (1972): 143-148; and R. W. Wenlock, "Nutritional Risk and the Family Environment in Zambia," Ecology of Food and Nutrition 10 (1980): 79-86. Do these Malawian households merit priority over their Zambian counterparts for production research? Is a special study required if these differences are to be understood? Would production research carried out with the caveat "Don't overlook female farmers" be sufficient in both countries?

[11] Per Pinstrup-Andersen, Nutritional Consequences of Agricultural Projects: Conceptual Relationships and Assessment Approaches, World Bank Staff Working Paper 456 (Washington, D.C.: World Bank, 1981), p. 31.

In contrast to studies of dietary preferences there seems to be less evidence of a well-defined strategy for linking nutritional and dietary surveys to production research. With respect to breadth of sample and depth of investigation, there is no clear set of guidelines on ways of generating information on nutritional problems that can help identify possibilities for improving production systems and delimit target groups. A few IARCs have used dietary or nutritional surveys in their work. ICARDA has been involved in two nutrition surveys, one in both rural and urban areas of a wheat-producing province in Jordan and the other in villages near Aleppo, Syria (see Chapter 8). ICRISAT participated in dietary and nutritional surveys in six villages in three agroclimatic zones in India (see Chapter 9). CIMMYT has experimented with a simple dietary survey as part of an on-farm research project in Ecuador (see Chapter 5). These surveys present an interesting range--a provincewide study, studies based on agroclimatic zones, and a survey related to a location-specific project. It must be decided when an upstream approach to dietary and nutritional surveying is appropriate and when a location-specific investigation is indicated. This will depend upon both the types of production problems and the nutritional situations under investigation.

To a certain extent this uncertainty about methods reflects an incomplete understanding of the etiology of malnutrition. One way of gaining better insight into this complicated area is through intensive studies. A few IARCs have initiated case studies in which nutritional issues were examined. IFPRI is carrying out several studies in which the effect of technological change in agriculture on nutrition is being considered and others in which the effects of shifts from semi-subsistence agriculture to cash cropping are being studied (see Chapter 10).[12] The IRRI conference on women in rice-farming systems led to a decision to study the effects of rice technology on underprivileged groups (see Chapter 14). CIP carried out a series of consumption studies in which a range of uses and preferences for potatoes in various countries was demonstrated (see Chapter 6). But the question remains how such case studies can be combined with other information so that general principles can be derived for ex ante procedures useful for production research.

AGENDA FOR DISCUSSION

There has been an expectation of results that would improve the general welfare, including beneficial effects on nutrition, from pro-

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[12] FAO has also sponsored a series of studies of this subject; for a preliminary discussion, see Paul Lunven, "The Nutritional Consequences of Agricultural and Rural Development Projects," Food and Nutrition Bulletin 4 (1982): 17-22.

duction research on farming systems.[13] Although the work by the IARCs that is reviewed here presents evidence of progress, it also raises many questions regarding the future function of production research in improving nutrition.

1. The most common strategy employed by the IARCs for achieving an effect on nutrition from their production research is to make sure that their work is relevant to the needs of the rural poor. Given the poor direction that has been characteristic of much of the work in agricultural development in the past, it may be that the emphasis of the IARCs on resource-poor farmers is both the best way of assuring nutritional relevance and a sufficient challenge for the present. That is, it may be that if IARCs were to invest extra resources into an effort to increase the effects of their production research on nutrition, all those resources should be directed toward the rural poor rather than be used for any specifically nutritional investigation or analysis.
2. Given the multifactored causality of most malnutrition, perhaps a logical next step beyond simply directing research toward the poor is to increase the collaboration between location-specific production research programs and general efforts at rural development. Increases in productivity might have a greater effect on nutrition if they were combined with improvements in rural infrastructure, sanitation, and education. Conversely, a successful production program provides a useful point of entry for other rural-development activities.
3. Underlying any strategy that points production research in the direction of resource-poor farmers is the assumption that there is a link between poverty and calorie-protein malnutrition but this does not involve any attempt to explore the etiology of the malnutrition further. Is it possible to use additional information to pinpoint the groups at risk? Is malnutrition more frequent in certain ecological zones and production systems or among farmers with fewer resources within a particular system? Is the variability in nutritional status greater between systems or within systems? How can this information be used to help direct a production program?

   Is it sufficient to know that families of small farmers are at higher risk of malnutrition and aim production programs at them; or is it necessary to understand the specific causal chain that leads from, for instance, small landholdings to malnutrition?[14] Is seasonal hunger an example of the need for more

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[13] Consultative Group on International Agricultural Research, Farming Systems Research at the International Agricultural Research Centers (Rome: Technical Advisory Committee, 1978); Shaner, Philipp, and Schmehl, Farming Systems Research and Development; Whelan, The Nutritional Component of Farming Systems Research.

[14] Ian Rawson and Victor Valverde, "The Etiology of Malnutrition among Preschool Children in Rural Costa Rica," Journal of Tropical Pediatrics 22 (1976): 12-17.

detailed information, or can it be diagnosed and dealt with through conventional production-research techniques?[15]

4. But it is well known that productivity and income are not perfectly correlated with nutritional status.[16] There are many other factors that contribute to the achievement of adequate nutrition. Some of them, discussed earlier, are related to agricultural production. These include crop diversity, the work of women in agriculture, commercial agriculture, and rural labor markets. In how many instances can these factors be treated through well-directed production research that increases the productivity of farming systems, and in how many are special studies or procedures required?
5. Finally, in production research for which an effect on nutrition is sought the issue of appropriate methods of collecting data must be faced.[17] A first step is to develop criteria for deciding when nutritional or dietary data are required in the research process. The next step is to assure the best use of existing data before initiating special studies. It must be realized that complete dietary and nutritional studies are too costly to be done in more than a small proportion of the cases. Flexibility is essential, and appropriate parameters for both diagnosis of problems and evaluation of results must be developed.[18] This is a matter of interest both to institutions concerned with agriculture and to those concerned with nutrition. Who should take the lead in developing the requisite procedures?

SUMMARY

This has been a brief review of the nutritional aspects of production research carried out by the IARCs. Its purpose has been to describe the current work of the IARCs and to propose a set of questions that may be helpful in guiding future work.

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[15] Richard Longhurst and Phillip Payne, Seasonal Aspects of Nutrition: Review of Evidence and Policy Implications, IDS Discussion Paper 145 (Sussex, England: Institute of Development Studies, University of Sussex, 1979); Michael Collinson, Farming Systems Research in Eastern Africa, International Development Paper 3 (East Lansing: Michigan State University, 1982), p. 51.

[16] Alan Berg, "Increased Income and Improved Nutrition: A Shibboleth Examined," International Development Review 3 (1970): 3-7; C. A. Taylor et al., "Child Nutrition and Mortality in the Rural Philippines: Is Socioeconomic Status Important?" Journal of Tropical Pediatrics 24 (1978): 80-86.

[17] Tripp, "On-Farm Research and Applied Nutrition."

[18] M. F. Smith, "Nutrition and Farming Systems Research and Extension: The State of the Art," paper presented at the Farming Systems Research Symposium, Kansas State University, Manhattan, Kansas, October 31-November 2, 1983; see also Chapter 14.

Most of the IARCs hold the view that the principal way of achieving an effect on nutrition for their production research is to make sure that it is aimed at those who are at high risk of malnutrition, namely, resource-poor farmers. They are also aware, however, that increases in productivity and income do not always lead to nutritional betterment of farm families and that there are other factors to be taken into account.

Both those who direct programs in applied nutrition and those who direct production programs must learn to diagnose problems and identify target groups. The relative merits of location-specific research and more general research were discussed.

The question of the amount of specific dietary and nutritional information that is necessary to guide production research is also important. The substantial congruence between the focus of the IARCs on small farmers and the high risk of malnutrition characteristic of this group has been pointed out. Even the attention paid to such issues as crop diversity, female farmers, household food supplies, and the effects on rural labor overlaps substantially with the concerns of nutritionists, without requiring separate studies.

This is certainly not to claim that further information is not needed. The challenge is to decide how existing knowledge, including the current studies of the IARCs, can be synthesized to provide guidelines for management of data to direct production research in ways that exploit its potential for nutritional effects.

Finally, not only will improving the nutritional focus of production research require the development of appropriate techniques of data collection and analysis, it will also require some decisions as to who is best able to carry out this work. Discussions about theory and method will be of limited use if no attention is paid to the issue of institutionalization.

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