HOW NUTRITION PRIORITIES CAN BE INTEGRATED INTO CROP IMPROVEMENT PROGRAMS

Hulse, J.H. and Pearson, O.E.*
International Development Research Centre, Ottawa, Canada

The World Food Problem

Nutritional survey statistics are a constant reminder that the world food situation is serious, even precarious. By recent estimates, (1) 500 million people live on the edge of starvation and 1.2 to 1.3 billion would benefit from a more varied diet. The greatest majority of these people live in Asia, Southeast Asia and sub-Saharan Africa. Clinical surveys and hospital records indicate that malnutrition wherever it exists is severest among infants, preschool children and pregnant and lactating women; that it is most prevalent in depressed rural areas and the slums of large cities; and that the problem is lack of calories as much as lack of protein.

The developing countries are generally characterized by high population growth rates showing little tendency to slacken and lagging food production which has become more pronounced in recent years. By recent estimates, the territories of the lesser developed countries account for two thirds of the world population but only one third of the world food production. During the past two decades, recorded world food production increased by an average of about 69 percent. Food production increased by 65 percent in the developed countries and by 75 percent in the less developed countries. World-wide, the annual rate of increase was approximately

---

* The views expressed in this paper are those of the authors and do not necessarily represent those of the International Development Research Centre.

(1) International Food Policy Research Institute, Recent and Prospective Developments in Food Consumption: Some Policy Issues. July, 1977.

2.8 percent for food production and 2 percent per annum for population. On this basis, it would appear that each of the 3.8 billion people alive in 1973 had nearly 20 percent more food to eat than did the 2.7 billion in 1954. However because of markedly different population growth rates, food production per capita rose at an annual rate of only 0.4 percent in the developing countries as compared with 1.5 percent in the developed regions. Although most of the major developing areas experienced some advances in per capita food production during the last half of the 1960's, in Africa, a major downtrend has been observed since 1961.

In Africa, the food supply problem is most critical in the low income food deficit countries of the sub-Saharan region in which the per capita GNP is less than US $200. In the five Sahelian countries (Tchad, Mali, Niger, Senegal and Haute Volta), staple crop production trends were negative for the whole of the 1960-75 period. During the most recent drought of 1970-75, cereal production in the Sahel was 8 percent below the production average for the 1960-70 period.

According to a recent report of the International Food Policy Research Institute (IFPRI),[2] to provide the undernourished in the developing countries with 100 percent of the caloric levels recommended by the 1971 Joint FAO/WHO ad hoc Expert Committee on Protein and Energy Requirements, would have required in 1975 additional imports of 45-70 million tons of cereal equivalent, over and above the 31 million tons of cereal actually imported. Asia would have required some 60 percent of these additional imports, sub-Saharan Africa 25 percent, with lesser amounts (5-10 million

(2) International Food Policy Research Institute, op.cit.

tons) going to each of North Africa/Middle East and Latin American regions. In order to balance indigenous production with projected demand by 1985, food production in the developing countries will have to increase by 4.2 percent annually or again by 5.5 percent per annum if internal production is to bridge the caloric gap.(3)

The Protein Controversy

Estimates of the caloric gap based on global production and population statistics must be carefully interpreted, in that production figures are not always a true measure of food supplies available to meet human nutritional requirements. In the first place, available data assumes total consumption of whole grain. However most cereals and legumes are processed by dehulling, soaking, boiling, milling and cooking, all of which result in significant nutrient losses. Second, it is a known fact that many of the seeds of edible subsistence plants including cereals and legumes, contain substances which seriously interfere with the nutritional quality of protein and other nutrients. Sorghum, for instance, which covers a world acreage larger than maize and is the primary subsistence crop of millions of the poorest people of the semi-arid tropics, contains tannins which reduce the digestibility of the cereal protein. Third, national averages are also misleading in that they take little account of the problem of the mal-distribution of food supplies among different regions of the world, among countries within regions, among families within a community and even among members within a family. Finally, further studies are needed to determine

---

(3) Gavan, J.D. and Hathaway, D.E., Recent and Prospective Developments in Food Consumption: Some Policy Issues. PAG Bulletin, Vol. VII, No. 1-2, March-June 1977.

the nutritional requirements of young children, particularly those suffering or recovering from infectious diseases.

The subject of nutrient requirements has fascinated physicians and nutritionists for over 100 years and continues to be the subject of much debate. The first comprehensive set of recommended allowances for 12 nutrients, including energy and protein, was produced by the Technical Commission on Nutrition of the League of Nations in 1935. The difficulties encountered in defining recommended dietary levels which describe an "optimum diet" cannot be overlooked. In setting nutritional requirements it is necessary to decide on an average per capita requirement for a nutrient based on available information and then to set recommended daily allowances at levels intended to cover at least 97.5 percent of the population. Adequate intake standards for energy and protein vary among different regions of the world, reflecting average body size, climate, physical activity, differences in dietary protein quality and other factors.

Since the mid-1950's, successive expert committees on energy and protein requirements from the Food and Agricultural Organization and World Health Organization of the United Nations, have convened to reevaluate estimates of adequate energy and protein intakes for humans. In April 1971, the Joint FAO/WHO Expert Committee lowered the levels of dietary protein intake for adults by 20 percent and thereby redefined dietary protein malnutrition. Nutritionists working with the planning commissions of several developing countries suddenly found themselves preparing a vigorous attack on a problem that no longer existed as a priority issue. Many nutritionists, economists and planners concluded from comparison with per capita dietary intakes that emphasis on protein could now be dropped or at least greatly reduced in the formulation of agricultural, educational, health and economic policy and in overall nutritional planning. The lowering of the protein requirement led to the conclusion that except in areas where roots and tubers are major dietary components, protein levels are adequate if caloric needs are met. According to Dr. Nevin Scrimshaw of the Massachusetts Institute of Technology, however, there is increasing evidence that these revised recommended levels for protein may be too low.[4]

Infants and preschool children and pregnant and lactating women are the primary target groups of nutrition intervention programs. In response to the statement that protein-calorie malnutrition can be prevented by increasing the quantity of the traditional diet consumed by children, Scrimshaw replies that it is useless to suggest that a child can get sufficient protein and calories from a cereal diet if he merely eats more of it, when he is unable to do so. The traditional diet of the developing countries is frequently bulky and young children do not have the capacity to ingest the large quantities that would be necessary to satisfy their full nutrient requirements. Furthermore, the dietary protein[5] needs of the very young in developing countries are increased, not only by the poorer absorption of dietary protein caused by intestinal parasites

---

(4) Scrimshaw, N.S., Shattuck Lecture - Strengths and Weaknesses of the Committee Approach. An analysis of Past and Present Recommended Daily Allowances for Protein in Health and Disease. New Engl. J. Med. Vol. 294 Nos. 3-4, Jan. 15 and 22, 1976.

(5) Protein Advisory Group Statement (No. 20) on the "Protein Problem". PAG Bulletin, Vol. III, No. 1, 1973.

and chronic damage to the gastrointestinal tract from repeated infections, but also by the extra protein lost from the body during the acute infections so commonly experienced by these children. This loss is induced by the stress response which causes amino acids to be mobilized from the protein in the lean body tissues for use by the liver in making glucose. The need for dietary calories may also be increased by impaired intestinal absorption and by fever, but the stress response is specific for protein. Moreover, whereas a deficit in calories may be compensated in part by reduced activity, the body has no comparable mechanism for protein deficiency. Dr. Scrimshaw concludes that:

> "There is no doubt that good nutrition requires a balanced complement of protein and calories, and neither can be neglected in the diets of the underprivileged and vulnerable. To the extent that the pendulum swung too far in emphasizing protein in the 1960s, and too far in emphasizing calories in the 1970s, it must come to a more appropriate intermediate position for the 1980s and beyond."[6]

Significance of Cereal Grains and Legumes in Human Nutrition

Among the food crops of the world, cereal grains contribute more than any other single group of food staples to both calories and protein in the human diet. In its major document on world agricultural development plans, published in 1969, the FAO stated that cereals, particularly wheat, rice, maize, sorghum, millet and barley provided more than 50 percent of

---

(6) Scrimshaw, N.S., Through a Glass Darkly Discerning the Practical Implications of Human Dietary Protein-Energy Interrelationships. Nutrition Reviews, Vol. 25, No. 12, December 1977.

calories and protein for the people of the Sahelian region, more than 60 percent of calories and protein for the people of Asia and more than 65 percent of calories and protein for the Near East. In Central America, maize provided 57 percent of the daily intake of calories and 45 percent of the daily protein for the adult population.[(7)]

Dietary surveys indicate that the diet of the majority of the population in developing countries is based on a cereal grain and food legume combination. In Southeast Asia, soybeans and mung beans supplement the rice staple; in Africa, cowpeas and pigeon peas supplement sorghum and millets, while in Latin America maize and beans are a familiar dietary combination.

Nutritionally, cereals and legumes are complimentary. Whereas most common varieties of cereal grains are deficient in certain essential amino acids (primarily lysine) and are relatively good sources of sulfur-containing amino acids, legume grains contain twice as much protein as cereal grains and are a rich source of lysine although relatively low in total sulfur-containing amino acids. The optimum nutritional combination is provided by a diet composed of roughly 65 percent cereal and 35 percent legume. However only in Latin America does the ratio of cereals to legume production approach the desirable 2:1 ratio. In South and Southeast Asia, because of the significant decline in per capita legume production over the past 25 years, the ratio of cereals to legumes produced is of the order of 9:1. The production of legumes throughout most of the developing world

(7) FAO, Provisional Indicative World Plan for Agricultural Development. C69/4. Food and Agriculture Organization, Rome, Italy, 1969.

has been steadily declining over the past two decades in relation both to cereal production and to population increase. During the past two decades in Asia, population increased by about 51 percent, total food production by 65 percent but legume production by little more than 20 percent. Consequently unless some significant changes occur, we may over the next twenty years be witness to a seriously inadequate food production in developing countries, both in terms of quantity and nutritional balance.

Priorities of Crop Improvement Programs

Keeping in mind the world food situation, agricultural scientists have focused most of their attention on increasing the total production and productivity of cereal grains and food legumes. To achieve increased productivity, scientists are attempting to maximize the efficiency of the plant to utilize energy, carbon dioxide, water and soil nutrients; attention is also being given to increasing the availability and efficiency of limiting soil nutrients and to biological processes dealing with a more efficient control of plant diseases and pests.

However in any major international breeding program, attention must not only be given to the quantitative aspects of production. Overall, the more efficient use of available land is defined by three factors:[8]

(a) Yield (kg/ha)

New varieties must be bred so as to give higher yields on the

---

(8) Bressani, R. and Elias, L.G., "Tentative Nutritional Objectives in the Major Food Crops for Plant Breeders", in Hulse, J.H., Rachie, K.O., and Billingsley, L.W., Nutritional Standards and Methods of Evaluation for Food Legume Breeders. International Development Research Centre, 1977.

lands they now occupy. They must also be adapted for other areas that can be economically opened up for cropping.

(b) Nutritive value

Nutritional considerations such as protein content, amino acid balance and digestibility also contribute to improve the efficiency of utilization of foods.

(c) Technological value

Technological value refers to the attributes related to consumer acceptability including milling and cooking characteristics.

The International Agricultural Research System

Although agricultural research of one form or another has existed for centuries, publicly supported research is little more than a century old. Until recently, almost all investment in agricultural research was made in North America, Japan and Northern Europe. While the number of agricultural scientists and annual expenditures on agricultural research are increasing in developing countries, in 1974 only 25 percent of the world's public expenditure on agricultural research occurred in Africa, Latin America and Asia, despite the fact that these areas have more than 75 percent of the world's farm population.[9]

A number of developing countries have made substantial progress in establishing a strong national research capability. These developing countries have attempted to increase research on specific problems by

(9) Boyce, J.K. and R.E. Evenson, National and International Agricultural Research and Extension Programs. Agricultural Development Council, Inc., New York, 1975.

establishing regional research centres and cooperative regional programs. However many of the institutions in developing countries lack the human or financial resources necessary to undertake all of the research required by their countries in any given area of agricultural activity. At the same time, several countries, particularly those in the same agro-climatic zone, demonstrate similar conditions, opportunities and needs.

In contributing to the advancement of agricultural research in developing countries, the International Development Research Centre has played a catalytic role in establishing research networks by bringing together scientists from developing regions who have undertaken to identify regional research priorities, and then, with IDRC financial support, to define and develop cooperative research programs based on these priorities. The scientists are able to map out a comprehensive program of research which is of interest to a great many countries but which is more diverse and demanding of greater resources than any single country can provide. In several instances, IDRC is providing a technical advisor or network coordinator who acts as a focal point for information exchange and technical advice and support.

One of the most positive developments in the last decade in increasing cooperative international agricultural research has been the establishment of the International Agricultural Research Centres. The first two centres, the International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Centre (CIMMYT) were established by the Ford and Rockefeller foundations in the 1960's. Recognition of the early successes of CIMMYT and IRRI in the production of new high-yielding varieties (HYV's) of wheat and rice led to the formation of a unique international organization known as the Consultative Group for International Agricultural Research (CGIAR). The CGIAR is a permanent body of international financial support for the international agricultural research centres. The official sponsors of the CGIAR are the World Bank, the Food and Agriculture Organization of the United Nations, and the United Nations Development Program (UNDP). Membership in the CGIAR which is entirely voluntary, includes a number of governments, international and regional organizations and private foundations. In 1972, its first year of funding, 15 donor members supported the work of five IARCs with a total budget of $15 million. In 1977, 29 donor members supported eleven IARCs with a total budget in excess of $80 million.

A major advantage of the IARCs is their ability to stimulate and support national agricultural research programs in developing countries. The IARCs provide national programs with a wider range of technological expertise in the form of improved germ plasm and agronomic practices which the lesser developed countries can adapt to their own agro-climatic and economic conditions. Links with developing countries are also strengthened by active training programs run by the centres. Over 3,000 scientists and production specialists have been trained in these centres to date.

IDRC's Contribution to Agricultural Research

The final portion of this paper will deal more specifically with IDRC's contribution to agricultural research.

IDRC's contribution to agricultural research has taken many forms. Principally, however, IDRC's mandate is to initiate, encourage and support research programs which produce tangible results in terms of practical solutions to specific agricultural problems. Most of IDRC's financial resources are directed to networks of applied research projects in developing countries or to research programs in regional centres and IARCs. IDRC's research networks emphasize the following criteria:

(1) cooperation between international and national research programs;

(2) an interdisciplinary approach to agricultural research; and,

(3) research design and testing in association with the intended beneficiary - the farmer.

Sorghum and Millets Research Network

The research network which focuses on the crops of the semi-arid tropics is a functioning example of the interrelationships outlined above.

The semi-arid tropics include most of the countries surrounding the Sahara, much of East Africa, a significant area of Central India and parts of Southeast Asia and South America. The principal cereal crops of these regions are sorghum and millets. Total world acreage of sorghum and millets exceeds 70 million hectares. In the US where sorghum is grown as a feed grain, average yields are seven times those attained in India and Africa. Clearly the opportunity exists for increasing yields in Asia and Africa through applied research and improved agronomic practices.

The hub of semi-arid crops research is ICRISAT, the International Crops Research Institute for the Semi-Arid Tropics. ICRISAT has primary responsibility for improving sorghum, millets, groundnuts, chickpeas and pigeon peas. The project network supported by the IDRC is linked with the central ICRISAT program which provides breeding materials and technical support to regional research programs.

In Ethiopia, IDRC has been supporting an important sorghum improvement program at the Agriculture Faculty of the University of Addis Ababa. The Ethiopian researchers have identified two particularly high-yielding cultivars that provide yields 7-10 times greater than the national farm average of approximately one ton per hectare. In addition several Ethiopian varieties have been found which contain more than 3 percent lysine. Normal sorghum protein contains 1.8-2.0 percent lysine. These new lines are now being distributed and crossed with other sorghums in many parts of the world to bring about an overall improvement in the nutritional quality of the sorghum grain.

IDRC has also established several contract research projects with research institutions in developed countries, conducting fundamental research on topics of importance to the sorghum, millet or legume improvement programs in the semi-arid tropics. At Canadian Universities, scientists are studying the biological factors that influence the ability of sorghum to tolerate drought stress. At the University of Sussex, in England, the Centre is supporting research on striga and orobanche, the parasitic weeds which attack the root system of sorghum and legume crops. Trials are now underway in many countries of Africa, the Near East and Asia, using substances synthesized at Sussex which cause striga and orobanche seeds to germinate before the crops are planted. Finally two scientists working at the University of Sheffield, in England, have made significant advancement in the identification of the "tannins", naturally occurring antinutritive factors present in the seed coats of many sorghums which seriously impair the digestibility of sorghum protein.

Food Legumes

In comparison to the cereal grains, the food legumes or pulses represent the most neglected food crops of the semi-arid region. Much less research has been done on improving their yield potential and nutritional quality despite the fact that they are an important source of protein and are good sources of thiamine, niacin, tocopherol, calcium, iron and phosphorus.

IDRC is presently encouraging and supporting research to develop nutritionally improved legumes capable of giving higher yields. Since its inception in 1970, the Centre has supported the chickpea and pigeon pea improvement program carried out by scientists at ICRISAT. The purpose of this program is to breed and select for higher and more stable yields, higher protein content, and resistance to diseases and pests.

Other food legume research projects underway include a network of cowpea improvement projects involving several West African countries, the International Institute of Tropical Agriculture (IITA) in Nigeria and the International Fertilizer Development Centre (IFDC).

Food legumes are also a major component in Centre funded research on multiple cropping systems.

Multiple cropping is generally defined as growing more than one crop in the same year on the same piece of land. Multiple cropping systems include intercropping in which several different crops are grown simultaneously, and sequential or rotational cropping in which two or more additional crops are planted before or after the normal cropping season.

Intercropping or mixed cropping like plant breeding is a fairly ancient practice. In the lowland tropics of Africa one of the commonest cropping mixtures involves grain legumes such as cowpea or groundnut planted under cereals such as sorghum, millet or maize. This planting pattern is the result of hundreds of years of trial and error research by the small farmer.

Several advantages are attributed to mixed cropping as compared to pure stands of the component crops. Through mixed cropping, the farmer is provided with food for his family and feed for his livestock. This system of farming offers insurance against poor harvests; it enables the farmer to utilize family labour more efficiently and provides family members with a more balanced diet. Above all however, there is evidence to suggest that combined yields per unit area from the intercrop are higher than the yields of either crop as a monoculture. Maize with mung bean intercrop trials, for example, have shown that the maize yield actually increased by 18 percent over maize grown alone as a result of the restriction of weed growth by the mung bean plant.

Recognition of these advantages has motivated renewed interest in the study of this traditional cropping method. IDRC is presently supporting an experimental program at IRRI which is examining the productivity of various crop combinations of corn, sorghum, legumes and vegetable crops with and around the main rice crop.

Further agricultural research is needed to gain a better understanding of the processes responsible for the attributes of mixed cropping so that proper screening of new high-yielding genotypes can be effected. Agriculturalists, nutritionists and economists should be working together in assessing the social, economic and nutritional impact of better cropping systems. Nutritionally, intercropping is destined to have a major impact on the nutritional status of the malnourished of the LDCs. For example in regions where cassava is a staple, the diet is generally low in essential vitamins, minerals and protein. Increasing the legume in the diet would overcome the vitamin and mineral deficiency and supply an increased amount of protein. To increase the available legumes, their production must be increased. This could be achieved through an intercropping system in which production of the major staple is maintained.

In view of the very important developments in agricultural research programs, there is little doubt that through the continued support of the international agricultural research centres and the expansion and strenghtening of national agricultural programs, significant improvements can be made both in the quantity and quality of the food crops of the lesser developed countries. However improving productivity and agronomic properties is only a first step in the integration of nutritional priorities into agricultural research programs.

In addition to yield and nutritional considerations, equal attention must be accorded to the selection of genotypes which meet consumer criteria in terms of grain size, colour, texture, milling and cooking characteristics. Clearly consumer acceptance of new varieties which cannot be milled using available tools or which require longer cooking may be delayed. Also there is little purpose in increasing grain production in order to increase the caloric intake of rodents, insects and microorganisms. For these reasons, post-harvest systems research which comprehends the total food system from the time of and including harvesting until the grain is delivered as food to the table must become part and parcel of research programs dedicated to the improvement of crop characteristics and cropping methods. As such, interdisciplinary approaches to agricultural research involving plant breeders, agronomists, food technologists, nutritionists and economists will bring us that much closer, that much sooner to alleviating the world food problem.

One might anticipate the reasonable question "How long will it take for these genetic and agronomic improvements to find their way into farmers' fields and the results into consumers' stomachs?" Though it is a difficult question to answer, there is no doubt that the lead time can be gradually and effectively reduced by involving the farmer in the early stages of the research process. In the research that it supports, IDRC encourages scientists to carry out at least part of their research in farmers' fields, where they can gain a better understanding of the farmer's primary constraints and his attitude to risk and change. Also only in on farm trials can research results be adjusted to the farmer's actual level of resource availability and management capabilities. Inasmuch as scientists strive to understand local, social and economic circumstances, if they comprehend why farmers do what they do, then their biological and technical research will be more likely to fit the farmers' needs.

The world's recent history of support for international agricultural development represents an important first step. There is yet a long distance to travel, however, before we can view with satisfaction the state of nutritional well-being among our poorest neighbours. If the distance between nutritional need and food supply is to be bridged during our lifetime, we must immediately move more swiftly, more imaginatively and more unselfishly in our support and encouragement for international food and agricultural research and development.

IDRC/Ottawa
June 1, 1978

BIBLIOGRAPHY

(1) International Food Policy Research Institute, Recent and Prospective Developments in Food Consumption: Some Policy Issues. July, 1977.

(2) International Food Policy Research Institute, op.cit.

(3) Gavan, J.D. and Hathaway, D.E., Recent and Prospective Developments in Food Consumption: Some Policy Issues. PAG Bulletin, Vol. VII, No. 1-2, March-June 1977.

(4) Scrimshaw, N.S., Shattuck Lecture - Strengths and Weaknesses of the Committee Approach. An analysis of Past and Present Recommended Daily Allowances for Protein in Health and Disease. New Engl. J. Med. Vol. 294 Nos. 3-4, Jan. 15 and 22, 1976.

(5) Protein Advisory Group Statement (No. 20) on the "Protein Problem". PAG Bulletin, Vol. III, No. 1, 1973.

(6) Scrimshaw, N.S., Through a Glass Darkly Discerning the Practical Implications of Human Dietary Protein-Energy Interrelationships. Nutrition Review, Vol. 25, No. 12, December 1977.

(7) FAO, Provisional Indicative World Plan for Agricultural Development. C69/4. Food and Agriculture Organization, Rome, Italy, 1969.

(8) Bressani, R. and Elias, L.G., "Tentative Nutritional Objectives in the Major Food Crops for Plant Breeders", In Hulse, J.H., Rachie, K.O., and Billingsley, L.W., Nutritional Standards and Methods of Evaluation for Food Legume Breeders. International Development Research Centre, 1977.

(9) Boyce, J.K. and R.E. Evenson, National and International Agricultural Research and Extension Programs. Agricultural Development Council, Inc., New York, 1975.