ploding population of the developing nations, vast amounts of capital for fertilizer production and distribution facilities would be required (around $25 billion is estimated as required between 1974 and 1980 to bring about the expected increases in production for that period). Besides, there are numerous constraints to increasing usage within the developing countries, such as lack of farmer educational programs, lack of farmer incentive, high interest rates, transportation and other distribution problems, and the existence of land tenure systems unfavorable to making improvements to the land.

Although insufficient amounts of low-cost hydrocarbon feedstocks for ammonia production are currently holding back production and use of nitrogen fertilizers, this is not expected to be a serious drawback to world nitrogen production in the decades ahead. Ammonia can be made from the vast amounts of natural gas being flared in the oil-rich countries, and over the longer pull, ammonia from coal gasification or from electrolytic hydrogen may become prominent. Phosphate ores and particularly potash are plentiful and should last for several centuries. Sulfur, although not absolutely essential to soluble phosphate production, is not expected to be in short supply for prolonged periods. Thus, raw materials for greatly expanded fertilizer production should not be a major concern for the foreseeable future.

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FOOD PRODUCTION: *Problems and Opportunities*

R. C. Pickett and G. Srinivasan

Abstract

Underproduction of food is a worldwide problem affecting the economic, physical, and social well-being of all people, urban and rural, rich and poor, in developed and developing nations alike. The problem is compounded by lack of accurate information and analysis of factors that limit production and distribution in specific areas, notably in the developing nations of the world. As a first step in improving food crop production, the natural resources, biotic competition, and crop genetic resources should be assessed and coordinated with appropriate management practices for their fullest utilization. Information systems are needed to provide adequate statistics on population growth and trends, total arable land and area planted to various crops, energy resources, climate, natural resources, and other information related to crop and livestock production. Nutrition education is a necessary accompaniment to upgraded food production in many countries of the third world. A possible solution to these problems lies in sharing our research findings and improved technology with the developing nations by means of programs for advanced training and education such as those already being sponsored by various government agencies and private foundations.

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The need for more food in the world is being given much attention. The emphasis has been on the negative factors, such as drought and the rapidly increasing human population with its larger food requirement. Few critical analyses are available on the true nature of the food problem in subsistence agriculture areas in remote rural sections of many developing countries.

The Problem

The rapidly increasing urban areas around the world are also a big and distinct part of the problem of food shortages and total developmental needs. Because they depend almost completely on food production in rural areas, urban problems will not be considered at length in this article. Suffice it to say that urban areas are now growing rapidly and will continue to do so as long as urban dwellers can be fed and as long as life is less desirable in rural areas. Rural productivity of food and other necessary products is a key not only to the well-being of farmers; it is also critical to the well-being of people in the cities. Most cities now are overpopulated (or underbuilt) and adequate food is necessary to prevent further build-up of misery and acute need in the cities of the future. Thus the problem of low rural productivity is accentuated by the continued flow of people (especially those who gain in education) from the farm or village to the city and the capital that goes with them. Appropriate reinvestment of both educated people and capital in rural productivity, especially food production, is now a necessity around the world.

Need for Census Data

One problem common to most developing countries is a lack of accurate census information on rural population and food productivity. At present only crude estimates are available, without analytical treatment of the real nature of the problems of rural areas. The identi-

fication of limiting factors in food crop production is critical to the development of programs for improvement. The interaction of domestic animals with cropping systems needs intensive study. Governments and businesses must interact to provide a favorable price and availability structure of the necessary inputs for adequate production, and to supply needed economical processing, storage, transport, and utilization systems. Often much more food could be produced (at least in some years and certain areas) but is not, because there is no incentive or because it is impossible to dispose of the food crop profitably even though starving or severely malnourished people may be located only a few hundred miles away.

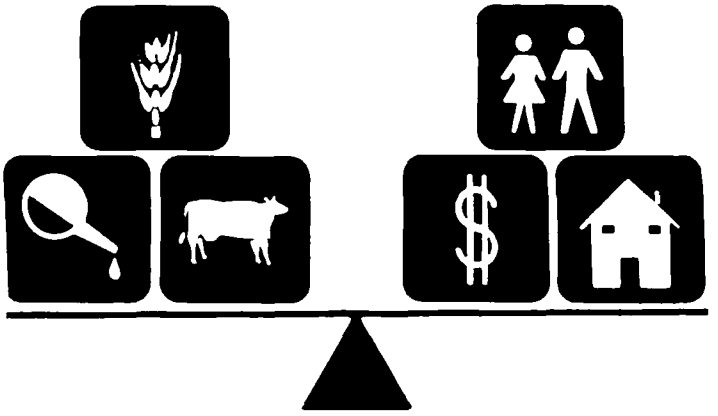
Part of the problem is the complexity of the coordinated package of inputs necessary for higher food production and of the rest of the chain of events needed for effective utilization in balanced diets. More knowledge is needed concerning the most appropriate and effective "package" and availability of the inputs.

Another complexity in man's food supply is the large number of food crop species involved (probably well over 200) and the limited research on most of them. Rice, wheat, and corn, as the major cereal crops, have received considerable attention to date but research is still needed in the other cereals such as sorghum and millets. Among the roots and tubers, the potato is the only one with much emphasis although cassava work is now beginning. International programs in food legumes are just being set up. Oil seed crops and vegetables have had relatively little improvement. Fruits, nuts, and miscellaneous food crops are even more neglected. In the tropics and subtropics the "plantation" crops such as coffee, cocoa, sugar cane, tea, rubber, and spices have often received research attention but most of these provide "empty calories," desirable in taste but having little nutritional value.

Some of the nonfood crops, such as cotton, compete greatly with food crops when the prices favor them. Because export funds are important to all countries, official government encouragement is given such nonfood crop money earners. This leaves not only the producing nation, or part of it, vulnerable to food shortages but often may cause deficiencies in neighboring countries. This may affect the world market price upward, reducing food availability to many poorer sectors, especially urban areas.

Subsistence farmers must be given tools and improved production and storage methods to relieve themselves and those in the cities from both seasonal and year to year food shortages. This in turn will relieve wild price variations that accentuate shortages, periods of actual famine, and chronic malnutrition. Periods of "excess production and low prices are followed by lower production and high prices which tends to perpetuate longer periods of shortage.

Many individuals, cultures, and governments are conditioned to look for someone or something to blame when food is scarce or expensive or both. One of the most



common and non-self-threatening things to blame is the weather or other natural resources such as soils. Drought is often named. Most areas involved in food production have climates with much variation in weather. Some seasons or years are much less favorable for food crop production than others. There are vast desert areas that are always too dry; limited rain forest areas are too wet; areas located at upper elevations and high latitude are usually too cold.

Where there is arable land with suitable rainfall or irrigation, then the "name of the game" is to design production systems modified to fit the weather conditions or climatic patterns. Unusual variations will drastically lower production in some years but that should be no reason for widespread famine and malnutrition. On the contrary, the good weather over vast areas each year *supports* adequate food production for the poor areas even in their poor years, if storage, transportation, and marketing facilities are adequate. The problem is one of adequate coordination of production practices and inputs to go with the natural climate and soil—which are much more abundant than have been recognized or used. Production of many food crops is now at very low levels (under 500 kg/ha). Yields of 2,000 to 5,000 kg/ha are attainable over wide areas, and yields of 6,000 to 10,000 kg/ha are possible under exceptional conditions. Multiple cropping with two or even three crops per year is possible in some areas. Mixed cropping is also practiced to extend the season and to spread the risks.

Coordination Needed for Food Production

As crop production factors are considered it is particularly important to avoid single factor improvement programs. All of the limiting factors must be properly assessed and improvements among them must be properly coordinated. Observation, inputs, and coordination are the keys.

Correct assessment of the true yield potential for each site must be made. The necessary research work and high production will not take place if high yield potentials are not hypothesized as being possible. Accurate observation of conditions and factors is essential.

Factors to Be Considered and Coordinated in Improving Crop Production:

Natural Resources (to be assessed)	Management Factors (to be coordinated)
Climate	
1. Solar radiation—amount and timing of light, heat, cloud cover.	Zone selected for crop and vice versa—"comparative advantage."
2. Temperature—extremes, daily patterns, length of seasons, frosts.	Times of planting, thinning, weeding and harvesting.
3. Moisture—rainfall amount and distribution, dew, variations, evaporation, humidity, amount of leaching and runoff.	Density of planting, species and varieties selected for degree of stress.
4. Wind—evaporation, mechanical effects, erosion.	Shelters, borders, leaf canopies, density.
Soil	
1. Depth and type, available water-holding capacity, amount of leaching.	Surface treatment during and between cropping for good water intake and moisture retention.
2. Structure—surface and internal drainage, oxygen supply, infiltration rate.	Excess water disposed of at least seasonally and then retained into dry season.
3. Inherent fertility—available nutrient-holding capacity (phosphorus, potassium, nitrogen, sulfur, zinc, and micronutrients); favorable pH (lime); lack of harmful substances, such as sodium.	Application of limiting nutrient elements and correction of pH if needed. Nitrogen, only one involving high-energy fossil fuels, also available from nitrogen-fixing legume-bacteria systems.
4. Erodibility—direction and amount of slope, wind, and water.	Farming; tillage practice adjusted to slope with protection against wind, water gravity.
5. Possibility of irrigation.	Sprinkler, trickle, or surface irrigation for local application.
Biotic Competition	Cropping sequence, crop leaf canopy and density, mechanical and chemical weed control.
1. Weeds.	Planned intercropping sequences or mixed cropping, or both.
2. Other crops.	Protective measures.
3. Animals—domestic, wild rodents.	Resistant varieties, sprays, rotations.
4. Diseases—bacteria, fungi, nematodes, other.	Resistant varieties and sprays.
5. Insects.	Scaring devices, resistance, nets, sprays.
6. Birds.	
Crop Genetic Resources	Selection of best varieties for yield, fertility and water efficiency, nutrient quality, preference, resistance, maturity.
1. Present and new varieties.	Shift to new improved varieties and better species where possible. Constant concern for broad-based resistances and mixtures of varieties.
2. Possibility of other species and varieties. Avoidance of crop genetic vulnerability.	Research programs for effective and rapid use.
3. Availability of crop genetic resources for new variety development.	

Expanding the Green Revolution

The "green revolution" during the last 12 years or more has had a tremendous impact in increasing production of several food crops, especially rice, wheat, and corn. When these highly significant yield increases in many countries were not followed by immediate sufficiency of food the critics were numerous. They pointed out that the green revolution has not solved all their problems, which is true. But it did help greatly in keeping up with feeding the very large population increase during this same period of time. When the cost of energy suddenly went up, another set of critics exclaimed that the so-called green revolution was not only inadequate, it was wrong—it had high energy inputs (primarily nitrogen) and therefore was impractical, too expensive, and unavailable to most of the world.

Instead of discounting such obvious improvements, the job for all researchers, teachers, and producers is to re-evaluate and assemble the most affordable, appropriate level of technology into a coordinated package of inputs for improved food production. Much remains to be done on rice, wheat, and corn but expansion of these improvement programs to other food crops is well underway. Included in new programs are other cereals (sorghum and pearl millet), edible legumes (beans, cowpeas, pigeonpeas, chickpeas, soybeans, peanuts, lima beans, grams, lentils, and so on), root and tuber crops (cassava, potato, yam, cocoyam, and so on) and vegetables (mung bean, tomato, sweet potato, chinese cabbage). Work on these is now being developed in the network of eight International Agriculture Research centers

being supported by the Consortium of Donor Agencies and others. New work on oil seed crops other than soybeans and on the many other fruits, vegetables, nuts, and miscellaneous food crops is limited.

Food Storage and Distribution

In the developing countries, only primitive methods exist for storing grain and other farm crops. Grain must be protected from insects and rodents and stored under relatively low humidity in order to preserve it adequately. A farmer who has a bumper crop should be informed (through extension education) about the most effective and economical method of storing his crops. Transportation is another extremely limiting factor. Effective distribution and marketing methods could eventually make such bumper crops a profitable agricultural business enterprise.

Undernourishment and malnutrition are constantly faced by people in the third world countries. Nutrition education and emphasis on utilization of a proper combination of foods for a balanced diet are needed. As a first step toward upgrading food production, farmers in a given locality should be encouraged to grow the necessary crops through distribution of improved seed and management practices. Adequate demonstration could help farmers to accept the new varieties and the improved production practices that have been found successful by scientists on small experimental plots, and superior yield and nutritional quality of the food crops will result.

Information Systems

Many countries face a disastrous situation in solving emergency and long-range food production problems due to lack of information and agricultural statistics. This often leads to poor planning with resultant poor food production. Accurate assessment of socio-economic and food production potentials is an absolute necessity before formulating long-term planning to increase food production. The U.S. Department of Agriculture Statistical Reporting Service is an example of the kind of national or central statistical reporting agencies that ideally should be established in other countries. The Food and Agriculture Organization (FAO) of the United Nations should encourage and assist in establishing such an agency in each country where agricultural statistics are inadequate for implementing future programs in food production.

The next step would be to outline the specificity or selectivity of information to be collected. Such information should involve population and population growth trends, total arable land, area under cultivation, percentage of land used for various crops, yield estimates, rainfall, irrigation, soil type, conservation methods, fertilizer or energy used, and other related information on crop and livestock production. This information can be documented, analyzed, and stored in computers. A retrieval and distribution system should be established in the specific language where it can be used locally, regionally, or nationally for program implementation.

Statistical reporting of this kind also can be utilized by agencies such as FAO, International Research Institutes, and others interested in working with a country on improvement of its food production. This statistical information will be useful to those in the public and private sectors, government policy makers, extension educators, research scientists, teachers, students, business investors, and farmers.

Education

International Crop Research Institutes and Livestock Research Institutes have been established with the principle of continuity of the so-called green revolution. The objective is to increase food production, with international brain power cooperating with developing countries. These agencies have programs for training research and production workers from developing countries as an essential part of their activity. Also they engage in constructive, practical, and applied work directly related to the increase of food production. However, in each country there should be greater emphasis on identifying the best local varieties of each food crop and their adaptability to local agronomic practices using the available resources of fertilizers and irrigation. The importance of other adapted crops as food should be identified and an intensified campaign mounted for increased local use.

Many students come to the United States from other countries for advanced training and education in agriculture and related areas. Their financial support has been sponsored by the host country, private foundations such as the Rockefeller Foundation or Ford Foundation, and public agencies including U.S. Agency for International Development (USAID), FAO, and others. A few U.S. educational institutions have established special programs for these students to relate the use of their time and study or training to a specific area of interest. The sponsoring agency, in cooperation with the educational institution, should outline a program of course work and research oriented to the needs of the student and his country. In many cases the student can finish his course work and then complete the research in his home country. The goal is the solving of problems directly related to food production under the supervision of cooperating educational institutes. The University of Tennessee used this principle in the early 1960s in training Indian agriculture graduates. Such a program could be used by many other institutions.

Education in agricultural extension should be emphasized as a part of foreign student training programs. This should include the methodology of the extension system, problem identification, program planning, establishing priority of goals, research application, and methods of reaching farm audiences with information related to improved agronomic practices and livestock management. Similar training in administrative work should be a part of the program to familiarize the student with the nature of work and responsibility.