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MORE FERTILIZERS FOR MORE FOOD

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We are dependent upon living plants for converting the energy of the sun into food for man and beast. The amount of food that plants can produce is influenced by climatic factors over which man so far has been able to exert little control, and by a series of other factors that he has learned to control to a considerable degree. The latter include the genetic character of the plant, the protection of the plant against diseases and insects, the conservation and utilization of water, and the amount and availability of mineral nutrients.

The extent to which man can meet the world's food requirements in the next 10–20 years will depend in large measure on his ability to manipulate those factors over which he has some control. In part of the world, the so-called developed countries, he has been highly successful and has produced more food than is immediately required to meet his needs. In other parts of the world, the underdeveloped countries, he has not yet learned to manipulate successfully the factors to the same degree and is suffering from malnutrition and facing possible famine as a result.

Drs. Mangelsdorf and Stakman have discussed two of the important factors that are subject to man's control, the genetic character of crops and the control of pests. Progress in the former even in the less-developed countries has been so great that the yield potential is increasing and the gap between national average yields and potential yields is becoming larger. The supply of plant nutrients, therefore, is limiting crop production to an increasing degree.

The production of good seed of improved crop varieties is a process of modern agriculture. The processing, storage, and sale of improved seed is essentially an industrial process requiring good technology but of low capital and foreign exchange requirements. Likewise, the capital requirement for the production of pest control materials is low. The developing countries, therefore, should have relatively little difficulty in meeting their requirements for good seed and pest control materials. The problem at least is of a different order of magnitude than the provision of fertilizer, as will be indicated later.

The water factor is too complex to discuss in this paper. Water supply, however, is not the major factor limiting production in the large areas having a rainfall of 20 or more inches. Its efficiency of use needs to be increased by a combination of soil, water, and crop management practices, but these are problems that must be handled at the farm level and do not require much capital. Only when irrigation and drainage are to be developed are large capital investments required.

Having briefly commented on three important controllable factors influencing the plant as an energy-converting organism, we will now consider a fourth factor—the supply of plant nutrients. Our discussion will consider the following topics: limiting of yields by plant nutrients; requirements for fertilizer; consumption and production; technological progress; marketing; and the opportunity for the developing countries and industry.

Limiting of Yields by Plant Nutrients.—Most of the soils of the less-developed countries are low to very low in one or more of the major plant nutrients, and there

is increasing evidence that many of them are deficient in some of the secondary and minor nutrient elements. Their low fertility status results from their development under high temperatures and rainfall which promote rapid weathering and loss of nutrients by leaching. In addition, many of the arable soils have been cultivated a long time with only small additions of plant nutrients in farm manures. The net effect of these factors is reflected in the results of more than 300,000 soil tests in India. They indicate that 85 per cent of Indian soils are low or medium in available nitrogen and phosphorus, and 65 per cent are low or medium in available potash.[3] Therefore, we would expect a good response of crops to chemical fertilizer. That such is the case has been widely demonstrated in field experiments, fertilizer demonstrations, and in farm practice in all regions of the world and most of the less-developed countries. This is not the place for a thorough review of the physical and economic returns from the use of fertilizers, but a summary is essential for an understanding of the nature and magnitude of the plant nutrient problem.

FAO[6] has summarized fertilizer response data for rice in nine countries of Asia and Africa. They show a good response to nitrogen in all countries, an average return of 7.7 kg of rice per kilogram of nitrogen when applied at a rate of 30 kg per hectare. Seven countries had a good response to phosphate, 6.9 kg of rice per kilogram of phosphate. Four countries had moderate average return to potash, 3.7 kg of rice per kilogram of potash. The effectiveness of fertilizer in crop production is confirmed by statistics on fertilizer consumption. In the nine countries, from 1955/1956 to 1963/1964 total fertilizer consumption increased from about 470,000 metric tons of plant nutrients to 1,160,000 tons, an increase of 145 per cent in 8 years.

A second FAO report[7] provides an economic summary of 15,000 fertilizer demonstrations and 2,000 field experiments conducted on farms in 16 countries of the Near East, West Africa, and northern Latin America in 1961/1962 to 1963/1964. A positive economic return was secured in 90 per cent of the demonstrations and 97 per cent of the experiments. The average crop value-fertilizer cost ratio for the best treatment in the demonstrations was 3.4 and for the experiments, 8.7. These rather high ratios reflect very favorable returns on vegetable crops. The average return on cereals was substantially lower.

Research and farmer experience in the less-developed countries has shown that best returns are only obtained when fertilizers are used along with improved crop varieties, pest control, and adequate soil moisture. A striking example from India is given in an annual report of the Rockefeller Foundation.[15] It showed that at 50 kg N per hectare, hybrid sorghum gave almost three times the response of the local variety. Furthermore, the hybrid responded to 150 kg of N, whereas the local variety did not respond to more than 100 kg N per hectare. Similar data are available for maize, wheat, rice, and other crops.

There is no question about the merits of a package of practices and the need for such a package to produce really high yields and it should be used when possible. Nevertheless, there is ample evidence that properly selected single practices, good seed, fertilizer, or other measures often give satisfactory physical and economic returns on a wide range of soils and crops in the less-developed countries.

The following conclusions can be drawn from the agronomic data that has been developed through technical assistance in the last 15 years.

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(1) Plant nutrients are the major limiting factor in agricultural production in the less-developed countries.

(2) A moderate rate of fertilization, 40–70 kg per hectare, will usually increase the yield of crops about 50 per cent.

(3) The response to fertilizer may be increased at least 50 per cent when it is used with improved varieties of crops, pest control, and good soil and water management practices.

(4) High levels of fertilization, 100–300 kg per hectare, and high yields are only possible when the fertilizer is used on crops bred for use at high levels of fertility and disease and insect resistance.

(5) Fertilizers can be used as effectively in the less-developed countries as in North America and Europe.

At this point it may be advisable to consider the relation between fertilizers and food. One ton of plant nutrients will produce about 10 tons of cereals, 36 million calories, enough to provide 2400 calories to 40 people for a year. A fertilizer plant producing 1000 tons of nutrients per day would therefore provide 2400 calories per capita for about 15 million people for a year. Isn't that worth an investment of $60 million or $4 per capita?

Requirements for Fertilizer.—In 1962, Parker[12] estimated the amount of fertilizer required in 1980 to attain nutrition levels of 2300 calories per capita in the Far East and 2400–2470 in other regions and somewhat more animal protein in Asia and Africa. Obviously, these are minimum targets and not really acceptable for 1980. They probably should be increased by 100 calories. The estimate of food needs was made by FAO and was similar to those given later in the Third World Food Survey.[5]

The estimates indicate that regional food requirements for the Far East, Near East, Africa, and Latin America would be 219, 190, 174, and 194 per cent, respectively, of the 1960 food supply. The estimated fertilizer required to achieve these increases was 20.0, 3.6, 8.6, and 7.3 million tons of nutrients, a total of 39.5 million tons. The estimates allowed for increased production from other yield-increasing practices but not for increases in the area of crop land. The estimated 1980 fertilizer requirement, therefore, was reduced to 30.0 million tons, 7.5 times 1960 consumption in the less-developed countries and equal to world consumption in 1961. That quantity of fertilizer effectively used would produce enough additional food to provide 2400 calories per capita per day for about 1.2 billion people for 1 year.

Subsequent estimates of requirements have usually been projections of consumption and are considered in the next part of this paper. There is obviously a need for a revision of the foregoing estimates of long-term requirements using the latest estimates of food requirements for improved nutrition, population, and crop response to fertilizers.

Consumption and Production.—World fertilizer consumption increased from 3.5 million tons of nutrients in 1920 to 9.6 and 40.0 million tons in 1947 and 1965, respectively. The annual rate of increase in consumption was 5.1 per cent compounded in 1920–1939, 8.0 per cent in 1947–1963, and has increased to 10 per cent in the last 3 years. In 1964 about 89 per cent of the world fertilizer was used in the more-developed countries and only 11 per cent in the less-developed coun-

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tries. However, the proportion is changing as the rate of increase in consumption in the less-developed countries is higher than in the more-developed.

Coleman,[2] Ewell,[4] TVA,[10] and International Minerals and Chemicals Corporation[8] have recently estimated world fertilizer consumption for 1970. Their estimates, including mainland China, range from 58 to 68 million tons of nutrients with three of the four estimates near the higher figure. By 1970 the less-developed countries will be using about 13 million tons, 20 per cent of the world fertilizer, almost twice the percentage used in 1964.

International Minerals and Chemicals Corporation (IMC)[8] estimates world consumption in 1980 will be 113 million tons with about 26 per cent being used in the less developed countries. The IMC 1980 estimate of 30.5 million tons for the less-developed countries is in very close agreement with Parker's[12] estimate of requirements, 30 million tons. If both estimates prove to be accurate, the food situation in 1980 should be slightly better than it is today. If the nutritional targets were increased by 100 calories per capita, there would be a substantial gap between fertilizer requirements and projected consumption in the less-developed countries.

That the governments and industry are planning for the higher estimated levels of consumption is indicated by a recent TVA[10] study of world fertilizer production capacity. It indicates that world capacity was 49.5 million tons in 1965 (consumption was 40 million tons, so production average 80% of rated capacity), and would be 85.5 million tons in 1970, an increase of 72 per cent. If operated at 80 per cent capacity, world production will be 68.5 million tons, essentially the same as the higher estimates of 1970 consumption. However, both the TVA and UN[16] reports indicate fertilizer production in the less-developed countries will be below the estimated consumption. There is obviously a need to increase production in many of the developing countries. This should be a priority item in country agricultural programs.

The indicated increase in fertilizer plant capacity will require capital expenditures of about $6.3 and $2.8 billion in the developed and less-developed countries, respectively. The foreign exchange requirements of the latter countries will probably be about $1.5 billion, most of which can be provided by industry.

Technological Progress.—The unprecedented boom in fertilizer producti n and use is being accompanied by great technological changes in production, transportation, and marketing. The process starts with the development of new sources of raw material. New sources for the production of nitrogen, phosphate, and potash fertilizers are being discovered and developed at a rate adequate to meet foreseeable requirements. There is a shortage of elemental sulfur, and the industry may have to utilize other forms or use processes that require less sulfuric acid.

The remarkable changes in the technology of ammonia production have substantially lowered the cost of production.[1, 9, 11] There have been substantial improvements in the urea process[11] and in the production of ammonium phosphates, nitrophosphates, and complex fertilizers. These changes are well summarized in the report of the UN Fertilizer Seminar.[16]

Anhydrous ammonia, the basic material for all nitrogen fertilizer, is now shipped in 10,000-ton refrigerated tankers and barges. This makes possible its production in very large plants at locations where low-priced natural gas is abundant, with subsequent shipment to any port. When more fully exploited, this should reduce the

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cost of producing nitrogen fertilizers in many countries. A similar development seems to be in the making with respect to the shipment of superphosphoric acid, containing 75–80 per cent P_2O_5.

One effect of these and other changes in technology is the increased plant nutrient content of fertilizers. This change has already occurred in most of the industrial countries. In the United States, for example, the average plant-food content of fertilizers increased from 22.4 per cent in 1950 to 35.8 per cent in 1964. The fertilizers in many less-developed countries should average around 40 per cent plant nutrients by 1970, thereby reducing transportation, storage, and handling costs per unit of plant nutrient almost 50 per cent.

A second important effect of the new technology is on the price of fertilizers. The world price of fertilizers has changed very little since World War II. For example, since 1950, fertilizer prices in the United States have only increased 6 per cent as contrasted with price increases of 46 and 50 per cent for farm machinery and labor. The new technology of production and distribution should prevent price increases and may well reduce the price to farmers in some countries. On the other hand, the price of agricultural commodities has increased and, in view of food and fiber shortages in the less-developed countries, may continue to do so. As a result, the fertilizer-crop value ratio and the economics of fertilizer use should improve.

Marketing.—One of the weaker aspects of the fertilizer program in many less-developed countries is the arrangement for marketing the fertilizers to farmers. In the early stages of fertilizer development, marketing is frequently done by a governmental agency. As domestic production develops and consumption increases, adjustments in marketing are needed. There are a number of alternatives that may be considered, as demonstrated by the various methods used in the United States, western Europe, Japan, and some other countries.

A good marketing system should provide farmers a source of fertilizer when and where it is needed. Obviously, provision must be made for warehousing so that deliveries may be made promptly. The system, through trained salesmen and dealers, should provide an educational and technical service to farmers. Such service should include information on the use of improved seed, fertilizers, and related practices. This will require men who will go to the farmers rather than wait for farmers to come to them. The system should make the fertilizer producer responsible for the sale of the product, so that full-scale production will depend on sales and the producer will become familiar with the farmer's problems and the end-use of fertilizers. The marketing organization will need to work closely with the research, extension, and agricultural credit agencies and may, in fact, handle part of the credit.

Several less-developed countries are developing good fertilizer marketing arrangements. Other countries could profitably study the methods used in Mexico, Taiwan, the Philippines, Pakistan, and some of the countries in Europe as well as the United States.

It seems apparent that the new marketing system must provide for a retail agent who will sell fertilizer, seed, farm equipment, pesticides, and other farm supplies. He will also provide an educational and technical service to customers to supplement that provided by governmental agencies. Such an agent and marketing system

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can be a great factor in increasing the proper use of fertilizer and agricultural production.

An Opportunity. The possible contribution of fertilizers to the solution of the food and agricultural problems of the less-developed countries presents their governments and the chemical industry of the industrialized nations with a unique opportunity. The production of fertilizers is an important base for the development of a domestic chemical industry. Their marketing, along with other agricultural chemicals and inputs, provides an opportunity to give farmers an information and technical service. Their use is an effective means of increasing crop yields and helping solve the food problem. All this can be done with a satisfactory return on the investment. The governments of the developing countries, therefore, should encourage domestic and foreign industry to undertake jointly the production and sale of chemical fertilizers. Several countries are doing this successfully and seem to be substantially benefited by such policies and joint efforts.

There is abundant evidence to show that the chemical industries of the developed nations are quite willing to make investments in fertilizer production in the developing countries. In the last few years such investments have been made in more than 20 countries. Obviously, industry, in seeking places for such investment, is concerned with having a favorable climate for investment, sources of raw materials, a demand for fertilizers, good marketing arrangements, and a minimum of price controls. Industry prefers to operate in countries where market forces, rather than government controls, dominate.

If the most is to be made of current opportunities, the governments of the developing countries and industry, domestic and foreign, must work together. They can achieve their respective objectives as well as the common goal of increased food production and economic development. They can count on the assistance of the many agencies that provide technical and economic assistance.

The favorable investment opportunities for producing fertilizers in the less-developed countries arise in large part from the technical assistance provided under foreign aid programs during the last 16 years. Bilateral and multilateral programs, including those of AID and FAO, have helped nations assess their need for fertilizers and the returns from their use, and have helped to create an effective demand. Without such assistance, fertilizer consumption in the less-developed countries would not be increasing at the rate of 15 per cent per year. These programs are being accelerated. AID, for example, is now utilizing the services of the TVA in its technical assistance programs in several countries. The industry-supported FAO fertilizer program is being enlarged and the UN Special Fund is financing fertilizer preinvestment projects. All this has helped to lay a foundation for profitable investment in fertilizer production.

The U.S. government has long recognized the importance of economic support for the use of fertilizers in agricultural production and economic development. Its economic assistance programs for 1947–1960 provided more than $700 million for the importation of fertilizers to help restore Europe and Japan and to assist in the development of other countries.[12] Since June 1960, AID has provided the less developed countries $276 million for the importation of fertilizer and $86 million for building fertilizer plants. That this governmental effort is to be increased was

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recently announced by President Johnson. He indicated that during F.Y. 1966 AID would vigorously support the increased production and use of fertilizers.

Summary. Conditions seem to be favorable for man in the less-developed countries to exercise greater control of four important factors influencing crop yields, namely, the genetic character of crops, the supply of plant nutrients, pest control, and better use of water. In order to do so, governments, industry, and farmers must work together, each performing those functions that are appropriate. An examination of modern agriculture in North America, Europe, and in developing countries indicates that such action was a common feature in all countries. The key question seems to be whether government and industry will adopt policies that assure effective roles for each in helping farmers increase crop yields.

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[16] Report on the United Nations Inter-Regional Seminar on the Production of Fertilizers held at Kiev, Ukrainian S.S.R., August 24–September 11, 1965, 73 pp.

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