D. H. PARISH (*)

The Role of Fertilizers in Increasing Food Productivity in Developing Countries (**)

SUMMARY. — The exploitation of the fertilizer/modern variety interaction has led to major increases in the production of rice and wheat, the staples of more than two billion developing country inhabitants. The lesser success with maize has been due to the poorer environment and infrastructure of many maize-growing areas of the developing countries, rather than to a lack of applicable technology. Fragile soils, unreliable rainfall, poor road networks, and the long distances are major problems, particularly in Africa.

Sorghum and millet, the key staples of the semiarid tropics (SAT), suffer to an even greater degree the problems facing the maize grower; in addition, new yield-increasing technologies relevant to the SAT situation have essentially eluded these crops. Production of the major starchy foods and protein-rich pulses of the tropics is still essentially based on traditional cultivars although improved seed material is now increasingly available.

Fertilizer use in the tropics will continue to grow and will be a major contributor to increased food production well into the 21st century. Most developing countries need to improve their fertilizer policies and sector management in order to encourage efficient and profitable use of fertilizers and related inputs by the millions of small-farm food producers.

INTRODUCTION

Agricultural production is the end result of human initiative based on exploiting the climate, soils, and plant ecology to meet man's needs for food, fiber, and fuel.

The human element in agricultural production is motivated by socioeconomic considerations. Because of the wide spectrum of cultural, social, and economic norms in the developing countries, the impact of the human element on agricultural production is extremely varied. The socioeconomic makeup of

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these countries is dynamic, but the degree of dynamism is affected by government policy [1]. This means, in practice, that developing country agriculture ranges from traditional nonmonetized subsistence farming to farms that use modern technology and sell off all their produce. Typically, however, the developing country farmer is a small farmer (1-3 ha) who produces food for subsistence and both food and industrial or export crops for cash and who uses a mixture of traditional and introduced crop production practices.

The level of crop production per unit area achieved by farmers reflects all crop production factors. Many of these (insolation, temperature, etc.) are uncontrollable. Other factors, however, can be changed if sufficient economic incentive exists. Such factors would be the genetic potential of the crops grown and correct agronomic practices including water management (drainage and irrigation) and the maintenance or improvement of soil fertility. Given crops with good genetic potential and sound agronomic practices, water and soil fertility are the keys to high crop production levels.

Although irrigation plays a key role in many countries, particularly those in Asia and of course Egypt, most tropical food crops are grown under rainfed conditions; to a large degree, these conditions dictate both the type of crops that can be grown and the achievable yields. In both irrigated and nonirrigated areas, the major modifiable constraint on crop production is low soil fertility. Improvement of soil fertility at the farm level is essential if crop yields are to be maintained and improved.

Soil fertility management is a complex issue. Organic matter recycling and the use of legumes are generally regarded as essential if soils are to remain productive and if dependency on fertilizer use is to be lessened. In developing countries organic matter recycling is labor intensive and is sometimes so physically demanding as to be unacceptable. Organic matter recycling by the farmer does not increase the level of plant nutrients of a farm; it merely shifts nutrients from one place on the farm to another.

With the notable exception of nitrogen, inputs of fertilizers are needed to increase the fertility levels of a farm. The potential for the fixation of atmospheric nitrogen is in theory almost limitless, and undoubtedly symbiotic nitrogen will play an increasingly important role in supplying soil nitrogen. However, this is seen in the major cereal producing areas as being complementary to fertilizer nitrogen use and not as a replacement.

For all farmers the integration of fertilizer use with good crop residue management is the ideal way to grow better crops and improve soil fertility.

This paper examines the role played by fertilizers in food crop production in developing countries and discusses some of the factors involved in improving crop yields in an economical way through fertilizer use.

(1) Policy can be taken to cover those government laws, regulations, and practices that affect prices and financial incentives and, therefore, impinge on the functioning of public and quasi-public institutions and the private sector, and through them on economic growth and, therefore, agricultural development.

THE DEVELOPING COUNTRIES AND THEIR NEED FOR INCREASED FOOD PRODUCTION

The World Bank defines 94 nations as developing (or less developed) countries — 35 low-income countries (average per capita GNP below $400) and 59 middle-income countries. They include all of Latin America, all of Asia except Japan, and all of Africa and the Middle East except for the high-income oil exporters. Three-fourths of the world's people live in these countries. The American President's Task Force on International Private Enterprise concluded in 1984 that in developing countries "rapid population growth and the need to improve the diets of millions of people create rising demands for the most basic human need — food".

The Food and Agriculture Organization (FAO) estimates that 500 million people suffer from hunger and malnutrition. Between 1961 and 1980 food production in developing countries increased at an average rate of 2.6%/year. This was slightly greater than the annual population growth rate of 2.4%. For the developing countries as a whole, per capita food production rose at only 0.2%/year. For sub-Saharan Africa, food production actually declined by 1.1% a year.

It is obvious from these general figures that food production must be increased, preferably in the developing countries themselves. Yet many countries have only limited potential for expanding their area of food crops. As shown by the FAO estimates in Table 1, except for Latin America, increases in crop yields rather than an expansion of the cropped area will have to account for most of the additional food needed.

TABLE 1 - Contribution of Changes to Increases in Production in Developing Countries - 1975 to 2000.

Region	Contribution to Output Growth Changes in (%)		
	Arable Land Growth	Cropping Intensity	Yields
90 countries	26	14	60
Africa	27	22	51
Far East	10	14	76
Latin America	55	14	31
Near East	6	25	69

Source: FAO.

FAO's *Agriculture: Toward 2000* contains a very relevant statement. It reads:

> After land and water, fertilizers are probably the most important input leading to increased yields: They are responsible for some 55% of the increase in yields in developing countries between 1965 and 1976. There is a clear relationship between higher or increasing applications of fertilizers and above-average agricultural production.

Fertilizers will be an essential component of crop production practices, and their level of use must increase for the foreseeable future.

Fertilizer and Increased Food Crop Production

Given that fertilizers will be needed in increasing quantities if food production is to increase, it is necessary to understand their role in increasing crop yields and the potential they offer for increasing national levels of production.

The major staples of the developing world are the cereals — rice, wheat, maize, millet, sorghum, and other cereals of the semiarid tropics. Starchy foods, which are major sources of calories in the more humid areas, are the root crops — cassava, yam, sweet potato, etc., and the bananas, including plantains. Pulse crops are important as sources of protein.

Within this wide range of both crops and the conditions under which they are grown, physical responses to fertilizer vary greatly.

Statistics of crop yield trends to indicate the impact of a new yield-increasing technology can be used only with care. For example, expansion of cropped areas into less favorable zones will bring down average crop yield levels. Conversely, reduction of the area by abandoning areas of marginal production will increase yields. Additionally, the reliability of statistics is often suspect. Certainly harvested area and crop yield data from zones of mixed cropping and of low crop yields are often unreliable. Nevertheless, over the long term, the national impact of a new yield-increasing technology must be assessed on the basis of national statistics.

Rice

Rice is the primary staple for more than two billion people in Asia and for hundreds of millions of people in Africa and Latin America. The countries of South and East Asia account for more than 90% of the world production of rice. Table 2 shows the major rice-producing countries — all of them in Asia.

Rice is grown in the tropics in five major situations — irrigated, rainfed lowland, upland, deep water, and tidal wetlands; because of the importance of irrigated rice, however, plant breeding research concentrated on this type of cultivation. Although the yields of tropical irrigated rice were low, they could not be increased with fertilizer because local varieties were tall and they lodged

TABLE 2 - Estimate of Population Whose Major Food Is Rice: South, Southeast, and East Asia, 1985.

	Population	Per Capita Consumption	
	Total (million)	Rice (kg/year)	Wheat
China	1,088	101	72
India	763	74	52
Indonesia	168	150	9
Japan	121	90	52
Bangladesh	103	155	28
Pakistan	100	24	125
Vietnam	60	151	16
Philippines	56	102	17
Thailand	53	177	4
Republic of Korea	43	140	50
Burma	39	218	2
Taiwan province, China	20	144	—
People's Rep. of Korea	20	141	40
Nepal	17	96	30
Sri Lanka	16	109	36
Malaysia	16	108	31
Kampuchea	6	145	—

Source: IRRI (1985).

easily when fertilized with nitrogen. In 1962, therefore, scientists at the International Rice Research Institute (IRRI) crossed a short-statured rice from China with a then-popular Indonesian variety, Peta. The result was IR8, a semidwarf, nitrogen-responsive plant type (²). Figure 1 shows the effects of nitrogen fertilizer on the yield of Peta and of IR8.

The development of IR8 was a breakthrough for tropical rice because it doubled the yield potential of this crop. This "green revolution" impacted essentially on irrigated rice, which accounts for about one-half of the world's rice area and for three-quarters of paddy production.

The impact of the fertilizer/modern rice variety interaction area on average

(²) When research results show response to nitrogen fertilizer only, it is assumed that adequate levels of phosphate, potash, and other needed plant nutrients were applied to the experimental site. Therefore, "fertilizer-responsive" is the more generally applicable term as it implies that balanced application of the needed nutrients maximizes the nitrogen/variety interaction. It should also be clearly understood that maximization of fertilizer/variety interaction to give high yields is dependent on sound agronomic practices, for which increasing fertilizer use is no substitute.

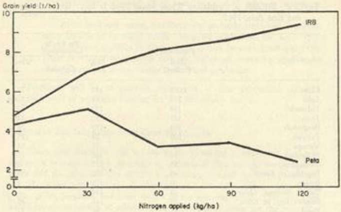


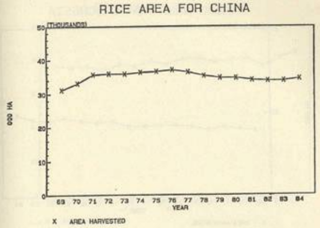
Fig. 1 - Nitrogen response of Peta and IR8. IRRI, 1966 dry seasons.

yield levels is shown in Figure 2 for China and Figures 3 and 4 for Indonesia and India, respectively. Also given is the harvest area.

China has made steady progress, and yields have increased from 3 to more than 5 mt/ha. Indonesia has followed the China pattern with steady increases in yield of from 2 to around 4 mt/ha. Both China and Indonesia sought rice self-sufficiency as national policies, and an increase in fertilizer use was a key strategy followed in both countries. For India, rice yields also have evolved steadily, and most of the increase has been due to exploitation of the fertilizer/variety interaction. For China, Indonesia, and India, which combined have almost two billion people who are mainly dependent on rice as a staple, the green revolution has merited its name.

In the Philippines (Figure 5) progress has been somewhat slower, but rice yields have increased steadily since 1972. The national average yield of around 2.5 mt/ha, however, shows that the modern rice technology available is not being fully utilized. This is due partly to the fact that there are both rice-deficit and rice-surplus areas in the Philippines. The latter areas, as a result of an inadequate marketing infrastructure, have little encouragement to increase their yields.

The graphs for Thailand (Figure 6) show that the impact of the green revolution on a rice-exporting country has been insignificant. There are two reasons for this lack of impact: rice production from the irrigated areas of


RICE AREA FOR CHINA
(THOUSANDS)
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YEAR
X AREA HARVESTED

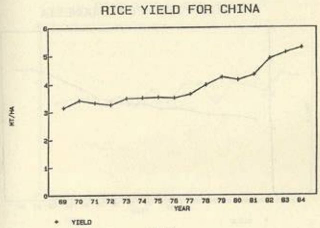
RICE YIELD FOR CHINA
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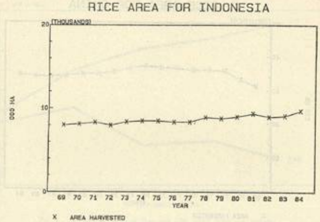
Fig. 2


RICE AREA FOR INDONESIA
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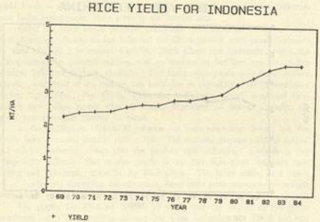
RICE YIELD FOR INDONESIA
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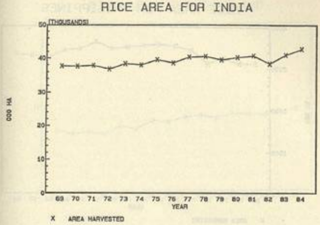
Fig. 3


RICE AREA FOR INDIA
(THOUSANDS)
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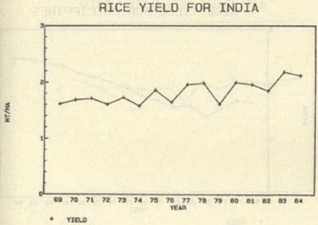
RICE YIELD FOR INDIA
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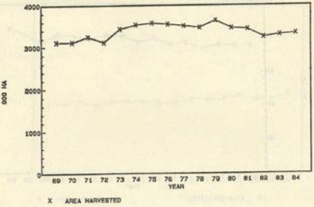
YEAR
+ YIELD

Fig. 4

RICE AREA FOR PHILIPPINES



RICE YIELD FOR PHILIPPINES

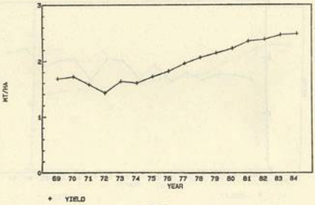
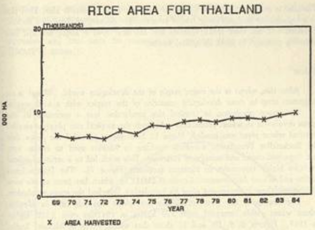


Fig. 5


RICE AREA FOR THAILAND
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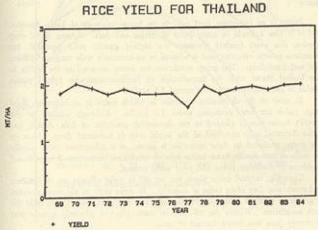
RICE YIELD FOR THAILAND
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69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
YEAR
+ YIELD

Fig. 6

Thailand is small compared to the total rice area and, important also, Thai rice is a high-quality internationally traded commodity. Because of these two factors, Thailand has not used IRRI varieties but has developed a major national rice breeding program to meet its special needs.

Wheat

After rice, wheat is the major staple of the developing world. Wheat is an important crop in those developing countries of the tropics with a cool season.

The green revolution in tropical rice production was a successor to the green revolution in wheat production. As with the tropical rice plant, a smaller statured wheat plant was needed; Norin 10 from Japan provided the genes that the Rockefeller Foundation scientists working in Mexico used to create new and improved dwarf and semidwarf varieties. This work led to a series of wheat varieties highly responsive to nitrogen fertilizer (Figure 7). The International Maize and Wheat Improvement Center (CIMMYT), which has been at the core of tropical wheat improvement since its foundation, launched the green revolution.

The impact of the green revolution for wheat was felt first in Mexico, where wheat yields increased from 770 kg/ha in 1941 to over 2,700 kg/ha in 1967. Figures 8, 9, 10, and 11 show that wheat yields in Mexico, India, Pakistan, and Bangladesh, respectively, continue to rise.

Maize

Maize is an important food crop in its home continent of Latin America, but it is also a staple in many parts of Africa and Asia. Among cereal crop species, *Zea mays* (maize) possesses the highest genetic yield potential, has enormous genetic variation, and is adapted to an extremely wide range of climatic and soil conditions. The green revolution for maize occurred in the 1950s in the United States with the introduction of fertilizer-responsive hybrid maize. Yields in the United States now exceed 7.5 mt/ha.

In most of the developing countries in which maize is an important food crop, yields are low, averaging about 1.5 mt/ha. Although one-half of the world's maize area is planted in the developing countries of Asia, Africa, and Latin America, only one-third of the world crop is harvested there. Most of the maize produced in these countries is grown as a subsistence crop, usually on soils of low fertility and under rainfed conditions characterized by seasonal problems of moisture stress and poor weed control.

Generally, tropical maize plants are too tall to make efficient use of fertilizer and space, and they often lodge at maturity. In some parts of the tropics, maize is grown as a mixed crop with beans, and these tall plants are not suitable for such association. Within the tall tropical maize plant, a relatively greater part of energy goes into stover instead of grain.

CIMMYT, which is at the center of tropical maize and wheat research, is putting more emphasis on reducing plant height while selecting for yield and other desirable agronomic characteristics. CIMMYT is now providing the national programs with tropical maize plants that are more manageable and fertilizer-responsive and that have the potential of greater grain yield per hectare (CIMMYT, 1980).

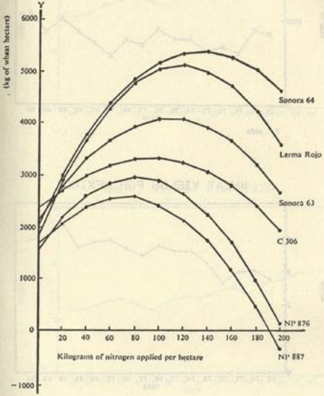
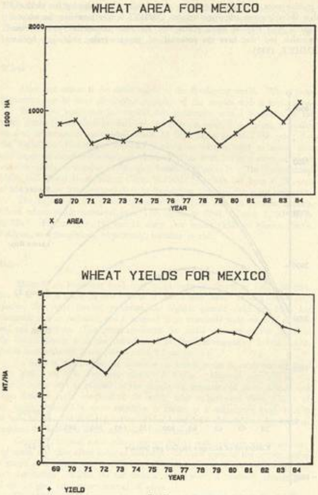


Fig. 7 - Production functions for some Mexican and improved Indian wheats.


WHEAT AREA FOR MEXICO
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WHEAT YIELDS FOR MEXICO
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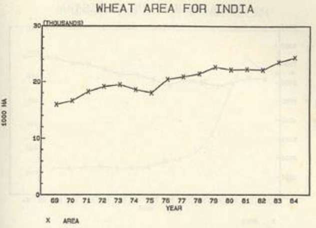
Fig. 8


WHEAT AREA FOR INDIA
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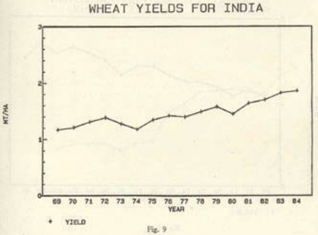
WHEAT YIELDS FOR INDIA
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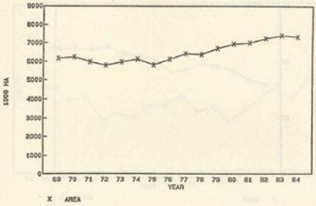
YEAR
+ YIELD

Fig. 9

WHEAT AREA FOR PAKISTAN



WHEAT YIELDS FOR PAKISTAN

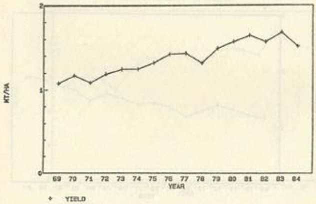
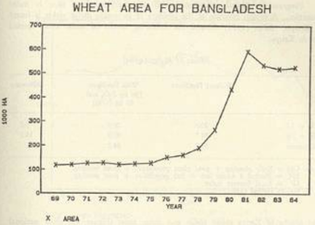


Fig. 10


WHEAT AREA FOR BANGLADESH
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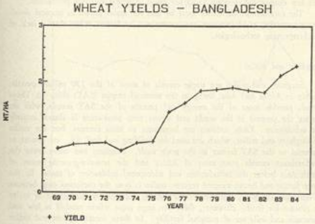
WHEAT YIELDS - BANGLADESH
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YEAR
+ YIELD

Fig. 11

Progress in tropical maize production, however, has been slow in many countries. A typical example of the problem of increasing maize yields is found in Kenya. Allan (1971) showed the following results of maize trials carried out in Kenya.

Yields of Maize (q/ha)

	Without Fertilizers	With Fertilizers (56 kg P_2O_5 and 80 kg N/ha)	Difference
BH + LF	20.9	26.0	5.1
GH + Hy	74.7	90.8	16.1
Differences	53.8	64.8	

Note: GH = Early planting + good plant population + clean weeding.
BH = Planted 4 weeks late + low population + poor weeding.
LF = Local farmers maize.
Hy = Hybrid 613B.

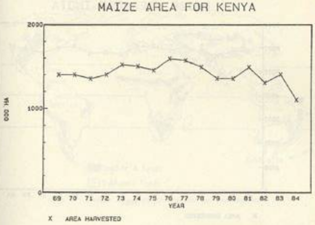
The graphs of Kenya maize yields and maize areas (Figure 12) show national average yields of around 1.5 mt/ha. Allan obtained maize yields of 7.5 mt/ha almost 20 years ago.

Yields of the 6 million ha of maize grown in India (Figure 13) are also still low despite the progress India has made in wheat and rice production.

The conclusions, therefore, must be that for maize grown in tropical developing countries, yield increases are constrained by factors other than a lack of yield-improving technologies.

Sorghum and Millet

Sorghum and millet are staple cereals of most of the 750 million people, mainly in Africa and Asia, living in the semiarid tropics (SAT) (Map 1). These cereals provide most of the energy and protein of the SAT people, who are among the poorest in the world and whose crop production is almost entirely for subsistence. Crop residues are important to most farmers, but the stalks of sorghum and millet, which are used for building and fuel, etc., are almost as essential to the SAT farmer as the grain itself. Sorghum and millet were the predominant cereals over most of Africa and the non-rice-growing areas of South Asia before the introduction and widespread cultivation of maize. In the more fertile and better-watered regions, maize is now the preferred crop because it outyields sorghum, stores better, is hardly damaged by birds, and is easier to process for food. However, there are large areas where rainfall is low and uncertain and soils are of marginal fertility. In these areas sorghum and millet are the more reliable crops because of their adaptability to a wide range of


MAIZE AREA FOR KENYA
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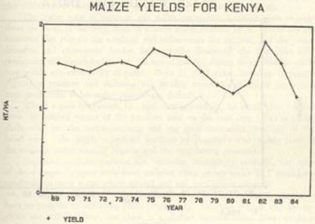
MAIZE YIELDS FOR KENYA
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YEAR
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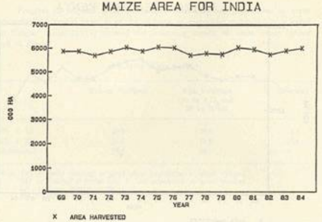
Fig. 12


MAIZE AREA FOR INDIA
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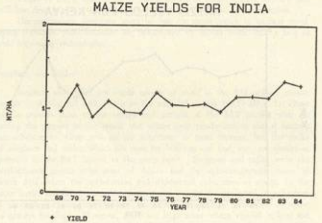
X AREA HARVESTED


MAIZE YIELDS FOR INDIA
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YEAR
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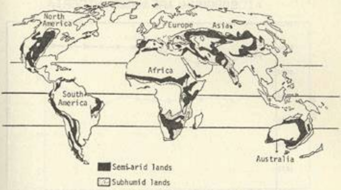
Fig. 13



Map. 1 - Location of the world's semi-arid and subhumid lands.

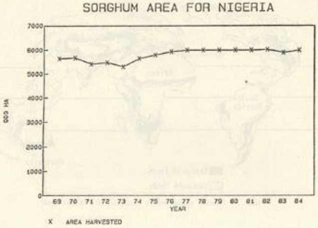
ecological conditions (Doggett *et al.*, 1970). Sorghum and millet will continue to have an important place in SAT agriculture as population pressure requires the cultivation of marginal lands unsuitable for maize or other cereals.

The major zone of sorghum and millet production in Africa runs through those countries of the SAT lying in a band across latitude 10°N. These are the countries that rely on the sorghum and millet crops for survival, and the recent droughts and consequent famine have cruelly illustrated the fact that food production and population growth are out of balance during those years in which crop yields are reduced by drought. Even in good years, however, increasing population pressure and declining soil fertility mean that adequate per capita crop production is becoming increasingly difficult.

Where a cash crop exists, i.e., cotton or groundnut, the cereal crop benefits from the residual effects of the fertilizer used on the cash crop. This is particularly true for the cotton-sorghum and the groundnut-millet rotations of the Sahel zone. The highly subsidized fertilizer of Nigeria is also widely used in the sorghum-millet zone of Nigeria and the neighboring countries.

Improved sorghum varieties are becoming increasingly available, but most of these cannot compete with local varieties when grown under SAT small-farm conditions or with maize where rainfall and soil fertility are adequate.

In Nigeria, the major sorghum producer in the African SAT, there has been no progress in increasing yields (Figure 14). In India (Figure 15), average yields are still very low, but there is a distinct upward trend. New sorghum varieties developed by International Crops Research Institute for the Semi-Arid


SORGHUM AREA FOR NIGERIA
7000
6000
5000
4000
3000
2000
1000
0
000 HA
69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
YEAR
X AREA HARVESTED

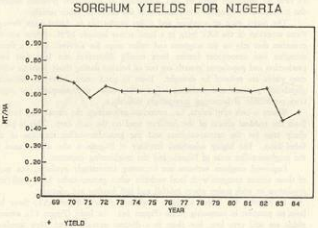
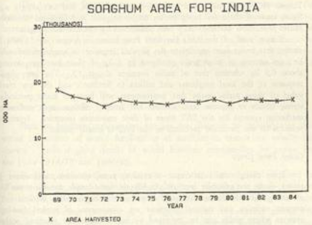

SORGHUM YIELDS FOR NIGERIA
1
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0
MT/HA
69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
YEAR
+ YIELD

Fig. 14


SORGHUM AREA FOR INDIA
(THOUSANDS)
30
20
10
0
000 HA
69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
YEAR
X AREA HARVESTED

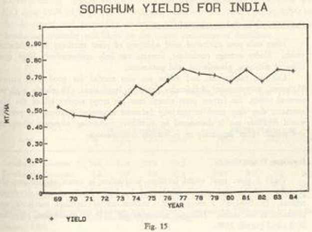

SORGHUM YIELDS FOR INDIA
1
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0
MT/HA
69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
YEAR
+ YIELD

Fig. 15

Tropics (ICRISAT) have been widely released in India, and increasingly significant areas of these are being grown under irrigated and fertilized conditions. Millet production has essentially been unaffected by modern technologies.

Recent work of the FAO Fertilizer Programme in Africa (Joly, 1985) has shown that under farm conditions the physical response of sorghum and millet, i.e., the amount of extra grain produced by 1 kg of plant nutrients, averages about 6.5 kg whereas that of maize averages almost 12. The low physical response of the local sorghums and millets to fertilizers and the low market value of these grains mean that governments will have to make particularly strong efforts to improve farm incomes and develop efficient input and output marketing systems for the SAT zones of their respective countries. Intensified research on the particular problems of the SAT is greatly needed.

Other Food Crops

Even though the root crops — cassava, yams, cocoyams, and sweet potatoes — are not generally fertilized, in Nigeria, for example, fertilizers are used on yams when the farmer has good access to the larger urban markets. The present varieties and cultural practices are components of typical low-input systems where yields can be improved by better agronomic practices without the need for purchased inputs. The same situation applies to the local bananas and plantains.

The pulse crops, particularly groundnuts and soybeans, generally respond to fertilizer phosphate, but disease control is a major problem.

Fertilizers in Developing Countries

Most soils now cultivated need additions of plant nutrients for satisfactory yields. Under average conditions, farmers use only comparatively large quantities of nitrogen, phosphorus, and potassium.

Calcium, magnesium, and sulfur are also needed for good crop growth. Moreover, micronutrient deficiencies occur in large areas. To obtain high economical yields, the farmer must ensure that his crops receive all of the plant nutrients that they need in carefully balanced amounts; however, in practice, world fertilizer use is dominated by fertilizers containing nitrogen, phosphate, and potash either separately or in various combinations.

Fertilizer Production

Table 3 gives total world fertilizer production in terms of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) and by both developed and developing regions. In 1984/85 a record 139.5 million mt of fertilizer nutrients were produced in the world. Nitrogen accounted for 53% of production, phosphate 26%, and potash 21%.

The key point from these statistics is the dynamic growth shown by the fertilizer industries of the developing countries. These countries as a group increased production from 12.1 million mt in 1974/75 to 36.1 million mt in 1984/85, for a growth rate of over 11% per annum. The developed countries, meanwhile, grew at an annual rate of only 2.4% per annum. In 1984/85 the developing countries produced 26% of the world's fertilizer compared with only 13% 10 years earlier.

Fertilizer Consumption

Data on fertilizer consumption for any one year can be unreliable in that actual inventories of stored fertilizer or of fertilizer in transit are usually not known. Table 4 gives details of world fertilizer consumption by region for the years 1974/75 and 1984/85.

Fertilizer consumption growth rates over the 10-year period declined in Western Europe, North America, Eastern Europe, and Oceania. Both Asia and the U.S.S.R. increased their share of the world's consumption during this time.

The developing countries, as a group, increased consumption almost 9% annually during this period while the developed countries increased their consumption at a rate of only about 2% annually. Table 5 gives comparative data for the developed and developing countries. In 1984/85 the developing countries consumed 37% of the world's fertilizer nutrients compared with only 23% 10 years earlier. Figure 16 gives the actual total consumption of N, P_2O_5, and K_2O from 1974 to 1984 and a "projected" consumption from 1985 to 1996 for the developed and developing countries. Before the end of this century, the developing countries will likely be the major consumers of fertilizers.

TABLE 3 - World: Fertilizer Production by Region, 1974/75 and 1984/85.[a]

Area	1974/75 Million Nutrient mt				1984/85 Million Nutrient mt			
	N	P_2O_5	K_2O	Total	N	P_2O_5	K_2O	Total
Developed Countries	34.6	21.8	23.1	79.5	47.5	27.1	28.5	103.0
Developing Countries	7.8	4.0	0.3	12.1	26.8	9.0	0.3	36.1
TOTAL WORLD	42.4	25.8	23.4	91.7	74.3	36.1	28.8	139.1

[a] Does not include ground phosphate rock. Calendar year data for 1984 would be included with 1984/85. Totals may not add due to rounding.
Source: FAO.

TABLE 4 - World: Fertilizer Consumption by Region, 1974/75 and 1984/85.*

Area	1974/75 Million Nutrient mt				1984/85 Million Nutrient mt			
	N	P_2O_5	K_2O	Total	N	P_2O_5	K_2O	Total
North America	8.3	4.6	4.2	17.2	11.7	4.9	5.4	22.0
Latin America	1.8	1.5	0.9	4.2	3.2	2.4	1.7	7.3
Western Europe	7.2	5.0	4.6	16.9	10.0	5.0	5.3	20.4
Eastern Europe	4.1	2.9	3.4	10.4	5.1	3.4	3.3	11.8
U.S.S.R.	6.7	3.3	3.9	13.9	10.3	5.9	6.2	22.3
Asia	9.1	4.0	1.9	14.9	27.9	9.4	3.3	40.6
Africa	1.1	0.7	0.3	2.2	1.8	1.2	0.4	3.4
Oceania	0.2	0.9	0.2	1.4	0.4	1.1	0.3	1.8
TOTAL WORLD	38.5	22.9	19.5	81.0	70.5	33.2	25.9	129.6
Developed Countries	27.5	17.7	17.3	62.5	38.7	21.5	21.3	81.4
Developing Countries	11.0	5.2	2.3	18.5	31.8	11.7	4.7	48.2
TOTAL WORLD	38.5	22.9	19.5	81.0	70.5	33.2	25.9	129.6

* Does not include ground phosphate rock for direct application. Calendar year data for 1984 is included with 1984/85. Totals may not add due to rounding.

Source: FAO.

TABLE 5 - World: Share of Fertilizer Consumption by Region and Annual Growth Rate During Past Decade, 1973/74 and 1984/85.*

Area	1974/75 Million mt Nutrients	1974/75 World, %	1984/85 Million mt Nutrients	1984/85 World, %	Annual Compound Growth Rate, %
Developed Countries	62.5	77	81.4	63	2.7
Developing Countries	18.5	23	48.2	37	10.1
TOTAL WORLD	81.0	100	129.6	100	4.8

* Does not include ground phosphate rock. Calendar year data for 1984 would be included with 1984/85. Totals may not add due to rounding. It should be noted that the 1974/75 consumption declined from the 1973/74 level because of high prices.

Source: FAO.

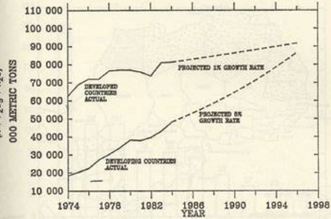


Fig. 16 - Total NPK consumption, 1974-84 (actual), 1985-96 (projected).

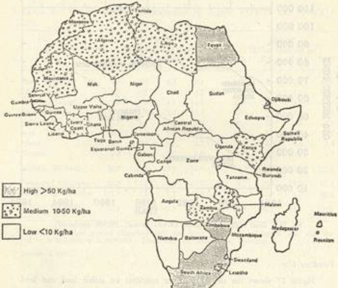
Fertilizer Use

Figure 17 shows the use of fertilizer nutrients on arable land and land under permanent crops for 1982. The average for all developing countries was 50 kg/ha. For Africa the figure of 19 kg of fertilizer nutrient used per hectare is misleading because Egypt (one of the world's heaviest users of fertilizer — 335 kg nutrient/ha) and South Africa together use more than one-half of all the fertilizer used on the continent.

Map 2 shows that most of food-deficit Africa has a very low level of fertilizer use; in fact, much of the little fertilizer used in these countries is used on export or industrial crops such as tea, coffee, cotton, sugarcane, oil, palm, etc.

The degree of efficiency of the fertilizer distribution and the crop marketing systems, crop and fertilizer price ratios, and national policy all affect the fertilizer use practices of the farmer who improves his production levels only as a response to economic incentives.

Reliable data on fertilizer use by individual crops are not generally available. The best available national level data from a developing country are from India. These data were established during a major statistical survey in the mid-1970s. Table 6 shows the areas of the major food crops of India, the percentage of each area that is irrigated, irrigated and nonirrigated yields, and finally the percentage of total national consumption of fertilizer nitrogen used on each crop. It is clearly seen that for rice, sorghum, millet, and maize, irrigation is essential for



Map. 2 - Africa: Map of fertilizer nutrient use per hectare of arable land and land in permanent crops, 1983. (*Source*: 1984 FAO Fertilizer Yearbook).

TABLE 6 - Major Food Crop Areas, Percent Irrigation, Yields, and Percent of National Use of Fertilizer Nitrogen by Crop (INDIA 1975-77).

Crop	Area			Yield			% Fertilizer N Used
	Total (million ha)	Irrigated (%)	Unirrigated (%)	Mean	Irrigated (kg/ha)	Unirrigated	
Rice	40.0	38	62	1,317	2,069	853	39
Wheat	21.2	62	38	1,477	1,694	1,095	27.6
Sorghum	16.3	5	95	726	2,461	632	1.6
Pearl millet	11.0	5	95	427	1,476	366	1.3
Maize	5.7	16	84	1,043	2,636	728	2.15

Source: FAO.

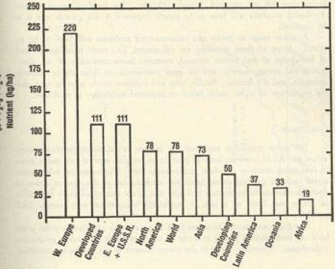


Fig. 17 - World: fertilizer use per hectare of arable land and land in permanent crops, 1982. (*Source*: FAO).

high yields. For the major irrigated rice area, the rice grown is mainly of the improved semi-dwarf type and is, therefore, very fertilizer responsive, which accounts for the high percentage of fertilizer nitrogen use on rice.

Wheat production, whether irrigated or not, is essentially based on improved varieties; it used 28% of the total fertilizer nitrogen consumed in India in the mid-1970s. Wheat and rice together account for two-thirds of the total fertilizer use in India.

Fertilizer Demand Projections

The increasing role of the developing countries in fertilizer production and consumption is expected to continue and, in fact, must continue if the rapidly growing population is to be adequately fed.

Potential growth rates of fertilizer demand in the developed countries appear to be less than 1% per year while for the developing countries growth rates higher than 5% are expected through 1995/96. The fertilizer sector of most developing countries will have to be greatly improved if this growth rate is to be exceeded.

A whole range of policy and infrastructural problems will have to be resolved. Many of these problems are self-created, i.e., tardy procurement, lack of knowledge of real farmer demand, excessive bureaucratization of the distribution and storage system, and the poor communication links among research, extension, and the farmer. Finally, crop and fertilizer prices must be such that the production of higher yields based on improved technology is profitable.

Conclusion

The green revolution exploited the modern cereal variety/fertilizer interaction and led to quantum leaps in production per unit area of two major crops in developing countries — wheat and irrigated rice. The impact on other major cereal crops of the tropics has been less marked, due in the case of maize to environmental and infrastructure problems and in the case of sorghum and millet in Africa and India to a lack of technology competitive with current SAT practices.

The important starchy root and fruit crops and the protein-rich pulse crops have not been affected greatly in terms of increased yields by modern production technologies. Therefore, many of the poorer farmers of the developing countries,

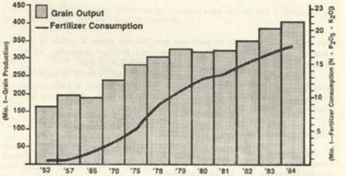


Fig. 18 - China: grain production and fertilizer consumption, 1952-84. (*Source*: Fertilizer International No. 214, October 31, 1985).

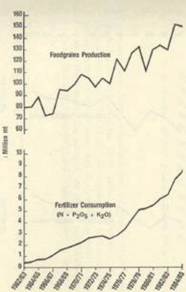


Fig. 19 - Fertilizer and food - India. (*Source*: FAO).

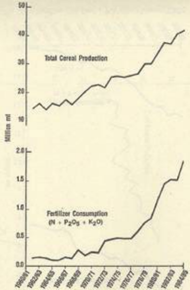


Fig. 20 - Fertilizer and food - Indonesia. (*Source*: FAO).

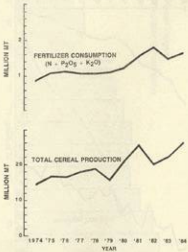


Fig. 21 - Fertilizer and food - Mexico. (*Source:* FAO).

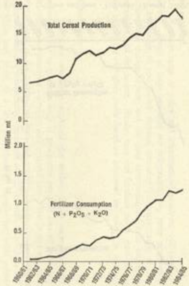


Fig. 22 - Fertilizer and food - Pakistan. (*Source:* FAO).

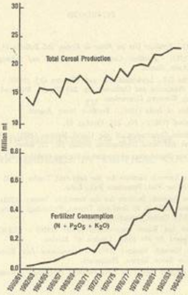


Fig. 23 - Fertilizers and food - Bangladesh. (*Source:* FAO).

who grow these crops, have not benefited from the green revolution. However, as Figures 18, 19, and 20 show, China, India, and Indonesia, whose joint population is almost two billion people, have exploited the modern cereal variety/fertilizer interaction to achieve major and absolutely indispensable advances in cereal output. Other outstanding examples are Mexico and Pakistan based on wheat (Figures 21 and 22, respectively) and Bangladesh based on rice and wheat (Figure 23).

REFERENCES

ALLAN A.Y. (1971) - *Fertilizer Use on Maize in Kenya.* Soil Bulletin 14, FAO, Rome.

DE GEUS J.G. (1973) - *Fertilizer Guide for the Tropics and Subtropics*, p. 75. Centre d'Etude de l'Azote, Zurich.

DOGGETT H., CURTIS D.L., LAUSCHNER F.X. and WEBSTER O.J. (1970) - *Sorghum in Africa.* In: *Sorghum Production and Utilization*, pp. 280-327, J.S. Wall and W.M. Ross (Eds.), Air Publishing, Westport, Connecticut.

Fertiliser Association of India (1985) - *Fertiliser News*, August.

Fertilizer International (1985) - No. 214, October 31.

Food and Agriculture Organization of the United Nations (1981) - *Agriculture: Toward 2000*, Economic and Social Developement Studies No. 23, Rome.

Food and Agriculture Organization of the United Nations (1984) - *FAO Fertilizers Yearbook 1984*, Rome.

International Crops Research Institute for the Semi-Arid Tropics (1982) - *ICRISAT in the Eighties: A 10-Year Plan*, Patancheru P.O., India.

International Crops Research Institute for the Semi-Arid Tropics (1984) - *Agrometeorology of Sorghum and Millet in 16 Semi-Arid Tropics*, Proceedings of the International Symposium, ICRISAT Center, Patancheru, India.

International Maize and Wheat Improvement Center (1980) - *CIMMYT Looks Ahead: A Planning Report for the 1980s*, Landres 40, Mexico.

International Rice Research Institute (1985) - *International Rice Research: 25 Years of Partnership*, Los Banos, Laguna, Philippines.

JOLY C. (1985) *Progress Report on FAO Fertilizer Programme Activities in Africa, 1984*, Rome.