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# The World Fertilizer Market

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The world fertilizer market has recently completed a second decade of almost uninterrupted expansion. Use of fertilizer nutrients is now over four times the 1950 consumption level and the market outlook continues to be one of promise. This chapter reviews the long-term effective demand for fertilizer, shows the past and present trends in both production and consumption, and indicates future market patterns. Some problems facing the industry in the next decade also are discussed.

## I. THE EFFECTIVE DEMAND FOR FERTILIZER

While many factors affect fertilizer use, the increasing world population and its pressure on food supplies is the primary determinant in evaluating long-term demand. With a projected world population growth of 1.8% per year, Notestein (1969), Brown (1963), Ewell (1964), FAO (1963), and others, have pointed out the imminent need for increased food production. Using 1962 as a base year, FAO (1969) has estimated that world population by 1985 will increase by 25% in the industrialized or developed regions of the world and by 60% in the developing regions of Asia (excluding Communist countries), Africa, and Latin America. While it is virtually impossible to forecast future population accurately, the direction of change and the order of magnitude indicated by these percentages suggest that the future fertilizer market must continue to expand merely to maintain existing nutritional levels and patterns of consumption.

Coupled with physical needs is the effect of increased income levels on total food supply. As spending power increases, some portion is used for diet improvement. While the effect is relatively modest when compared with the population factor (70% from population increase and 30% from improved in-



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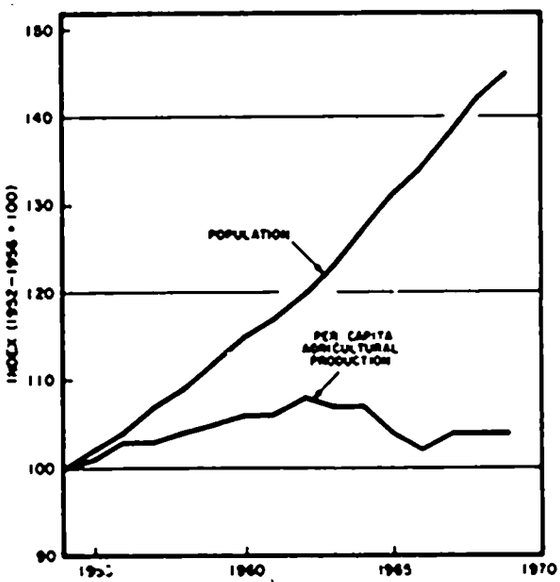



Fig. 1 – Population increase and per capita agricultural production in developing regions.

come levels in the developing nations), the result is that FAO estimates a growth in food demand in the developing regions of 142% over the period 1962 to 1985.

If these levels of food production are to be attained, a rapid up-turn in agricultural production will be needed. Figure 1 shows population growth over a 15-year period in the developing countries, along with agricultural production per capita. Although increases in agricultural production have averaged only 2.6 to 2.7% a year, a 4.3% increase will be needed to meet the 1985 projection. On a per capita basis, however, agricultural production has increased only 7% since 1954.

Increasing per capita food consumption will depend on the achievement of a balanced and growing economy at satisfactory rates of development to avoid a conflict between expectations and economic reality. Progress will be slow even with an exceptional growth in gross national product (GNP). Cochrane (1969) points out that a 50- to 100-year period would be needed on the average for countries whose per capita production of goods and services is now $100 to $150 to attain the 1966 average income level in Mexico of over $400.

Future development of the fertilizer industry will be determined by the effective economic demand for food and fiber and the resultant fertilizer requirements. Needs based on the attainment of a theoretically desirable nutrition level are not a true indicator of the future fertilizer market. Levels of fertilizer use depend on the individual farmer's response to the economic incentives of the market place. When these incentives do not exist, farmers will not approach the optimum use of fertilizer or accept new management ideas; this is

indicated by the insignificant use of fertilizer in subsistence agriculture, and by its extremely high use on cash crops such as tobacco and cotton.

Although continued expansion of the fertilizer market can be anticipated as food demands increase, the industry must recognize that the problem is not of short duration and make plans accordingly. Production additions should be in phase with the steady rise in demand rather than in great surges which lead to chaotic market situations such as occurred in the 1960's.

### A. Factors Contributing to Fertilizer Demand

In addition to the demand base established by population growth, other factors will contribute to the overall fertilizer market. Greater agricultural production will remove increasingly larger tonnages of plant nutrients from the soil. With agricultural land no longer available in unlimited quantities, a potential nutrient-demand base must be developed which will maintain soil fertility levels and crop production.

The amounts of plant nutrients removed by the harvested portions of different crops vary with plant composition, yield, and other factors; however, average values reported by Fried and Broeshart (1967) show the magnitude of the potential demand for fertilizer necessary to maintain soil fertility levels. Nitrogen removal can range from 40 to 286 kg/ha, P from 2 to 40 kg/ha, while K removal varies widely from as low as 4 to over 268 kg/ha. Table 1 illustrates the total nutrient removal by four of the world's major crops, based on 1967 harvested areas as reported by FAO (1969). These values do not take into account the high nutrient levels of many soils that can be "mined" for many years nor, conversely, the relatively poor recovery of nutrients under present cropping systems.

Adequate soil moisture is essential to good crop growth, and while fertilizer does not substitute for soil moisture, more efficient water use occurs at higher fertility levels. Irrigation helps insure adequate soil moisture; however, in many areas the capital costs are prohibitive unless large yield increases can be realized. Often irrigation without adequate fertilizer application and improved varieties is unprofitable because yield increases do not cover the additional costs. Yet, additional or expanded irrigation projects will be needed in many

Table 1—Plant nutrient removal by major crops

| Crop | World total harvested hectares | Average nutrient removal/hectare | | | Total nutrient removal |
|---|---|---|---|---|---|
| | | N | P | K | |
| | million ha | kg/ha | | | metric tons |
| Corn, grain | 106.7 | 106 | 18 | 17 | 15,044,700 |
| Wheat, grain | 221.9 | 58 | 11 | 11 | 17,752,000 |
| Rice | 128.8 | 43 | 11 | 8 | 7,985,600 |
| Cotton | 31.2 | 150 | 41 | 134 | 10,140,000 |
| Total | | | | | 50,922,300 |

areas if food requirements are to be met. These will lead to an expansion in the use of fertilizer.

Generalized response curves presented by Russel et al. (1970), indicate that yields of native varieties of rice and wheat begin to decline when applications of N exceed 50 kg/ha. Corn and sorghum yield little more when applications of N exceed 100–125 kg/ha. On the other hand, the new high-yielding varieties of wheat and rice continue to yield more up to N rates exceeding 150 kg/ha.

New varieties of corn and sorghum appear to require about the same amount of fertilizer as the native varieties; however, significantly higher yields are realized.

The effect of high-yielding varieties on long-term fertilizer demand has yet to be determined. In the early development stage, the introduction of improved seed and management practices likely will increase fertilizer demand; however, as these practices become more widespread, it may be possible to meet grain requirements by substituting well-fertilized, high-yielding varieties for land. Ultimate fertilizer demand will depend on total grain requirements, land area available, and rate of fertilization required to obtain desired goals.

Accurate land statistics are not available and little is know about additional potentially productive lands. One-fifth of the world's land is classified as agricultural, while only half of that area can be classified as arable (United Nations Ind. Develop. Organ., 1967). Obviously, with increasing population, it will be necessary to bring additional land under cultivation through irrigation, drainage, clearing forests, or reclamation. This potential will be limited, however, because of large capital outlays, and progress will be slow. Thus, as a short-term means of increasing food supply, this alternative is limited. In the long-run, however, expanding cultivated land areas must be considered.

Much has been written on substitution of fertilizer for land. With the rapid rise in land values, the general opinion is that applying more fertilizer to present land area is the more suitable alternative. Ibach (1966) notes that the 1960–64 USA level of crop production could have been obtained from 32 million fewer hectares by increased use of fertilizer. As long as marginal returns favor additional fertilizer use, substitution of fertilizer for land will continue.

### B. New Markets

There are other sources of potential fertilizer demand that could develop into a significant part of the overall fertilizer market. Forest fertilization research could eventually bear fruit for the fertilizer industry. While little economic justification is presently available, Malac (1968) reported a marginal rate of return exceeding 18% per annum from fertilization of a 14-year-old slash pine plantation.

Forest fertilization is relatively new in the USA, but several European countries have had extensive fertilizer programs for many years. Tamm (1968) indicates that forested acreage in Finland receiving fertilizer will double by

1975, reaching over 600,000 ha. He also reports that Sweden is planning consumption of 45,000 tons of N on forested lands, with one company increasing use from 3,400 tons of 15,000 tons in 1 year.

The Sulphur Institute (1969) indicates a potential fertilizer use of North American forests of 87,000 tons of N; 17,160 tons of P; and 19,920 tons of K. While relatively small in terms of the total fertilizer market, the growing demand for wood products, increasing land values and interest rates, plus other production costs make fertilization of forests a long-range possibility.

The Sulphur Institute (1969) has calculated that hay and pasture could represent 40% of the total potential fertilizer use in North America. Like forest fertilization, however, the growing use of fertilizer on hay and pastures represents a long-term potential. It will develop slowly because of present land availability and economic conditions. In Europe, however, hay and pasture land already accounts for a large percentage of the fertilizer market. In the Netherlands, for example, where average nutrient application rates exceed 500 kg/ha, fertilization of improved pastures is of primary importance.

Fertilization of hay lands, forests, and pastures is a prime example of the way in which economic factors influence fertilizer use. Although it has been demonstrated that fertilization increases yields in most instances, economic alternatives too often dictate a better use of capital for some other enterprise.

### C. Other Factors and Requirements

Input-output price relationships are important both to the farmer and to the fertilizer producer. Douglas (1968) calculated that a fertilizer price decrease of 50% resulted in a 20% increase in fertilizer use. Fertilizer demand is relatively inelastic because usage responds little to large price changes over a short time period. Although decreasing prices may mean use of a little more fertilizer by farmers, this will result in a lower net return to fertilizer retailers.

Government policy in developing countries can be a major stimulant to fertilizer use. A favorable economic climate is essential to encourage investment in production facilities. Too, credit must be available to the farmer, as well as a market for his products and assurance that prices will be relatively stable.

Beyond these, other obvious requirements are that transportation facilities and retail distribution, whether by private enterprise or government, must be adequate to supply the necessary fertilizers at the right time. Storage facilities are needed to avoid crop surpluses, which are disastrous to the producers, and food deficits, which are a hardship on the lower income groups.

Government-sponsored agricultural research programs must try to achieve a balance between those projects designed to answer immediate problems of increasing food production with those having a longer term significance. For example, our research and teaching institutions must be maintained if we are to have the professional personnel needed for research, education, and the operation of necessary services to insure orderly agricultural development. This has been well brought out by Johnston and Couston (1970).

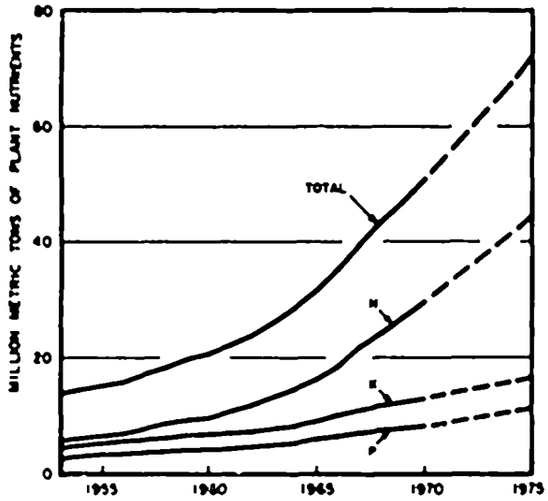



Fig. 2 - World plant nutrient consumption.

A sound fertilizer marketing system, from the basic producer, through the distributor, to the retailer and the farmer, is as essential to agricultural development as is the establishment of a marketing system to bring the farmer's product to the market place. These, together, provide the base for continued industrial progress and overall expansion of a country's total economy.

## II. WORLD FERTILIZER CONSUMPTION

According to FAO (1970), world fertilizer consumption in 1969 was approximately 47.0 million metric tons of plant nutrients. This represents a 15.4 million ton increase over 1965, and is 30 million tons more than consumed in 1955.

TVA (Harre et al., 1970) projections of use in 1975 (Fig. 2) indicate growth to almost 72 million tons, or slightly more than 50% over the 1969 level.

The world fertilizer market has been one of steady increase, exceeding an annual growth rate of 10% between 1962 and 1969. While an expanding market is anticipated for the next decade, annual growth is not expected to reach this level. Preliminary consumption for 1970 is 49.7 million metric tons, a 6% increase over 1969.

During the recent period of world market expansion, significant changes have occurred in nutrient use patterns in the major regions of the world. The following section discusses each of the major nutrients and indicates emerging regional use patterns.

Micronutrients are of major concern in many areas; however, their scattered use in small quantities makes the compilation of marketing data difficult. The USDA is attempting to obtain this information for the USA and has con-

Table 2—World N fertilizer consumption

| Year | North America | Western Europe | Eastern Europe | Oceania and Japan | Asia | Africa | Latin America | Communist Asia | Total |
|---|---|---|---|---|---|---|---|---|---|
| | million metric tons of N | | | | | | | | |
| 1955 | 1.83 | 2.10 | 0.92 | 0.56 | 0.43 | 0.18 | 0.25 | 0.24 | 6.51 |
| 1960 | 2.55 | 3.02 | 1.62 | 0.62 | 0.73 | 0.22 | 0.29 | 0.58 | 9.63 |
| 1965 | 4.38 | 4.28 | 3.37 | 0.80 | 1.36 | 0.51 | 0.74 | 0.96 | 16.39 |
| 1966 | 5.04 | 4.66 | 4.10 | 0.85 | 1.48 | 0.56 | 0.76 | 1.16 | 18.61 |
| 1967 | 5.74 | 5.02 | 4.76 | 0.96 | 1.96 | 0.55 | 0.86 | 1.96 | 21.83 |
| 1968 | 6.44 | 5.52 | 5.49 | 1.04 | 2.53 | 0.62 | 0.96 | 1.76 | 24.37 |
| 1969 | 6.59 | 5.87 | 6.33 | 1.09 | 2.87 | 0.68 | 1.09 | 2.29 | 26.81 |
| 1970* | 6.92 | 5.95 | 6.84 | 1.10 | 3.02 | 0.71 | 1.18 | 2.74 | 28.46 |
| 1975 (Est) | 9.87 | 7.47 | 11.41 | 1.26 | 5.63 | 1.29 | 1.70 | 4.68 | 44.04 |

* Preliminary.

ducted a survey (USDA, 1969) of the fertilizer industry for the last 2 years. Information is not yet sufficient for a comprehensive market review.

### A. Nitrogen Consumption Patterns

In terms of total tons of plant nutrients entering the fertilizer market, N is of primary importance. Presently, it represents 45% of total nutrient consumption. World N use, shown in Table 2, expanded from 6.5 million metric tons in 1955 to 26.8 million metric tons in 1969, an increase of over 300%. According to TVA projections (Harre et al., 1970), N use will exceed 44 million metric tons in 1975, a growth of more than 60%. It is apparent, therefore, that N will continue to increase in importance.

North America is the largest N consumer, followed closely by Eastern and Western Europe. These three regions account for over 18 million metric tons or 70% of the world N market. Consumption patterns in these regions vary widely, because each has followed a different path of agricultural development.

Nitrogen consumption in North America is centered around the direct application of anhydrous ammonia, N solutions, and solid ammonium nitrate, as shown in Fig. 3. Urea is a substantial part of the nitrogen market, with consumption primarily in N solutions. Complex fertilizers make up a relatively small percentage of the N demand. Due to larger and larger farming operations, farmers are moving steadily toward greater use of high analysis liquid N materials because of lower transportation, storage, and other costs per ton of nutrient.

In Europe, farms are smaller and greater amounts of N are applied in complex or mixed fertilizers. Solid ammonium nitrate and calcium ammonium nitrate also are primary N sources. While large quantities of solid urea are manufactured in the USA and Europe, much of this production has found its way into the export market.

Asia, including Japan, Oceania, and the Communist countries, represents another large N market. While N use in Japan and Oceania doubled in the last

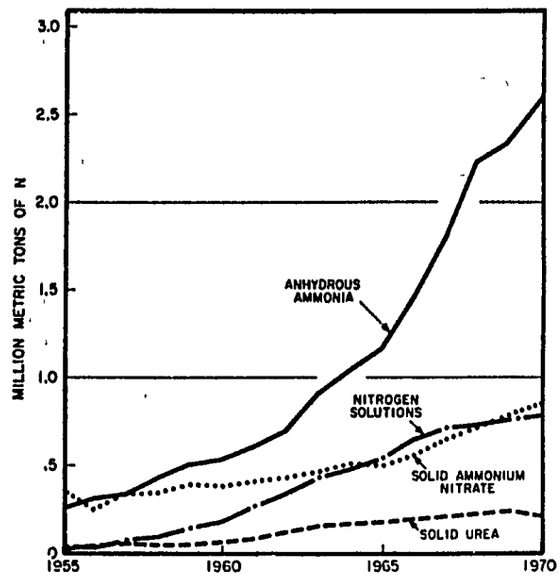



Fig. 3–Consumption of direct application N fertilizers in the USA.

15 years, much greater increases occurred in the other Asian nations. Use in Communist Asia increased over 850%, while the other nations had an increase of over 550%. Starting from a very low consumption level in 1955-60, Japan, Oceania, and Asia now account for 15% of the world market.

Because rice is a major world food crop, much market development has centered around ammonium sulfate, and more recently urea. Of the 3 million metric tons of N presently consumed by the Asian countries, urea accounts for almost half. Types of facilities presently under construction throughout this region indicate that urea will gain further in importance.

The world N product mix has been characterized by a steady growth in use of liquid N sources and a shift to urea as shown in Table 3. During the period 1954 to 1968, ammonium nitrates have held 25-30% of the total market, while ammonium sulfate declined from 33% to 16%. On the other hand, consumption of solid urea steadily increased, reaching 16% of the market in 1968, as opposed to 10% 5 years earlier, and 2% in 1955.

### B. Phosphorus Consumption Patterns

Although the increase in world consumption of P fertilizers has not been as rapid as for N fertilizers, growth has been steady, from 3.3 million metric tons in 1955 to 7.8 million metric tons of P equivalent in 1969. Actual use almost doubled in the 10-year period 1955 to 1965, and projected demand (Harre et al., 1970), as depicted in Fig. 7, shows that by 1975 total P consumption should double the 1965 level.

Table 3—Product share of world N production

| Year | Ammonium sulfate | Ammonium nitrates | Other solid N products* | Solid urea | Other† |
|---|---|---|---|---|---|
| | % | | | | |
| 1954 | 33 | 25 | 17 | - | 25 |
| 1955 | 33 | 27 | 15 | 2 | 23 |
| 1956 | 33 | 27 | 12 | 3 | 25 |
| 1957 | 31 | 28 | 12 | 2 | 27 |
| 1958 | 29 | 28 | 12 | 4 | 27 |
| 1959 | 29 | 27 | 11 | 5 | 28 |
| 1960 | 26 | 29 | 10 | 6 | 29 |
| 1961 | 25 | 29 | 9 | 7 | 30 |
| 1962 | 24 | 29 | 8 | 8 | 31 |
| 1963 | 22 | 30 | 6 | 9 | 33 |
| 1964 | 19 | 31 | 6 | 10 | 34 |
| 1965 | 19 | 29 | 5 | 11 | 36 |
| 1966 | 19 | 28 | 5 | 12 | 36 |
| 1967 | 17 | 26 | 4 | 13 | 40 |
| 1968 | 16 | 26 | 3 | 16 | 39 |

* Includes sodium nitrate, calcium nitrate, and calcium cyanamide.
† Includes anhydrous and aqua ammonia, nitrogen solutions containing ammonia, urea, and ammonium nitrate, ammonium phosphate and other complex fertilizers, and other N sources.

Similar to N, the consumption of P is centered in North America and the European countries. These regions accounted for almost 75% of the 7.8 million metric tons of P consumed in 1969 (Table 4). Australia and New Zealand are relatively large consumers of P fertilizers, while the developing regions account for much smaller tonnages.

The world P fertilizer market is made up of four major products, normal superphosphate, basic slag, concentrated superphosphate, and complex fertilizers. Its shift to the higher analysis materials is similar to the N market except that complex fertilizers are major carriers rather than single nutrient direct-application materials. These changes are shown in Table 5 where it will be observed that complex fertilizers have increased their market share from 26% in 1961 to 38% in 1968, while normal superphosphate declined from 48 to 40% during the same time, and basic slag declined from 14 to 7%.

A good example of the changing world product mix is reflected by P pro-

Table 4—World P fertilizer consumption

| Year | North America | Western Europe | Eastern Europe | Oceania and Japan | Asia | Africa | Latin America | Communist Asia | Total |
|---|---|---|---|---|---|---|---|---|---|
| | million metric tons of P | | | | | | | | |
| 1955 | 1.00 | 1.25 | 0.47 | 0.40 | 0.06 | 0.08 | 0.05 | 0.01 | 3.32 |
| 1960 | 1.13 | 1.54 | 0.70 | 0.52 | 0.10 | 0.10 | 0.07 | 0.03 | 4.19 |
| 1965 | 1.51 | 1.91 | 1.16 | 0.76 | 0.22 | 0.11 | 0.20 | 0.17 | 6.04 |
| 1966 | 1.71 | 1.93 | 1.29 | 0.81 | 0.22 | 0.16 | 0.20 | 0.20 | 6.53 |
| 1967 | 1.88 | 1.99 | 1.40 | 0.83 | 0.31 | 0.18 | 0.24 | 0.20 | 7.03 |
| 1968 | 1.94 | 2.10 | 1.53 | 0.81 | 0.43 | 0.21 | 0.28 | 0.20 | 7.49 |
| 1969 | 2.00 | 2.15 | 1.62 | 0.84 | 0.42 | 0.23 | 0.34 | 0.19 | 7.79 |
| 1970* | 1.98 | 2.28 | 1.77 | 0.82 | 0.46 | 0.23 | 0.34 | 0.27 | 8.15 |
| 1975 (Est) | 2.54 | 2.48 | 2.24 | 1.14 | 1.03 | 0.33 | 0.75 | 0.73 | 11.22 |

* Preliminary.

Table 5—Product share of world P production

| Year | Normal superphosphate | Concentrated superphosphate | Basic slag | Complex and other fertilizers |
|---|---|---|---|---|
| | % | | | |
| 1954 | 66 | 9 | 14 | 11 |
| 1955 | 63 | 12 | 15 | 10 |
| 1956 | 61 | 13 | 15 | 11 |
| 1957 | 58 | 11 | 16 | 15 |
| 1958 | 55 | 13 | 16 | 16 |
| 1959 | 54 | 13 | 15 | 18 |
| 1960 | 52 | 13 | 16 | 19 |
| 1961 | 48 | 12 | 14 | 26 |
| 1962 | 47 | 13 | 14 | 26 |
| 1963 | 46 | 12 | 13 | 29 |
| 1964 | 45 | 13 | 10 | 32 |
| 1965 | 41 | 14 | 12 | 33 |
| 1966 | 41 | 17 | 11 | 31 |
| 1967 | 42 | 16 | 7 | 35 |
| 1968 | 40 | 15 | 7 | 38 |

duction data (Harre, 1969) for the USA, as illustrated in Fig. 4. Note the steady decline in production of normal superphosphate and the rapid growth in complex fertilizers. (These include ammonium and diammonium phosphates.) Production of concentrated superphosphate also increased but not as rapidly as the complex fertilizers. Indications are that the latter are beginning to replace both normal and concentrated superphosphate, not only in the USA but also worldwide.

Five years ago world phosphate exports were made up of 30% basic slag, 17% normal superphosphate, and 26% each for concentrated superphosphate and complex fertilizers. In 1968 complex fertilizers accounted for 47% of all P entering world trade while the low analysis materials combined accounted for only 26% of the market.

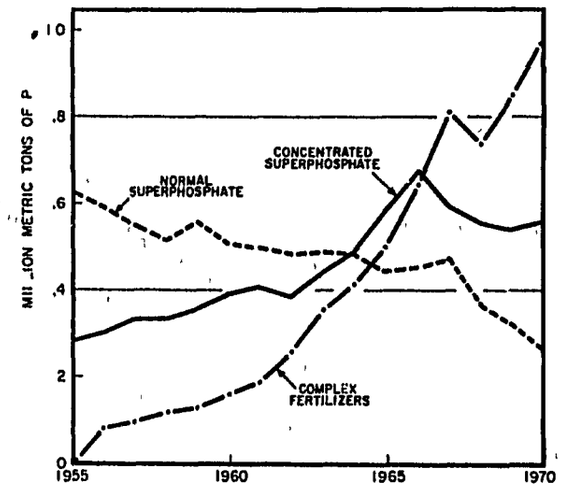



Fig. 4—Production of major phosphate fertilizer materials in the USA.

Table 6—World K fertilizer consumption

| Year | North America | Western Europe | Eastern Europe | Oceania and Japan | Asia | Africa | Latin America | Communist Asia | Total |
|---|---|---|---|---|---|---|---|---|---|
| | million metric tons of K | | | | | | | | |
| 1955 | 1.47 | 2.06 | 1.28 | 0.34 | 0.05 | 0.04 | 0.09 | 0.00 | 5.33 |
| 1960 | 1.69 | 2.71 | 1.56 | 0.49 | 0.10 | 0.06 | 0.11 | 0.01 | 6.73 |
| 1965 | 2.23 | 3.24 | 2.45 | 0.61 | 0.19 | 0.13 | 0.23 | 0.08 | 9.17 |
| 1966 | 2.54 | 3.26 | 2.99 | 0.65 | 0.25 | 0.14 | 0.26 | 0.10 | 10.19 |
| 1967 | 2.92 | 3.28 | 3.20 | 0.66 | 0.32 | 0.17 | 0.28 | 0.11 | 10.92 |
| 1968 | 3.07 | 3.53 | 3.49 | 0.67 | 0.44 | 0.17 | 0.32 | 0.12 | 11.81 |
| 1969 | 3.10 | 3.49 | 3.78 | 0.73 | 0.43 | 0.20 | 0.48 | 0.14 | 12.35 |
| 1970* | 3.16 | 3.75 | 4.07 | 0.74 | 0.45 | 0.20 | 0.50 | 0.25 | 13.12 |
| 1975 (Est) | 4.09 | 3.85 | 5.05 | 0.85 | 0.97 | 0.42 | 0.85 | 0.38 | 16.51 |

* Preliminary.

Ratios of N to P use vary widely with each region and between developed and developing regions. North America and Europe use relatively greater amounts of P than Asia which relies almost entirely on N. While Asia has a N/P ratio of almost 7:1, the ratio in North America and Europe is 3.2:1. Because of the small nitrogen use in Oceania the ratio of N to P is .34:1.

Projected demand estimates (Harre et al., 1970) for 1975 show that N use in North America and Europe will increase faster than P, resulting in N/P ratios approaching 4:1. Use of P in Asia, on the other hand, is expected to increase relatively faster than N, thus lowering the N/P ratio to 5.5:1. Africa should approach the same ratio found in the developed regions, while in Latin America use of P is expected to increase relative to N, giving a projected 2.2:1 ratio.

### C. Potassium

Potassium fertilizer consumption reached 12.4 million metric tons of K in 1969, almost twice its use in 1960. Projected demand (Harre et al., 1970) for 1975 indicates an increase of 4 million metric tons over 1969. Of the 12.4 million tons consumed in 1969 almost 60% was used in Europe. North American consumption was slightly over 3.0 million metric tons, while the developing regions of Asia, Africa, and Latin America accounted for only 1.0 million tons. Although use in these areas will double by 1975 (Harre et al., 1970), to around 2.0 million tons, with minor increases in other developing regions, it is obvious that potassium markets will continue to be concentrated in the developed areas (Table 6).

## III. WORLD FERTILIZER PRODUCTION AND FUTURE SUPPLY

Annual increases in fertilizer consumption have followed a relatively smooth path with only minor short-term deviations from the growth curve. Fertilizer supplies, on the other hand, have followed a sawtooth pattern with

alternate periods of shortage and oversupply. As producers attempt to anticipate changes in demand, the supply line reflects their view of future market developments.

As a result, a different type of market analysis is needed to anticipate future production of fertilizer and to relate supplies to anticipated effective demand. The methodology used to estimate future supply revolves around estimated total production capacity and the resultant fertilizer production capability.

In this discussion, capacities for those materials that contribute directly to plant nutrient production are considered. For example, N capacity is based primarily on anhydrous ammonia. Phosphorus capacity is based on normal superphosphate, phosphoric acid, the contribution of phosphate rock to concentrated superphosphate production, and the P content of nitric phosphates and other complex fertilizers not derived from any of the above products. Potassium chloride is the primary potassium product considered.

To determine estimated production capability certain conditions such as operating efficiency, production losses, start-up delays, and allowances for industrial demands must be assumed. Assumptions will vary for each nutrient, and must be adjusted to reflect the industrial development and technical manpower levels of a country or region. The values obtained are an indication of total supply that would be available at any level of installed capacity. Market conditions, unexpected downtime, inventory build-up, and other factors will determine the actual production level.

The National Fertilizer Development Center at Muscle Shoals, Alabama, has been studying world fertilizer supply-demand relationships since 1965. Findings were reported by Kennedy et al. (1968) and later revised and updated (Harre et al., 1970). These findings show that world production exceeds consumption by 4% to 6% per year, and that handling losses, overformulation, increasing inventory requirements, and unreported consumption contribute to this gap. The ratio between production capability and actual production is more difficult to determine and is assumed to be 90% of the capability. In determining the supply-demand relationship, a ratio of 1.16 to 1.18 implies a balanced market assuming a zero net trade level. Table 7 indicates the ratio of world estimated production capability to consumption of N, P, and K.

The following discussion reviews past production trends, future supplies, and their relation to estimated demand levels of N, P, and K. While not reviewed in detail, a discussion of phosphate rock and sulfur is included because of their importance to the world fertilizer markets.

Table 7—Ratio of estimated world fertilizer production capability to consumption

| Year | N | P | K | Year | N | P | K |
|---|---|---|---|---|---|---|---|
| 1965 | 1.24 | 1.12 | 1.28 | 1970 | 1.22 | 1.32 | 1.37 |
| 1966 | 1.19 | 1.16 | 1.19 | 1971 | 1.23 | 1.33 | 1.37 |
| 1967 | 1.15 | 1.24 | 1.17 | 1972 | 1.22 | 1.35 | 1.38 |
| 1968 | 1.15 | 1.28 | 1.10 | 1973 | 1.17 | 1.29 | 1.43 |
| 1969 | 1.18 | 1.31 | 1.23 | 1974 | 1.10 | 1.22 | 1.41 |
| | | | | 1975 | 1.03 | 1.16 | 1.35 |

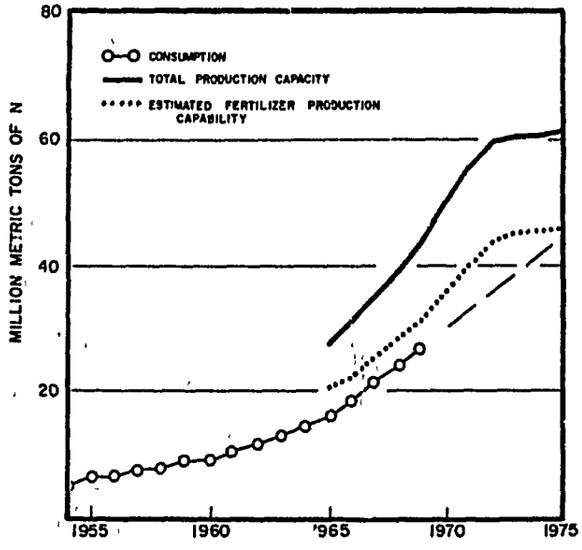



Fig. 5—World N supply-demand relationship.

### A. Nitrogen Supply

Beginning in 1964-65 the world N industry started an expansion program that in 10 years will result in a capacity of over 60 million metric tons of N, or more than double the available capacity in 1965. Most of this capacity is scheduled for completion by 1972. Thus, even with the expected large demand increase, supply will be increasing faster than demand. This capacity level will result in a production capability of over 45 million metric tons by 1975. The ratio of production capability to consumption by 1975 indicates that demand increases may justify further additions to capacity. For intervening years 1970-73 indications are that the industry overestimated effective demand and will be faced with an increasing ratio of production capability to consumption. This means continuing heavy inventories, closing obsolete facilities, or operating the relatively new 1,000-tons-per-day units at levels below full capacity. Using the suggested 1.16-1.18 ratio as an indicator of a supply-demand balance, it now appears that by 1973 N markets will stabilize. Rapid demand increases for N, however, dictate careful evaluation of market conditions to insure that supply levels do not move from a surplus to a shortage position within one or two seasons. Figure 5 shows the world N supply-demand relationship based on capacity additions, production capability estimates, and anticipated demand increases.

The world increase in N capacity began in North America with a net addition of 3 million metric tons in 1965-66. Figure 6 shows that between 1966 and 1972 another 4.5 million metric tons will be added, bringing the total in-

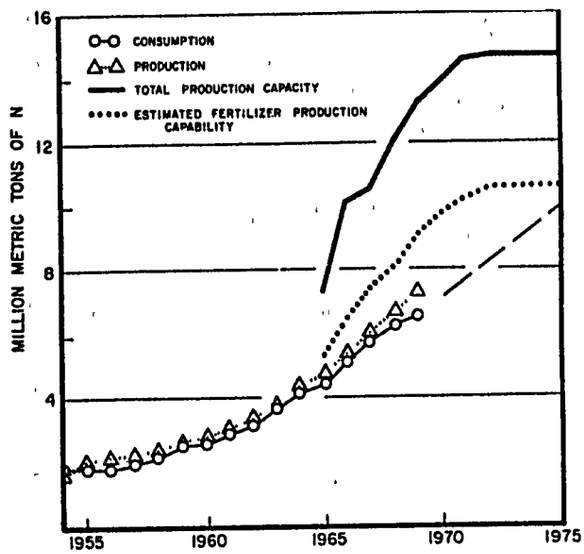



Fig. 6—Nitrogen supply-demand relationship in North America.

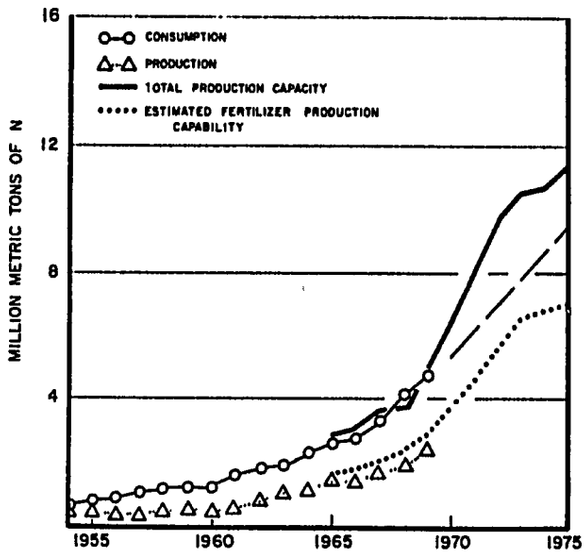
stalled capacity to almost 14.7 million metric tons. Assuming no change in the percent of production capability entering world trade, a N supply-demand balance should be achieved by 1973.

Western Europe, too, is in the midst of a large N expansion. Although producers there added 2.3 million metric tons of capacity between 1965 and 1969, they will add 2.7 million tons in 1971. Total N capacity by 1975 will exceed 15 million metric tons, resulting in production capability of almost 11 million metric tons of N. Projected market demands will not equal this additional supply; thus, Western Europe will need to increase its participation in the export market or adjust production levels downward.

Japan, now exporting half of its N production capability, has steadily increased N capacity while demand increases have been relatively small. By 1975, a production capability to consumption ratio of 2.61 is expected. This indicates a severe oversupply situation unless export markets are expanded rapidly.

The developed regions as a whole will have a capacity of over 48 million metric tons of N by 1975, or 80% of total world N capacity. Their production capability will exceed 37 million metric tons while consumption is estimated at 30 million metric tons. About 12% of the N production capability of the developed regions has been exported to the developing regions, including Communist Asia. Although unlikely, should this level of export be continued through 1975, the developed regions could achieve a balanced N market.

Competition in world N markets will be increased, however, because the developing regions will make a significant gain in their ability to produce their own fertilizer. In the last 5 years, these regions were able to produce only 60-70% of their total consumption. In 1967, a building program began in these




*EXCLUDING COMMUNIST ASIA

Fig. 7—Nitrogen supply-demand in the developing regions.

regions that will be largely completed by 1973–75. At that time their capability will reach about 80% of their projected consumption levels. Figure 7 shows that the developing regions presently have a total N capacity roughly equal to total demand, Capacity is projected to increase rapidly, indicating an improving production capability. With increased efficiency in existing plants and the projected new facilities, the developing regions will be much closer to achieving a production level approaching their demand, thus lessening their dependence on world trade.

Self-sufficient production is not necessarily a desirable goal for all developing countries. Depending on location, raw material supplies, and level of agricultural and industrial development, careful economic evaluation of all possible alternatives should be made before the projects are undertaken.

### 1. UREA IMPORTANT

In the current round of N capacity expansions, urea has been of primary importance. It is expanding faster than any of the other N products, especially in the developing regions. Table 8 shows urea's share of the total market in 1967 and 1970, with estimates for 1975. Note that the developing countries of Asia will be the major producing areas by 1975, with over 4.6 million metric tons of N capacity. This region will rely heavily on urea as its primary N source since urea capacity in 1975 will represent more than 65% of the total N capacity for the region. Latin America also will rely heavily on urea in the future, moving from a current share of 20% to almost 40% of total capacity by 1975.

Table 8—Urea capacity for selected regions and percent of total N capacity

| Region | Urea capacity and % of total N capacity | | |
|---|---|---|---|
| | 1967 | 1970 | 1975 |
| | million metric tons of N | | |
| North America | 1.49 (14.2%) | 2.14 (15.4%) | 2.26 (15.4%) |
| Western Europe | 1.29 (12.3%) | 2.46 (17.1%) | 2.85 (18.8%) |
| Japan and Oceania | 0.99 (40.6%) | 1.56 (43.2%) | 1.94 (42.4%) |
| Asia* | 0.83 (44.8%) | 2.06 (57.6%) | 4.62 (65.7%) |
| Latin America | 0.17 (16.0%) | 0.37 (19.7%) | 1.21 (39.9%) |

* Excludes Japan and Communist Asia.

In North America and Western Europe, urea capacity has increased steadily; however, very little change in the market share has taken place. With the rapid increase in urea exports from North America and Western Europe, it is evident that much of the production from the capacity buildup between 1967 and 1970 entered the export market.

Urea technology has advanced rapidly in the last few years. Large production units are now commonplace and unit costs of production have been reduced sharply. Because urea is a high-analysis product, with relatively low unit transportation and distribution costs, plus the fact that it can be used either as a solid, or solution, or as an intermediate in producing compound fertilizers, it offers obvious advantages over certain other N sources.

It appears obvious that the fertilizer industry will concentrate on products such as urea, which yield the greatest benefits from the integration of the production, transportation, and marketing systems that will develop in the next decade.

## B. Phosphorus Supply

In relation to demand changes, the recent expansion in the world phosphorus industry was more drastic than that for N. The ratio of world P production capability to P consumption shown in Table 7, has been climbing steadily from a low of 1.12 in 1965. It should reach a peak of 1.35 by 1972. After 1972, effective demand increases should exceed added supply, thus bringing about a balanced market by 1975.

Trends in world P consumption are shown in Fig. 8, and by regions of the world in Table 4. World consumption in the last 4 years has increased from 6 million metric tons of P to 7.8 million metric tons in 1969, an increase of 30%. Total production capability moved, however, from 6.8 million metric tons to over 10.2 million metric tons, a 50% increase, during the same period. By 1975, total P capacity will reach almost 16 million metric tons resulting in a production capability of 13 million metric tons, or 27% above the 1969 level. Consumption in 1975 is expected, however, to be only about 11.2 million metric tons of P.

It is possible that world P markets may achieve a balance somewhere between 1975 and 1980. As noted previously, there has been large-scale sub-

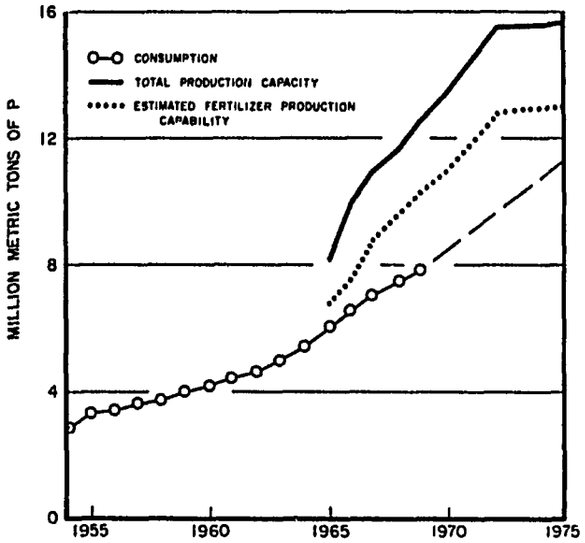



Fig. 8—World P supply-demand relationship

stitution of high-analysis complex fertilizers for normal superphosphate. Many normal superphospahte plants are relatively old and are being closed or rebuilt to produce complex fertilizers using wet-process phosphoric acid produced at the phosphate rock mine site. If this substitution continues, the future production capability of the industry could approach the demand line sooner than presently indicated.

North America will have installed 4 million metric tons of P capacity by 1970. With no additions scheduled after this, the P supply-demand picture could move slowly toward equilibrium. North America has a net P export balance which accounts for over 60% of all P trade by developed regions. Over 13% of the production capability in 1968 entered world trade. As shown in Fig.9, if North America maintains this favorable trade balance and current restraints on production, the market will tend to stabilize by 1973. Taking all factors into account, it is doubtful if any additional capacity will be required for several years thereafter.

Figure 9 illustrates the relationship between actual production and estimated production capability. In 1969, the estimated production capability in North America exceeded 2.97 million metric tons; however, in response to inventory build-up and decreased exports, production was curtailed by 8% of 1968 output, to a level of 75% of production capability. Actual production levels are determined by market conditions, while the capability estimates indicate the maximum supply possible.

Present capacity additions in Western Europe appear to be adequate to meet regional demand and world trade requirements with no oversupply projected. Large ratios of production capability to consumption are expected in the East European countries. Oceania will also have excessive supply levels as

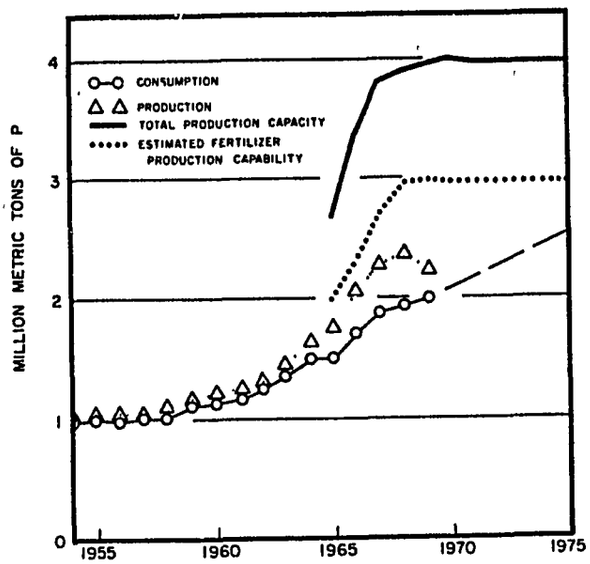



Fig. 9—Phosphorus supply-demand relationship in North America

demand for P appears to have leveled off during the 1965-69 period while capacity additions continued. Under present growth trends, the increase in demand is not expected to bring the market back into balance until after 1975.

The developing regions, excluding Communist Asia, have a total capacity exceeding demand estimates. Their production capability is within 10% of expected consumption; however, production efficiency has been very low, requiring large imports of P. Unless operating levels can be improved, the developing regions will continue to be net importers of P.

Africa is the only developing region having a production capability for P that exceeds its consumption level. Phosphate rock is an important natural resource and Africa is a leading rock exporter. Phosphorus capacity has been scheduled at the mine sites in Africa that will be capable of producing large tonnages of finished P materials or intermediates for export to other developing regions or to Europe.

### 1. CHANGING PRODUCT MIX

With the expansion of N facilities in the developing regions, a shift in the export product mix for P fertilizers may be forthcoming. While the complex fertilizers, containing both N and P, have the major share of the market at the present time, concentrated superphosphate may increase in importance as a carrier for P because the developing nations will produce their N requirements.

Exports of phosphoric acid or superphosphoric acid for the manufacture of complex fertilizers in developing regions using domestically produced N has begun to appear on the world scene. Waitzman et al. (1968) reviewed the economics of this alternative under varying sulfur and export prices and found that

Table 9—Wet-process phosphoric acid capacity for selected regions

| Region | Wet-process phosphoric acid capacity | | |
|---|---|---|---|
| | 1967 | 1970 | 1975 |
| | million metric tons of P | | |
| North America | 2.43 | 2.51 | 2.49 |
| Western Europe | 0.98 | 1.11 | 1.28 |
| Eastern Europe* | 0.09 | 0.23 | 0.41 |
| Oceania | 0.07 | 0.07 | 0.07 |
| Asia† | 0.34 | 0.58 | 1.00 |
| Africa | 0.19 | 0.23 | 0.33 |
| Latin America | 0.04 | 0.25 | 0.25 |
| Total | 4.14 | 4.98 | 5.83 |

* Excludes USSR. † Excludes Communist Asia.

processing phosphate rock at the mine site and exporting either finished products or intermediates had economic advantages for the developing regions. Also, a large-scale wet-process phosphoric acid plant located in Mexico recently started production for export. Elemental P also has been evaluated as an intermediate for fertilizer production in developing regions. Scott et al. (1968) determined, however, that economic advantages existed only under a unique set of circumstances, including high sulfur costs.

Whether imported or obtained from domestic sources, wet-process phosphoric acid is gaining in importance in the world fertilizer market. Capacity data for selected regions, listed in Table 9, indicate a shift to phosphoric acid as a basic material in P fertilizer production. Total capacity, excluding Communist countries, has increased from 4.1 million metric tons P in 1967 to 5 million tons at the present time. By 1975, new capacity of almost 1 million tons P is scheduled for completion, bringing the total of the free world to 5.8 million metric tons P from wet-process phosphoric acid, or a 48% share of the total P capacity for the regions listed.

## 2. PHOSPHATE ROCK

A discussion of the phosphate fertilizer industry is not complete without a review of the supply situation for phosphate rock. As depicted in Fig. 10, world production of phosphate rock has increased at a rapid rate, going from 31 million metric tons of material in 1955 to an estimated 78 million metric tons in 1968. The USA supplied over 40% of the total world market, while Africa and Russia each accounted for 25%. The remainder was supplied by the Near East, Pacific Islands, and Communist Asian countries.

Windridge (1968) estimated that world requirements for phosphate rock by 1970 would approach 90 million metric tons. Capacity estimates shown in Fig. 10 indicate an adequate supply of phosphate rock to meet these needs and allow for future growth in the use of phosphate fertilizers. In 1965, USA producers had a total production capacity of 27 million metric tons, while world capacity approached 71 million metric tons. By 1970, the USA had added over 19 million metric tons bringing the total capacity to 46 million metric tons.

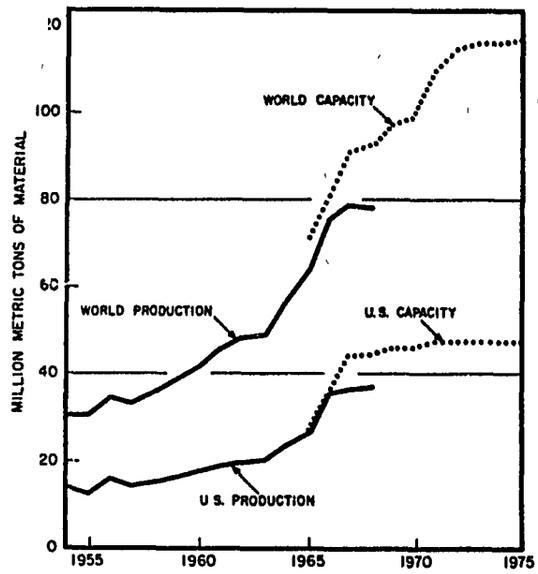



Fig. 10–Phosphate rock production and future production capacity.

During this time, world capacity has grown to almost 100 million metric tons, or 10 million above estimated demand.

Further expansion in capacity is expected to raise world phosphate rock capacity to a level between 117 and 130 million metric tons, depending on completion dates of several new mining projects presently under various stages of development. As shown in Fig. 10, USA capacity in 1975 will exceed 47 million metric tons. Present USA phosphate rock capacity of 46 million metric tons of material exceeds total world production of just 10 years ago.

World reserves of phosphate rock reported by Sweeney and Hasslacher (1970) show that the USA has 33% of the known world phosphate rock resources, ranking second to Morocco which has more than 40%. Phosphate rock deposits are found throughout the world; however, few are of economic importance. Of the 20.4 billion metric tons of known P reserves, 92% is located in the USA, North Africa, and USSR. New projects under development in Australia, Peru, Colombia, Spanish Sahara, and India will add substantially to phosphate rock production insuring adequate supplies for many years to come.

### C. Potassium Supply

It is expected that the world potassium industry will be faced with a continuing overcapacity situation for the next 5 years. While the percent increase in K capacity over the last 10 years has been the same as P, the expected demand increase for K will not be as great. Demand for K in 1969 was 12.4 million metric tons and is expected to exceed 16.5 million metric tons by 1975.

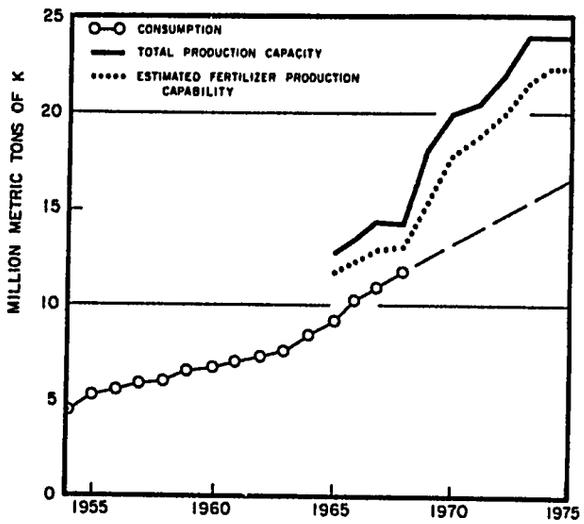



Fig. 11—World K supply-demand relationship.

Additions to be completed by 1973 will give a capacity of 24.0 million metric tons, resulting in an estimated production capability of 22.3 million tons, almost 6 million over expected demand. As a result of this rapid build-up between 1969 and 1975, the ratio of capability to consumption for K will remain between 1.35 and 1.43, as shown in Table 7. Although some improvement will be made in the market situation after 1973, as observed in Fig. 11, a balanced supply-demand situation is not anticipated during the 1970-75 period.

Three regions, North America, Western Europe, and Eastern Europe, produce almost all of the world's supply of K. The remaining production is centered in the Near East and Africa. As a result of the concentration of production areas, approximately half of all K produced enters world trade, mostly between developed countries since K demand in the developing regions is still small. If expansion plans materialize by 1975, it is expected that the Eastern European nations will be leading K producers with North America ranking second. Western Europe, with an expected capacity of 4.4 million metric tons by 1975, will have half the capacity level expected in Eastern Europe or North America.

In only 8 years, Canada has emerged as a major K-producing area. Although K was first discovered there in 1943, development of Canadian reserves did not begin until 1952, with large-scale production following 10 years later. Present capacity exceeds 4.8 million metric tons of K, almost double the USA capacity. The supply-demand relationship of K for North America is shown in Fig. 12. Note that capacity will reach 8.6 million metric tons by 1972, and that no new additions are planned beyond that year. The spread between production and consumption indicates the change in North American exports from 12% of capability in 1965 to 20% in 1968.

Even though the demand for K in North America is expected to reach 4.1 million metric tons by 1975, this will not be enough to offset supply increases.

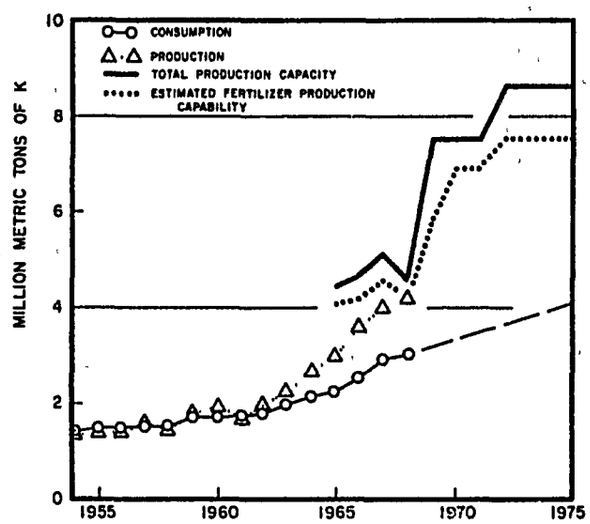



Fig. 12—Potassium supply-demand relationship in North America.

The serious oversupply situation in 1967 and 1968 led to financial losses for K producers as prices fell to levels that did not cover costs. Action taken by the Government of the Province of Saskatchewan early in 1969, setting a production quota for each producer and establishing a price floor for the industry, resulted in supply being brought more nearly in line with demand. It will be many years, however, before production again approaches installed capacity levels.

### D. Sulfur Supply and Demand

Even though S is not considered one of the primary plant nutrients, it is nevertheless vital to the fertilizer industry. About half of the world's S consumption is used to produce P fertilizers and ammonium sulfate or for direct application. Sulfur can be produced by Frasch mining of sulfur domes, recovery from sour natural gas or refinery gas, or processing pyrites of gypsum. Stack gases contain sulfur dioxide which, if recovered, will be an important source of S in the future.

World production of S in 1969 was 29 million metric tons, made up of over 18 million metric tons from elemental S production and almost 11 million metric tons from pyrites. Frasch sulfur production in the USA and Mexico accounted for 8.6 million metric tons or half of all elemental S produced. Frasch production, however, has been losing its share of the S market due to large increases in recovered sulfur production in recent years. With the decline in Frasch production and with another large increase in recovered S production, Lancaster (1970) pointed out that 1970 marked the first time in the history of the industry that recovered S production exceeded Frasch production.

The USA, Canada, France, and more recently the oil-rich countries of the Near East, have been expanding facilities to recover S from sour natural gas. As a result of this rapid expansion plus the weak demand for P fertilizers, the S industry has moved from a period of serious shortage with rising prices, to a period of oversupply, with sharp price declines.

The higher price levels of the last few years brought many new producers into the market, and also resulted in the development of new S recovery processes. Expected high returns on investment stimulated exploration and several new S deposits were developed. As a result, S supplies appear adequate for the next few years, especially if recovered sulfur from pollution-abatement programs is considered in the long-term supply picture.

The growth in world S production is shown in Fig. 13 along with production levels for North America, including Mexico. In 1967, recovered S production in Canada was 2 million metric tons, double the production level of 1963. A review of S capacity at the present time shows that the USA has about 11 million metric tons of Frasch capacity presently installed with another 2.5 million metric tons available in Mexico. Recovered S capacity totals 3.5 million metric tons in the USA and 5 million metric tons in Canada Since sour-gas recovery plants produce S as a byproduct of natural gas production, capacity data do not reflect actual production levels. Generally, these units have been operating at about 50% of capacity because markets have not been available for natural gas. Future increases in natural gas demands in the USA and Canada indicate that larger tonnages of S may be forthcoming from Canadian producers in the next few years.

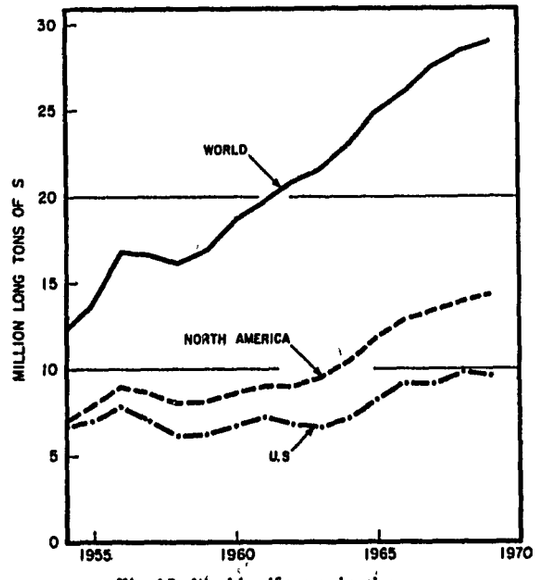



Fig. 13—World sulfur production.

## IV. THE DEVELOPING NATIONS

FAO (1966) estimates that world population will reach almost 4 billion people by 1975. Of this total, 2.8 billion, or 72%, will be located in the less-developed regions. In 1965, these regions were estimated to have 68% of the total. Due to the rapid population growth in these regions, the concentration of population will continue to shift away from the more developed regions, meaning that the less-developed regions must increase food production or rely more heavily on food imports.

The developing regions are attempting to increase food production as indicated by the growth in fertilizer use compared to the developed regions—16% vs. 9% per year. Although the ....ensity of fertilizer use in the developing regions is now only about 20% of the average application rate in the developed nations, this represents a sharp increase from the 10% level in 1955. A steady increase in the developing regions' share of the world fertilizer market has occurred and is forecast to continue. In 1965, the developing regions used 14.5% of the world's fertilizer. In 1969, this had increased to almost 19%, and by 1975 will approach more than one-fourth of the world market.

Current fertilizer use in the developing regions, excluding Communist Asia, is 6.8 million metric tons of plant nutrients. One country, India, has over 20% of the total demand for the developing regions. Six countries, India, Brazil, Mexico, South Africa, South Korea, and Cuba, account for over half of the total fertilizer demand, while only 15 countries represent 75% of the market.

A closer look at the locations of the developing countries making up the largest share of the market gives some indication that environmental conditions may have an effect on the level of fertilizer use. The six primary consuming countries are located on latitudes 25° to 30° from the equator (Brazil appears to be an exception, however. Its major consuming area is in the southern part of the country.). With the exception of Colombia and several island nations, this is also true for the remaining nine countries which account for 75% of fertilizer use in the developing regions.

Because fertilizer production is only about 50% of apparent consumption, the developing regions have been forced to import large amounts of fertilizers. Production facilities have been built in some of the developing nations and, as a whole, reliance on imported materials has declined somewhat from the 70% level of 1960.

To meet expected demands for fertilizer, a building program was started in the developing countries in 1966-67. This will raise total capacity from 3.6 million metric tons of plant nutrients in 1965 to over 14.4 million metric tons by 1975. While progress has been slow and delays frequent, the increasing level of domestic production has enabled the developing countries to maintain a production capability ratio of .61 to .67 during the years 1965 through 1969. If present schedules can be met, the projected production capability ratio could reach as high as .75 to .90 for the years 1970-75 (Ratios are for N and P only. K production is limited in developing regions from lack of minable reserves.).

Self-sufficiency is not necessarily a desirable goal for all developing countries. Delivery of the product to the farmer at minimum cost should be a primary consideration in determining whether to import or to produce fertilizer. Economic factors may encourage world trade with the developed regions or other developing countries, especially for countries whose demand levels, either present or future, do not justify a large-scale production complex. Some supply-demand imbalances will continue to exist because certain countries with abundant natural resources have planned production facilities far in excess of future demand requirements. As a result, competition for fertilizer markets will increase. Market programs and establishment of adequate distribution systems are of highest priority if the developing regions expect to achieve a high level of plant operation efficiency.

### A. Industrial Development Relationship

Development of a sound fertilizer industry contributes to overall economic progress in developing countries but should not be independent of their overall industrialization program. Basic materials available from other industries can be utilized by the fertilizer industry and many fertilizer materials have industrial applications. For example, ammonia, ammonium nitrate, urea, phosphoric acid, and some ammonium phosphates are used as industrial chemicals. The oil and natural gas industries are a primary source of hydrogen and sulfur feedstocks as a byproduct of hydrocarbon processing. The mining industry can be a substantial source of sulfuric acid. Steel mills and caprolactam plants produce either ammonium sulfate or ammonium phosphates as byproducts. The integration of the fertilizer industry with other industries should not be overlooked as, in many cases, a more efficient use of resources can be achieved.

Even though developing nations will meet more of their own fertilizer needs by domestic production, the role of the developed nations need not diminish with respect to assisting in agricultural development. This role, suggested by Douglas (1967), is made up of four overlapping stages of exporting: (i) food, (ii) fertilizer, (iii) technology and know-how, and (iv) raw materials.

The first step, supplying food for immediate short-term needs while development programs are started, and the fourth stage, supplying raw materials for fertilizer production, need no further explanation. The second stage, which should begin with the export of food, is the provision of finished fertilizer materials for farmers to use in growing next year's crops, thus stimulating fertilizer market development, and building a demand base. As these programs develop, imports satisfy demand until a level that justifies plant construction either to produce basic materials or fertilizers based on imported intermediates is reached. Then, the third stage of assistance begins—design, construction, and management assistance for production facilities. Domestic production will then lessen dependence on imported finished products. An idealized illustration of the interaction of stages 2 and 3 is shown in Fig. 14.

As production levels approach demand, it may be economically advantage-

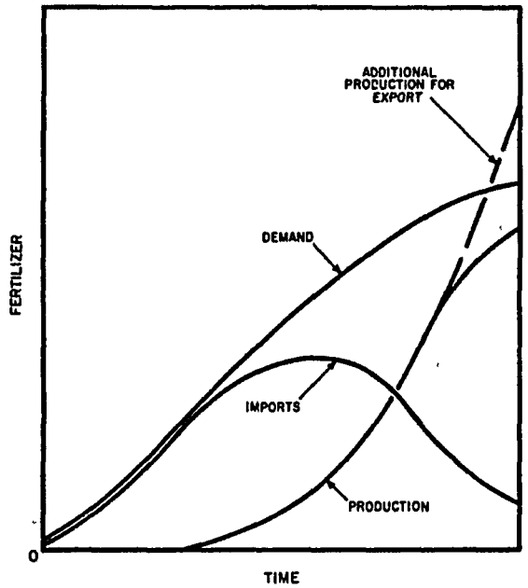



Fig. 14—Stages of development in the fertilizer industry.

ous to continue importing certain finished goods or intermediates; thus imports may not cease altogether. On the other hand, an export market may exist and production capability increase beyond demand, as illustrated by the broken line in Fig. 14. It should be pointed out, however, that the justification of production facilities should be based primarily on domestic demand and not anticipated export markets. Domestic market development should have priority unless a unique comparative advantage for trade exists for the individual country.

### B. Economic Evaluation of Alternatives

The increased competitiveness expected in the world fertilizer market raises the possibility that a favorable investment climate may not be possible in the developing countries because of lower-priced imports. Only a complete economic evaluation of all alternatives should determine what course of action is to be followed. Trade barriers or tariffs offer protection to the domestic producers; however, they may inflate the price of fertilizer enough to remove the economic incentive for farmers to use it. Agricultural production would decline requiring greater food imports, thus using more foreign exchange than if fertilizers had been purchased on the world market.

It may be, however, that a country having a unique set of natural resources for fertilizer production, such as natural gas, phosphate rock, sulfur, or potassium, can utilize these by the production of finished fertilizers or intermediates for export. Production costs along with transportation charges to prospective

importing nations, and income generated from these facilities, may encourage resource development. Trade agreements between countries may also be a way to satisfy demand with little foreign exchange requirements.

Regional production has been suggested as a way to achieve maximum efficiency in the fertilizer industry. Plants would be gigantic and located at the raw material sources. Large-scale ocean transport would move the products to the countries sharing in the investment. While the prospects of economic efficiency seem readily apparent, the social and political problems are great. Relatively few countries have the raw materials or capital necessary to participate, and trade agreements would be one-sided in many cases. Only where all countries could achieve some advantage would regional production be workable. The establishment of common market organizations may help foster the establishment of regional production units.

### E. Marketing and Distribution Patterns

Along with rapid advances in fertilizer production technology, certain marketing and distribution patterns also have undergone significant changes. Douglas and Coleman (1968) have discussed some of the changes in distribution of mixed fertilizer in the USA brought about because existing channels could not be adapted to handle new types of fertilizers. Granular materials, bulk blending, and liquid mixing are now familiar terms, although relatively new to the industry. Vertical and horizontal integration has changed the market structure as producers moved to secure captive markets for the output from their high investment, large-scale production facilities. Fertilizer producers still are attempting to match gains in marketing efficiency with their recent large-scale gains in production efficiency.

The developing regions cannot afford to concentrate solely on achieving greater production efficiency by installing new, modern plants. They must expend an equal effort, if not a greater one, in developing a marketing and distribution system capable of delivering the right materials to the right place at the right time. Transportation, storage, and investment costs for marketing facilities are equal to, or can exceed, investment in production facilities (Pres. Sci. Advis. Comm., 1967).

Short-term credit is an absolute necessity or most farmers in the developing regions cannot approach the recommended usage of fertilizers. Low-cost credit is an essential part of the marketing system and should be provided primarily by reliable credit institutions. Credit also is required to cover inventory and to provide working capital for both producer and distributor.

The objective of the marketing and distribution system is to get fertilizer into use by the farmer. To accomplish this, educational and technical service must be a part of the system. Programs must be taken to the farmer until he begins to seek out the advice and services that are available. Adequate capital must be made available for providing the physical production facilities and the market system. The future demand estimates presented earlier in this chapter

assume that conditions will be favorable for both public and private investment and that required financing will be available. Without a healthy investment climate, including minimum risk of expropriation, satisfactory return on investment, and a cooperative effort by all individuals involved, these estimates will far exceed actual fertilizer use, and food shortages of major consequences will follow.

The increase in fertilizer and agricultural productivity in the developing countries will have an impact on the agricultural sector and the fertilizer industry of the developed nations. Imported fertilizers will be a small portion of the developing regions' supply and their requirements for imported food grains should diminish. In some cases, agricultural exports from the developing regions may find their way into world markets and trade balances will change. It appears that many developing countries are moving into the third phase of the development cycle.

The future role of the developed regions will be one of providing greater technical assistance rather than greater quantities of food and fertilizer. Training of the large number of technicians needed for technical and engineering assistance can be a major contribution to the development process. Through the efforts of both developed and developing countries, the world fertilizer market can build a firm base from which progress can continue and the challenges of the future can be met.

## LITERATURE CITED

Brown, L. R. 1963. Man, land and food: looking ahead at world food needs. USDA, Foreign Agr. Econ. Rep. no. 11, Washington, D. C.

Cochrane, Willard. 1969. The world food problem. Crowell, New York. 331 p.

Douglas, J. R., Jr. 1967. U. S fertilizer industry's opportunity in fulfilling world fertilizer needs. Fert. Solutions 10(1):75-77

Douglas, J. R., Jr., and R. Coleman. 1968. Distribution and marketing of fertilizers. p. 67-84. *In* L. B. Nelson (ed.) Changing patterns in fertilizer use. Soil Science Society of America, Madison, Wis.

Douglas, J. R., Jr., J. H. Parker, and E. A. Harre. 1968. Need for analyzing fertilizer production and distribution costs. Commer. Fert. 117(3):18-26.

Ewell, Raymond. 1964. Famine and fertilizers Chem Eng. News 42(50):106-117.

Food and Agriculture Organization of the United Nations. 1963. Third world food survey. FFHC basic food study no. 11. FAO, Rome.

Food and Agriculture Organization of the United Nations. 1969. Production yearbook. FAO, Rome. 825 p.

Food and Agriculture Organization of the United Nations. 1969. Provisional indicative world plan for agricultural development. Vol. 1, August. 327 p.

Food and Agriculture Organization of the United Nations. 1970. Monthly bulletin of agricultural economics and statistics. 19(2):12-14.

Fried, Maurice, and Hans Broeshart. 1967. The soil-plant system in relation to inorganic nutrition. Academic Press, New York. 358 p

Harre, Edwin A., et al. 1970. Estimated world fertilizer production capacity as related to future needs 1970 to 1975. TVA, Muscle Shoals, Ala.

Harre, Edwin A. 1969. Fertilizer trends—1969. TVA, Muscle Shoals, Ala.

Ibach, Don B. 1966. Fertilizer use in the United States, its economic position and outlook. ERS, USDA, Washington, D. C.

Johnson, Sherman E., and John W. Couston. 1970. High-yielding varieties in the strategy of development. Mon Bull. Agr. Econ. Statist. 19(2):1-8.

Kennedy, F. M., et al. 1968. Estimated world fertilizer production capacity as related to future needs 1967 to 1972-80. TVA, Muscle Shoals, Ala

Lancaster, J. M. 1970. Outlook for sulphurous raw materials. Fert. News 15(10).17-20.

Malac, Barry F. 1968. Research in forest fertilization at Union Camp Corporation. p. 203-208. *In* Forest fertilization, theory and practice. TVA, Muscle Shoals, Ala.

Notestein, Frank W. 1969. Population growth and its control. p. 9-39. *In* Overcoming world hunger. The American Assembly, Columbia Univ , New York

President's Science Advisory Committee. 1967. The world food problem. Vol. 3, p. 95-118. U. S. Government Printing Office, Washington, D. C.

Russel, D. A., et al 1970. High-yielding cereals and fertilizer demand TVA, Muscle Shoals, Ala.

Scott, W. C , et al. 1968. Economic and technical evaluation of overseas shipment and utilizaof elemental phosphorus for fertilizer production. TVA, Muscle Shoals Ala.

Sulphur Institute, The. 1969. Potential plant nutrient consumption in North America. The Sulphur Institute, Washington, D. C.

Sweeney, J. W , and K N Hasslacher. 1970. The phosphate industry in the southeastern United States and its relationship to world mineral fertilizer demand. USDI, Bureau of Mines, Washington, D. C

Tamm, C. O 1968. The evolution of forest fertilization in European silviculture. p. 242-247. *In* Forest fertilization, theory and practice. TVA. Muscle Shoals, Ala

United Nations, Department of Economic and Social Affairs 1966 World population prospects as assessed in 1963. UN, New York Population study no. 41. 149 p

United Nations Industrial Development Organization. 1967 Fertilizer manual UNIDO, New York 218 p.

United States Department of Agriculture. Statistical Reporting Service. Crop Reporting Board. 1970 Consumption of commercial fertilizers in the U S., fiscal year ending June 30, 1969. USDA, SpCr(5-70), Washington, D C.

Waitzman, D. A., et al 1968. Economic evaluation of overseas shipments and utilization of phosphoric acid for fertilizer production TVA, Muscle Shoals. Ala.

Windridge, K. L. C. 1968 Phosphate rock: trends in supply and demand in relation to world requirements in 1970. p. 330-339. *In* Fertilizer Production, Technology, and Use. United Nations, New York.