World Production of Phosphate Rock

Phosphate rock is the only economical source of P for production of phosphate fertilizers and phosphate chemicals. Most of the U.S. and world phosphate rock resources are widely distributed marine phosphorite deposits.

Phosphorus (P) is a vital resource for sustaining world agriculture. Reserves of phosphate rock are identified in many regions of the world.

Identified reserves and reserve bases of this vital resource are shown in **Table 1**. Morocco has the greatest reserves, followed by South Africa and U.S. China's reserves may be much greater than indicated and could rank as high as fourth in the world.

Phosphate rock is produced in some 40 countries, but 12 countries account for 92 percent of the world's production (**Table 1**). Approximately 144 to 150 million tons of phosphate rock were produced annually between 1995 and 1997. Igneous deposits in Russia, Brazil, and the Republic of South Africa accounted for about 17 million tons of production in 1997. The remaining production (about 133 million tons or 89 percent) was from sedimentary deposits.

The U.S. is the world's leading producer, with about 33 to 34 percent of total production, followed by China, Morocco and Russia. In 1996, 10 U.S. companies operated 18 phosphate rock mines in four states. Florida and North Carolina produced about 86 percent of the marketable phosphate rock with the remaining production coming from Idaho and Utah.

Total capacity of the phosphate rock industry in the U.S. is 56 million tons, with mines currently operating at about 90 percent of capacity.

Phosphate rock production in the U.S. surpasses domestic needs, and the excess is exported to international markets. Domestic

TABLE 1. World phosphate rock reserves, reserve bases, and production.

Countries	Reserves	Reserve base	Production 1995	Production 1996	Production 1997
	million tons		thousand tons		
United States (U.S.)	1,300	4,900	47,937	50,031	51,023
Brazil	360	410	3,890	3,967	4,408
China	230	230	23,142	23,142	24,244
Israel	200	200	4,477	4,188	4,298
Jordan	100	630	5,492	5,896	6,061
Kazakstan			2,424	551	551
Morocco and Western Sahara	6,500	23,100	22,260	22,922	23,142
Russia		1,100	9,698	9,367	9,367
Senegal		180	1,763	1,763	1,763
South Africa	2,800	2,800	3,075	2,975	2,975
Togo		70	2,204	2,865	2,865
Tunisia		300	8,166	7,824	7,934
Other countries	1,100	2,800	10,019	11,130	11,020
World total (rounded)	**12,600**	**36,700**	**144,362**	**146,566**	**149,872**

Reserve and reserve base cost less than $36/ton and $90/ton, respectively. Cost includes capital, operating expenses, taxes, royalties, and a 15 percent return on investment, FOB mine.

consumption was about 46.3, 48.2 and 46.8 million tons in 1995, 1996 and 1997, respectively. The Republic of Korea, Japan, and India were the top importers of U.S. phosphate rock in 1996.

Mining of phosphate rock in the U.S. and elsewhere is accomplished mainly by strip mining techniques. Shaft mining is practiced at one mine in Montana.

Apatite in several different forms is the basic P compound in commercially important deposits of phosphate rock. Phosphorus in apatite minerals is only slightly soluble and of limited availability to crops. However, reactive phosphate rock and partially acidulated phosphate rock are satisfactory sources of P for crops grown on some acid tropical soils.

Acidulation or heat treatment of phosphate rock is usually necessary to break the apatite bond to render the contained phosphate more soluble. Wet process sulfuric acid acidulation is the most commonly used technique for improving the agronomic suitability of phosphate rock. The majority of finished P-containing materials used in North American agriculture are made from wet process phosphoric acid. Phosphoric acid is made from the reaction of sulfuric acid with phosphate rock.

Wet process orthophosphoric acid is often further concentrated by evaporation of water to form superphosphoric acid. In this process, two or more orthophosphate molecules combine to form polyphosphate compounds. These polyphosphate products are well suited for the manufacture of clear liquid fertilizers.

Phosphate materials widely used in modern crop production systems are listed in **Table 2**, with both P and P_2O_5 concentrations expressed as percent. Some of these products supply other essential plant nutrients including nitrogen (N), calcium (Ca), and sulfur (S).

For many years, normal or ordinary superphosphate was the predominant phosphate fertilizer. Because of relatively low analysis and high shipping and handling costs, it has been largely replaced by higher analysis, more economical sources such as concentrated superphosphate and ammonium phosphates.

TABLE 2. Concentration of P in phosphate products.

Material	Concentration, % P	Concentration, % P_2O_5
Superphosphoric acid	30-35	68-80
Wet process phosphoric acid	23-24	52-55
Concentrated superphosphate	20	46
Diammonium phosphate	20-21	46-48
Monoammonium phosphate	21-24	48-55
Normal superphosphate	7-10	16-22
Phosphate rock	12-18	27-41

TABLE 3. Top 10 states in P_2O_5 consumption, 1996-1997

State	P_2O_5 Consumption, thousand tons
Illinois	444
Iowa	320
Minnesota	294
Texas	242
Nebraska	212
California	208
Indiana	202
Kansas	196
Missouri	187
North Dakota	183
Total in U.S.	**4,613**[1]

Source of data: Association of American Plant Food Control Officials (AAPFCO) and The Fertilizer Institute (TFI).
[1]Note: The original value published was 4,569, later corrected upward to 4,613 thousand tons.

Consumption of fertilizer phosphate in the U.S. increased steadily from the early 1960s, peaking at a high of approximately 5.2 million tons annually during the 5-year period

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Courtesy of Potash Corporation of Saskatchewan Inc.

Most phosphate rock mining in the U.S. is by strip mining methods.

another as new cells are formed. Large quantities of P are found in seeds and fruit where it is believed essential for seed formation and development.

Phosphorus is also a component of phytin, a major storage form of P in seeds. About 50 percent of the total P in legume seeds and 60 to 70 percent in cereal grains is stored as phytin or closely related compounds. An inadequate supply of P can reduce seed size, seed number, and viability.

Nutrient Transport

Plant cells can accumulate nutrients at much higher concentrations than are present in the soil solution that surrounds them. This allows roots to extract nutrients from the soil solution where they are present in very low concentrations.

Movement of nutrients within the plant depends largely upon transport through cell membranes, which requires energy to oppose the forces of osmosis. Here again, ATP and other high energy P compounds provide the needed energy.

Phosphorus Deficiency

Adequate P allows the processes described above to operate at optimum rates and growth and development of the plant to proceed at a normal pace.

When P is limiting, the most striking effects are a reduction in leaf expansion and leaf surface area, as well as the number of leaves. Shoot growth is more affected than root growth, which leads to a decrease in the shoot-root dry weight ratio. Nonetheless, root growth is also reduced by P deficiency, leading to less root mass to reach water and nutrients.

Generally, inadequate P slows the processes of carbohydrate utilization, while carbohydrate production through photosynthesis continues. This results in a buildup of carbohydrates and the development of a dark green leaf color. In some plants, P-deficient leaves develop a purple color, tomatoes and corn being two examples. Since P is readily mobilized in the plant, when a deficiency occurs the P is translocated from older tissues to active meristematic tissues, resulting in foliar deficiency symptoms appearing on the older (lower) portion of the plant. However, such symptoms of P deficiency are seldom observed in the field...other than loss of yield.

Other effects of P deficiency on plant growth include delayed maturity, reduced quality of forage, fruit, vegetable, and grain crops, and decreased disease resistance. BC

World Production... *(continued from page 5)*

1975 to 1979 (**Figure 1**). Consumption declined to an average of 4.3 million tons yearly during the 1985-1989 period, but has since begun increasing, averaging about 4.5 million tons since 1995.

Illinois led the U.S. in phosphate consumption in 1997, followed by Iowa, Minnesota and Texas (**Table 3**). Others in the top 10 consuming states included Nebraska, California, Indiana, Kansas, Missouri, and North Dakota. These 10 states accounted for 55 percent of U.S. phosphate consumption.

Canadian consumption of fertilizer phosphate followed similar trends to the U.S., but reached a high of 798,164 tons of P_2O_5 in 1985 (**Figure 1**). Consumption declined to 637,175 tons in 1991, but has since increased to 775,370 tons in 1997. About 75 percent of Canada's phosphate consumption occurs in the prairie provinces (Alberta, Manitoba and Saskatchewan). BC

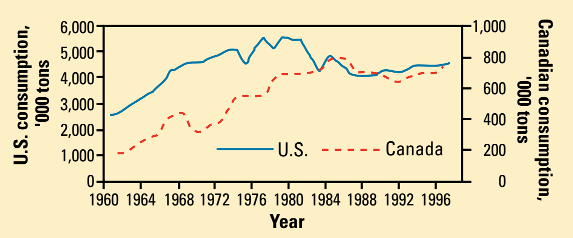

Figure 1. Consumption of P_2O_5 in North America.