

## DIRECT APPLICATION OF PHOSPHATE ROCK (DAPR)

### Phosphate rock

All plants and animals require phosphorus (P), an essential macronutrient. The major source of phosphorus is phosphate rock (PR), a phosphate-bearing mineral which is a finite and non-renewable natural resource. Phosphate rock is the primary raw material for producing soluble P fertilizers. It can be applied directly and can solubilize in the soil, making the P available to crops depending on the type of rock, soil properties, climatic conditions, crops/cropping systems, and nutrient management practices. Direct application of phosphate rock (DAPR) is an alternative fertilization option that can contribute to sustainable intensification of agriculture, particularly in developing countries with suitable PR resources and agro-ecological conditions.



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### Determining the suitability of phosphate rock for direct application

#### *Type/source of apatite and solubility characteristics*

The chemical, physical and mineralogical/crystallographic characteristics of the phosphate rock determine its suitability for direct application. The phosphate compounds in PR are in the form of apatite, which is not water soluble. Therefore, the P content is not directly available to plants. There are two main types of apatite: igneous and sedimentary. According to United States Geological Survey (USGS) estimates of world phosphate rock reserves (Mineral Commodities Summaries, USGS 2012), the highly soluble sedimentary deposits in North Carolina (USA), Sechura (Peru) and Tunisia make up about 1% of the world's reserves, while low-solubility igneous rock and metamorphosed sedimentary phosphate rocks make up approximately 10% of the world's listed reserves. The remaining 89% of the world's PR reserves would be in the range of medium to medium/high solubility, which may make them suitable for direct application.

Various chemical-extracting solutions have been used to estimate the solubility of PR and its potential for direct application. The most common extracting solutions are neutral ammonium citrate (NAC), 2% citric acid and 2% formic acid (Table 1).

The solubility of the PR in the different extraction media aids in classifying its potential effectiveness, but should not be used to evaluate the amount of plant-available P and its agronomic effectiveness

**Table 1. Classification of phosphate rock (PR) for direct application by solubility in aqueous media (extracting solutions) and potential initial response.**

	Potential response NAC	Solubility (% P <sub>2</sub> O <sub>5</sub> )*	
		2% citric acid	2% formic acid
High	>5.4	>9.4	>13.0
Medium	3.2-4.5	6.7-8.4	7.0-10.8
Low	<2.7	<6.0	<5.8

*\*The phosphorus content expressed as a percentage (by weight) measured as P<sub>2</sub>O<sub>5</sub>, the anhydride of phosphoric acid.*

*Source: Diamond, R.B. 1979. Views on marketing of phosphate rock for direct application. In IFDC, ed. Seminar on phosphate rock for direct application. Special Publication SP-1. Muscle Shoals, USA, IFDC.*

as these depend on a range of factors. Rock solubility varies greatly around the world and even within a single mine, depending on where the samples were collected. Table 2 shows the solubility spectrum of phosphate rocks provided by the International Fertilizer Development Center (IFDC), based on known deposits around the world. In general, younger deposits that have not been deeply weathered, such as the sample collected from the continental shelf off Khouribga in Morocco, would tend to have higher solubility (Table 2).

## Factors affecting agronomic effectiveness

### *Soil properties*

The potential for applying phosphate rock directly on soils varies in each location. PR dissolution is favoured by soil properties such as increasing soil acidity, high cation exchange capacity (CEC), low levels of calcium and phosphate in the soil solution, and high organic matter content. Generally, DAPR is recommended in soils with pH 5.5 or less, such as tropical and subtropical soils which are predominantly acidic and are often deficient in P. Soils of medium phosphate status are considered more suitable for DAPR than severely phosphate-deficient soils.

### *Crop species*

Perennial plantation crops such as oil palm and rubber are responsive to DAPR. However, DAPR is less effective for short-season crops in temperate regions, particularly during the first year of application.

### *Management practices*

DAPR should be finely ground and should be incorporated in the soil to promote dissolution. Fine grinding leads to coverage of more surface area and higher solubility. Potential users should be aware that DAPR must be applied way in advance before planting since it is slowly soluble.

### *Socio-economic conditions*

In many developing countries, addition of P to the soil is necessary for intensification of agricultural production. However, in many of these countries water soluble P fertilizers are often imported and are expensive for poor farmers. DAPR is a cheaper alternative that can be explored to facilitate access to fertilizers by poor smallholders.

**Table 2. Solubility of apatite in selected phosphate rocks from various sources (IFDC, 2013, unpublished data).**

PR type and origin	Phosphorus content as P <sub>2</sub> O <sub>5</sub> (wt. %)	Solubility		
		NAC2*	2% citric acid	2% formic acid
<i>Sedimentary origin</i>				
Negev (Israel)**	33.0	5.2	11.0	18.0
North Carolina (USA)	29.9	7.0	13.9	23.0
Sechura (Peru)	29.3	7.0	16.0	23.0
Gafsa (Tunisia)	29.0	6.4	12.2	22.2
Khouribga (Morocco)	31.7	5.2	11.0	17.8
Abu Tartur (Egypt)	27.3	5.1	10.7	8.9
El-Hassa (Jordan)	33.3	4.0	16.0	23.0
Central Florida (USA)	32.0	3.9	7.5	8.3
Hahotoe (Togo)	37.0	2.7	7.1	7.0
Parc W (Niger)	28.7	1.9	6.6	5.4
Mussoorie (India)	18.6	1.3	0.6	0.7
<i>Igneous origin</i>				
Araxa (Brazil)	36.1	1.5	4.9	3.7
Dorowa (Zimbabwe)	33.1	1.5	4.2	3.8
Phalaborwa (South Africa)	39.5	1.1	2.3	1.6

\*NAC<sub>2</sub> is a second sequential extraction procedure with neutral ammonium citrate (NAC) to eliminate the effects of free carbonates which suppress dissolution of the PR during the first extraction with NAC. This method has been used by IFDC for over 25 years.

\*\* Negev, Israel PR, known as 'Arad' in Brazil, data is from Dr. Vieira of Agroconsult Projectors, Brazil.

The main perceived cost advantage of DAPR over processed phosphates consists in low capital investment, low processing costs, low use of raw materials, and low energy use for processing. DAPR would not prove to be economically advantageous compared with processed, highly water soluble P fertilizers as regards transportation costs per tonne of nutrient, especially if the phosphate rock was transported long distances.

## A model to predict the agronomic effectiveness of PR

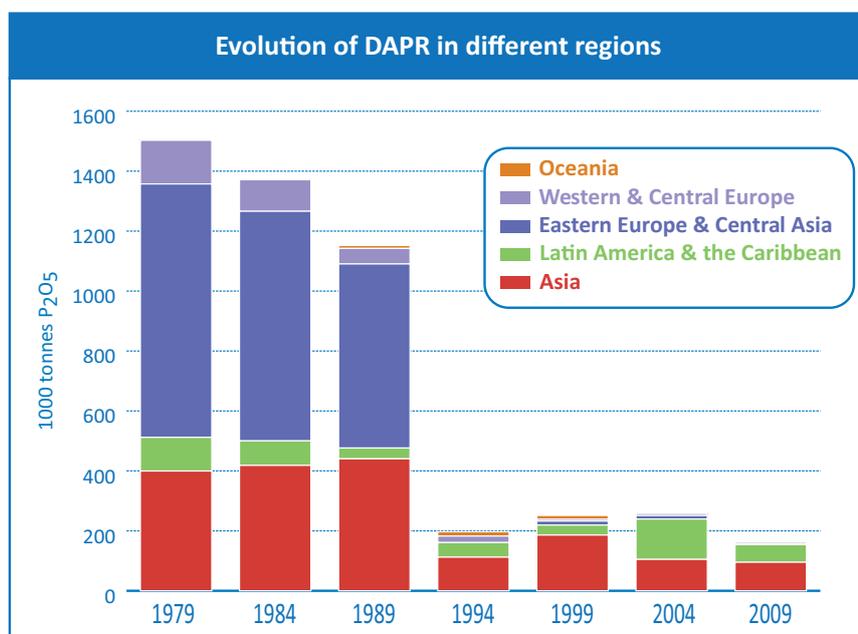
A mathematical model, the phosphate rock decision support system (PRDSS,) has been developed to predict the relative agronomic effectiveness of PR with respect to water soluble phosphorus (WSP). To use the PRDSS, information is needed on soil pH, the source/origin of the PR, and the species of crop to be grown. The PRDSS predicts whether a given PR at a specific site is a good substitute for water soluble P fertilizers. More information on the PRDSS can be found at the FAO/IAEA/IFDC Direct Application of Phosphate Rock website: [www-iswam.iaea.org/dapr/srv/en/daprIntroduction](http://www-iswam.iaea.org/dapr/srv/en/daprIntroduction).

## DAPR evolution in different regions

The use of DAPR varies around the world (Figure 1). DAPR as a percentage of total phosphate fertilizers used has decreased globally, from about 5 per cent in the 1970s to less than 1 per cent since the beginning of the 1990s (IFADATA, 2012). Restructuring of the former Soviet Union and the resulting economic conditions severely affected demand for DAPR in Russia and several other countries. In China, liberalization of trade and rapid growth of production capacity for high-analysis phosphate fertilizers has led to a massive reduction in the use of DAPR. Even in Brazil (probably

the highest recorded user of PR for direct application), the use of DAPR has fallen because of environmental restrictions in the unloading of finely ground PR and the increasing availability of water soluble P sources like SSP, TSP and MAP.

Nevertheless, in tropical regions DAPR has proved highly effective in treating weathered, high P-fixing soils. Studies in these countries have shown that there is no difference in effectiveness between water soluble phosphate fertilizers and DAPR under conditions in specific countries (i.e. Malaysia and Indonesia) with high acreages of oil palm and other tree crops and tropical acidic soils.



## Summary and recommendations

Replenishing the soil with necessary macronutrients, including phosphorus, is imperative in intensive agriculture to avoid nutrient mining and soil degradation. The decision to promulgate the use of DAPR as an alternative P source is a complex one that involves consideration of various factors and their interactions. Furthermore, many of the world surveys of phosphate rock deposits should be reassessed in more detail due to considerable changes in the technology and economics of mining and processing.

In developing countries where farmers are poor, such as in Sub-Saharan Africa, indigenous alternative sources of plant nutrients, which may be cheaper, are sought over imported fertilizers. In principle, DAPR should be recommended where reactive phosphate rock resources are available locally for use in acidic soils, on responsive crops, and when economic returns outweigh those of using water soluble phosphorus.

Use of DAPR worldwide is currently negligible, as large-scale production of high-analysis water soluble P fertilizers has brought the delivered costs of these materials down to the point that DAPR has little cost advantage. Furthermore, granular P fertilizers are much easier to handle and apply to the soil than the fine particle phosphate rock.

**Feeding the Earth** represents a series of issue briefs produced by the International Fertilizer Industry Association to provide current information on the role of fertilizers in sustainable agriculture and food production.