Welcome!

This information booklet is designed for extension officers and field workers who work with NGOs, CBOs, research institutions or national extension departments and participate in the *Rocks for Crops Project*. We hope this information will also be useful for others working with farmers' groups; we encourage you to share and distribute this resource.

This booklet is a follow-up to the first booklet "Phosphorus for Agriculture", which emphasized the importance of phosphorus for agriculture. Here, we explore an alternative phosphate fertilizer - *phosphate rock* - and its potential for improving soil fertility on smallholder farms. We will look at the factors that influence the performance of phosphate rock in agriculture. We describe the advantages and limitations of using it. This resource provides extension officers with information about the range of available phosphate rock products and recommendations for application procedures.

Our goal is to provide you with clear information that can be used in your work with farmers. There are many technical papers on phosphate fertilizers, and we have included some important papers in the references for those who want additional information. Also, please feel free to contact us should you have any questions.

We hope that this information package is a useful tool for you!

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Phosphate Rock Fertilizer

An Alternative Nutrient Source for Smallholder Farmers in Africa

Introduction

In order to grow healthy crops, there must be enough available mineral nutrients in the soil. One of the most important mineral nutrients is phosphorus (P). Plants need a P source that is both soluble and reactive. Many of the soils in Africa suffer from serious phosphorus deficiencies due to naturally poor soils and the intensification of agriculture (see the "Phosphorus for Agriculture" booklet for more information). Farmers can add organic matter to increase the amount of plant-available P in the soil, but organic matter usually doesn't contain enough P to improve deficient soils. Farmers can increase P content in the soil by supplementing organic sources of P with inorganic chemical fertilizers like MAP, DAP or

TSP.[1] Alternatively, they can choose a phosphate rock fertilizer.

Phosphate rock (PR) is defined as *"naturally occurring materials containing one or more phosphate minerals with chemical characteristics that make it acceptable for commercial use as a source of phosphate."*[2] In other words, it is a phosphate product that comes from rocks that is just as good as human-made sources of phosphate.

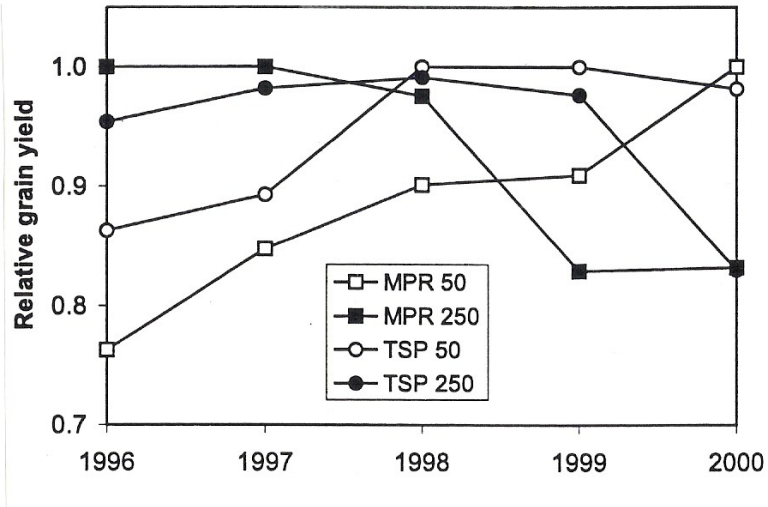
Small cobs and leaf discolouration indicate that the maize suffers from a P deficiency.

* Note that phosphate rock is sometimes called *rock phosphate* in papers or by researchers.

Agronomic effectiveness of phosphate rock

PR fertilizers can be just as effective as chemical fertilizers. Researchers from the World Agroforestry Centre (ICRAF) and Kenya Agricultural Research Institute (KARI) conducted tests in western Kenya and found no difference between chemical and PR fertilizers (Figure 1).[3]

Fig. 1. Relative maize yields over 5 years in western Kenya with Minjingu Phosphate Rock (MPR) or TSP added once at 250 kg P/ha, or 50 kg/ha each year for 5 years (Smithson, *et al*., 2001). There are no significant differences between the two types of fertilizer.



In general, four main factors affect the agronomic effectiveness of PR for direct application:

1. Nature of the phosphate rock applied
2. Soil conditions on the farm
3. Type of crop grown
4. Soil management practices

The role of each factor is outlined below.

1. The nature of the phosphate rock applied


Minjingu mine, Tanzania.

The three major sources of PR that are available in eastern and southern Africa and can be used to benefit agriculture include:[4]

- Sedimentary phosphate deposits
- Igneous phosphate deposits
- Guano phosphate deposits

Sedimentary PR, such as Minjingu PR found in northern Tanzania, is generally quite reactive and water soluble. It can improve P deficiencies on acidic P-deficient soils. In fact, applying sedimentary PR on farmers' fields produces results similar to results observed using commercial fertilizers such as TSP (Fig. 1).


Farmer using pelletizer to modify Busumbu PR in Uganda.

Igneous PR deposits are less soluble than sedimentary phosphate rocks and are not very effective when applied directly to the soil. For example, Busumbu PR found in eastern Uganda is less soluble and must be modified for agricultural use. To improve the solubility of igneous PR, farmers and researchers have experimented with various methods. These methods include: combining PR with green manure, phospho-composting, and pelletizing PR with an acid-generating substance and then incorporating it into cattle manure.

Bird and bat excrement are excellent sources of *guano phosphate deposits*, and they can be reactive sources of P. Bat guano deposits are generally small and found in caves. Larger bird guano deposits, also called insular deposits, were found off the coasts of Tanzania and Madagascar and on smaller islands near the main islands of the Seychelles. Bird guano is easy to find, extract and transport, as most sources are located close to the sea. Despite these advantages, extraction of guano deposits can cause major environmental damage and also poses health risks for those involved.

2. Soil conditions

The nature of the soil can also limit the agronomic effectiveness of PR. In other words, the application of PR, even the most reactive and soluble PR, will not be very effective without certain soil conditions.

For PR to dissolve quickly and make P readily available for plants, the soil should be:

- Acidic (pH 5 to 6)
- Low in calcium

PR is most effective in soil with low amounts of available P.

3. Type of crop grown

All plants need P for early root growth and strong development (see for more information). However, some crops are better than others in their ability to extract and use P from PR sources. Plants with a high ability to extract and use P from PR sources are said to have high P-mobilizing capacities. Some examples include:

- Clover
- Kale, or rape (sukuma wiki in Swahili)
- Cabbage
- Pigeon pea

Other plants, including most cereal grains and cotton, have low P-mobilizing capacities.

Some types of plants can make PR more soluble so that plants with a low P-mobilizing capacity can uptake more P. These include legumes and agroforestry shrubs (e.g. *Tithonia diversifolia*).

4. Soil management practices

Soil management practices, such as the placement of PR and the timing of the application, can influence the effectiveness of PR or water-soluble P fertilizer. We discuss these practices and provide recommendations on pages 6 to 10.

What are the advantages of using PR?

A farmer will want to know why he or she should decide to use PR instead of the more common P fertilizers like DAP or TSP. After much research and several farmer field trials in eastern and southern Africa, we learned that there are advantages to using PR. The main advantages of using PR fertilizer include:

- Lower cost
- Use of a local resource
- Longer lasting effect
- No chemicals required to process the resource

Lower cost

Many farmers recognize that their soils are low in nutrients and could benefit from the application of a nitrogen or phosphate fertilizer. However, the fertilizers sold in the shops are often so expensive that farmers cannot afford to buy them. The fertilizers are imported from South Africa, Jordan, Norway, and even as far away as the USA or Japan! The cost of transport to a port city like Mombasa and across hundreds of kilometers inland increases the price of fertilizers substantially.

One of the main advantages of PR fertilizer is that it is a cheaper product than imported chemical P fertilizers. PR is extracted from local phosphate deposits and doesn't need to be transported long distances. PR doesn't need to be processed like chemical P fertilizers, which also reduces the cost.

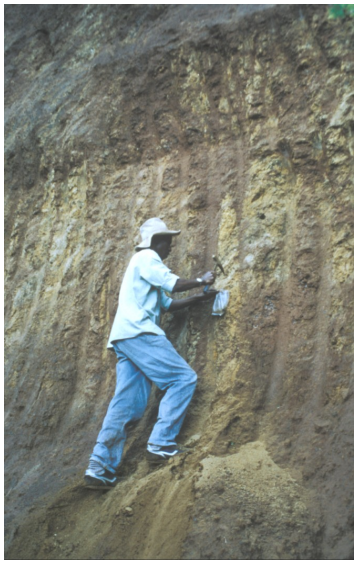
Recent price checks by the *Rocks for Crops* project partners revealed the following prices for chemical P fertilizers and various PR fertilizers available in the region. The prices displayed in Figure 2 show the higher cost for chemical P fertilizers compared to PR fertilizers and the variation of prices throughout the region.

LOCATION	PRICE OF CHEMICAL P FERTILIZER (in USD) per 50 kg bag	PRICE OF PHOSPHATE ROCK FERTILIZER (in USD) per 50 kg bag
Mombasa, Kenya	$20.75 DAP $19.35 TSP	No price available
Nairobi, Kenya	$19.00 DAP $ 21.00 TSP	$7.25 - $10.50 Minjingu Phosphate Rock (MPR)
Western Kenya	$23.70 DAP $21.70 TSP	$15.80 MPR
Tanga and Dar es Salaam, Tanzania (as sold by the Tanzania Farmers' Association (TFA))	$19.00 TSP	$6.00 MPR
Uganda	$24.75 TSP $24.75 MOP	No price available
Zambia	No price available	No price available
Tunisia and Morocco	$9.50 TSP	No price available

*Note: Retail prices are approximate and can vary between shops

Fig. 2. Prices of chemical P and PR fertilizer in select locations throughout the region.

Local resource



Busumbu PR deposit in Uganda.

Farmers who use locally extracted PR instead of imported P fertilizer can provide economic benefits for both farmers and the wider local community. Farmers get a cheaper source of P to improve their crop yields. The extraction and sale of PR could create local jobs and business opportunities.

There are many sources of PR in eastern and southern Africa. The Minjingu PR deposit is in the Eastern Rift Valley of northern Tanzania. The phosphate rocks of Minjingu are highly soluble and effective. The Mbeya area of Tanzania has igneous PR sources of agronomic interest, but they are low in solubility. The Busumbu PR found in eastern Uganda near the Kenyan border also has low solubility, but it

can be modified for agronomic use. Another igneous source of PR in eastern Uganda is Sukulu. In Zambia, there are Chilembwe phosphates in Eastern Province, but these phosphates must be modified because they have low solubility.[i]

Long lasting effect

A farmer using a chemical phosphate fertilizer on his or her farm usually applies it at the start of ***each*** growing season. If instead, the farmer applies PR at the start of the growing season, the P that is released can benefit crops for up to ***three years***. This is because PR is a slow release fertilizer and continuously adds P to the soil over a longer period of time. The benefits to farmers are lower costs and lower labour requirements because PR does not have to be applied every year.

Chemical-free processing

Most commercial fertilizers require chemical processing; this increases the cost of the product. NP fertilizers, for example, rely on cheap ammonia produced from natural gas. The processing makes the fertilizer more soluble and easier to apply, but it also increases the price. Another problem is that natural gas is a non-renewable resource and is becoming more expensive.

On the other hand, PR doesn't need to be chemically processed. It may only require minimal grinding or crushing. Because there are no added chemicals, PR doesn't burn the roots of crops as some chemical fertilizers do and can be used by organic farmers.

[i] More country specific information about PR deposits are included in P. van Straaten's *Rocks for Crops*, available on-line at http://www.uoguelph.ca/~geology/rocks_for_crops/

What are the limitations to using PR?

Despite its advantages, PR is not perfect. Farmers do have some complaints about using this alternative fertilizer.

- **Dusty product**

  In its simplest form as finely ground PR, the fertilizer product is dusty. This means that when PR is being applied, it can blow away in the wind. It can be very messy for farmers to use.

- **Low reactivity**

  As explained earlier, reactive sedimentary PR sources can be applied directly. On the other hand, most igneous PR sources need to be modified to increase their reactivity and solubility. This can require experimentation or labour intensive application of additional materials like *Tithonia diversifolia* or green manure. Because igneous PR has a low solubility rate, farmers will have to wait until there is plant-available P for crop uptake.

Tithonia diversifolia, also known as Mexican sunflower, is a shrub that often grows along roadsides and is high in nutrients.

- **Availability**

  PR fertilizers can be hard to find at local agricultural input shops despite the fact that PR is extracted from regional sources. Some retailers may not carry this product because it is relatively new, and not well-known or well-marketed.

- **Cost**

  While PR is a cheaper source of inorganic P than most chemical P fertilizers, it is not free. Some smallholder farmers will still have difficulty affording it, despite being a more affordable option.

Addressing the limitations

Several groups are working to address the limitations of PR and to make it more attractive to and effective for farmers. For example, researchers and field staff developed a simple pelletizer machine that forms small pellets from PR. The pellet form of PR is less dusty and easier to apply. Research continues throughout the region to improve the potential of PR for farmers' use. One example is the PREP-PAC designed by researchers at Moi University in Eldoret, Kenya to address the problem of P deficiency. They included Minjingu PR in their efforts to keep the cost of the product down.

If the agricultural input shops in your region do not sell PR fertilizers, you have several options. Find out whether local NGOs or agricultural research stations have access to PR fertilizer. Or, ask other agricultural extension workers if they have any information about where PR fertilizer can be obtained. This information booklet lists contacts in your region that can help you find PR. Increased demand and use of PR should improve accessibility over time.

Current options for using PR fertilizer

As discussed earlier, PR fertilizer may be available in different forms depending on what is available in your region. Currently, there are five major options for farmers who wish to purchase and use PR fertilizer:

1. *PR for direct application*
   Minjingu PR from Tanzania (available in some parts of Tanzania, Kenya and Uganda).

2. *The PREP-PAC*
   Developed by researchers at Moi University in Eldoret, Kenya, this soil management product combines 2.0 kg MPR, 200 g of urea, seeds of various nitrogen-fixing food legumes, rhizobial inoculant, gum Arabic, seed adhesive and lime. The instructions are given in various local languages. By supplying a source of P, N and seeds for food legumes, the product can improve patches on the farm with poor productivity.[5]

3. *Partially Acidulated PR*
   Chilembwe PR modified through partial acidulation is available in Zambia through the University of Zambia (see p.14 for contact information).

4. *Minjingu Mazao fertilizer*
   This new product is being developed by Farm Inputs Promotions Project (FIPS), based in Nairobi. The organization has been working with Minjingu mines to develop a fertilizer which is 40% MPR, 40% DAP, 15% MOP and 5% elemental sulfur. This blended P fertilizer is as good as DAP but costs half the price. They are also looking at using a pelletizer to make a product which is easier for farmers to apply. Tests are currently underway on sites in Kenya and Tanzania and show promising results.

5. *Alternative arrangements*
   If it is not possible to find a source of PR in your region, consider collaborating with an agricultural research institute in your area. Many institutes conduct research related to the use of PR and might be willing to work in partnership with farmers' groups, CBOs or NGOs.

The contents of a PREP-PAC.

- Eastern and southern Africa: Organizations such as the World Agroforestry Centre (ICRAF) and the Tropical Soil Biology and Fertility Program (TSBF) are working in all our partner countries.

- Kenya: Kenya Agricultural Research Institute (KARI), Kenya Forestry Research Institute (KEFRI), Kenya Institute of Organic Farming (KIOF).

- Uganda**:** National Agricultural Research Organisation (NARO), Uganda Forestry Authority (UFA), Kawanda Agricultural Research Institute (KARI).

- Tanzania: Research institutions in the agricultural research zones: ARI Mlingano, Eastern and Central Zones; ARI Selian, Northern Zone; ARI Ukiriguru, Lake Zone; ARI Naliendele, Southern Zone. Other institutions are Uyole for the Southern Highlands Zone, and Tumbi for the Western Zone.

- Zambia: Kasisi Agricultural Training Centre.

What is the recommended application procedure for using PR fertilizers?

Here is a general application procedure to increase levels of P in P-deficient soils using PR fertilizer. In Tanzania, Kenya and Uganda, the PR available and most suitable would be Minjingu PR.

***Procedure for the simple application of PR:**

1. Three to four weeks before the onset of rains, prepare soils using three to four 50kg bags of PR per hectare mixed with chopped up *Tithonia* leaves (either dried or wet). This will supply 22-25 kg/ha of P, which is the P requirement for maize.
2. Broadcast evenly over the whole plot and incorporate into soil.

How can farmers maximize the agronomic effectiveness of PR fertilizers

It is important to remember that phosphorus is just one of the important nutrients essential for healthy, fertile soils and good crop production. We must not forget about the importance of nitrogen (N), and potassium (K), secondary nutrients like calcium (Ca), and magnesium (Mg), as well as micronutrients. Therefore, in order to maximize the benefits of using PR fertilizer, farmers should be encouraged to apply organic inputs in combination with PR (for example, green manure, cattle manure, compost and crop residues). The organic matter will supply some of the additional nutrients required by plants and help to build soil structure. As well, organic matter is locally available and often free of charge!

The use of PR is not a solution to soil degradation on its own. It is part of a growing list of options that are being recommended as appropriate for smallholder farmers. Farmers should also be encouraged to adopt good management practices including crop rotation and improved fallows.[6]

Sharing information about PR fertilizers with farmers

Here are some ideas for activities you could organize in order to share information about PR fertilizers with farmers:

- An informational workshop to raise awareness about the potential of PR fertilizer.
- A farmer field day involving a demonstration of how to apply the PR fertilizer.
- Farmer-to-farmer visits where farmers could visit a fellow farmer who is using PR fertilizer.
- Conduct research together with farmers by establishing test plots with farmers to determine the different agroeffectiveness of PR fertilizer, organic P inputs, chemical P fertilizers, etc. (as explained in first).

A variety of methods could be used to inform farmers about this alternative option to increase P levels on the farm. It is important to keep the information simple, clear and interesting. It is also very important to engage farmers so that they have a chance to learn-by-doing, ask questions, and share their experience and knowledge.

In review

In this booklet, we provided information about phosphate rock fertilizer and discussed the factors that determine its agronomic effectiveness. We described the advantages of using PR and the limitations to this technology. We detailed the types of PR products that are currently available, the procedure for application and ways to maximize the effectiveness of PR. Finally, we listed some ideas on how to share this information with farmers.

For more technical and country-specific information about PR and agrominerals, please consult *Rocks for Crops*, which is available online at http://www.uoguelph.ca/~geology/rocks_for_crops/

Contact information

Here is the contact information for resource people who are or have been involved in PR research in the region:

KENYA

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Acronyms

Ca: calcium
CBO: community based organization
DAP: diammonium phosphate
FIPS: Farm Input Promotions Africa Ltd.
K: potassium
MAP: mono ammonium phosphate
Mg: magnesium
MOP: muriate of potash
MPR: Minjingu phosphate rock
N: nitrogen
NGO: non-governmental organization
NP: nitrogen phosphate
P: phosphorus
PR: phosphate rock
TSP: triple superphosphate

Endnotes

[1] C.A. Palm, R.J.K. Myers, S.M. Nandwa, *Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment.* In R.J. Buresh, P.A. Sanchez, and F. Calhoun (eds.) Replenishing Soil Fertility in Africa (Madison, Wisconsin: SSSA Special Publication 51, 1997) 193-217 .
[2] P. van Straaten. Rocks for Crops: Agrominerals of sub-Saharan Africa (Nairobi, Kenya: ICRAF, 2002).
[3] P. Smithson, B. Jama, R. Delve, P. van Straaten, R. Buresh. *East African Phosphate Resources and Their Agronomic Performance,* Direct Application of Phosphate Rock and Related Appropriate Technology- Laterst Developments and Practical Experiences, (Kuala Lumpur, Malaysia: International Center for Soil Fertility and Agricultural Development, 2001), 123-133.
[4] van Straaten.
[5] P. L. Woomer, J. R. Okalebo, H. K. Maritim, P. A. Obura, F. M. Mwaura, P. Nekesa, E. J. Mukhwana, *PREP-PAC: a nutrient replenishment product designed for smallholders in western Kenya*, Agriculture Ecosystems & Environment, 100 (2003) 295-303.
[6] B. Amadalo, et al. Improved Fallows for Western Kenya: An Extension Guideline (Nairobi, Kenya: World Agroforestry Centre, 2003) Retrieved July 10, 2005 from http://www.knowledgebank.irri.org/cglrc/icraf/Improvedfallow.pdf