PROM Technology Update - 2014

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Rock phosphate minerals of any geological origin even if low in grade work as efficiently even in alkaline soils as chemical phosphatic fertilizers that contain water soluble P_2O_5 provided the phosphate rock particles are sufficiently fine and are accompanied by N containing materials of either organic or inorganic origin.

Introduction

Phosphorus is a major nutrient element for plants [1, 2] and it plays an important role in the life processes as a constituent of DNA/RNA and in energy transfer mechanism *via* Adenosine Tri Phosphate / Adenosine Di Phosphate. Plants take up P in its water soluble form $(PO_4)^{-3}$, $(H_2PO_4)^{-1}$, $(HPO_4)^{-2}$. Plants exude organic acids (citric and malic acids) through the roots [1] which dissolve available soil phosphates. Phosphates that are soluble in water or 2% citric acid are known as available forms. Rock phosphate mineral essentially contains tri calcium phosphates which are not water soluble. Some rock phosphates of sedimentary origin may contain varying amounts of P soluble in 2% citric acid depending on the geological process setting of the deposit formation. Soil pH plays an important role in the P take up of plants. Soil pH range of 5.5 to 7 is most favorable [2] for P up take by plants. Below 5.5 pH soil cations such as Fe, Al and Mn lock up P there by making it unavailable to the plants and Ca, Mg ions lock up the available P in the soil pH range above 7. The problem of locking up of available P by the soil cations is known as phosphate fixation problem to soil scientists and agronomists because of that the use efficiency of P from the applied mineral fertilizers by plants in agriculture is just 15% in the first year [3] and 1 – 2% per year in the subsequent years. The water soluble P of the applied mineral fertilizers is misplaced by leaching, run off with rain/ irrigation water or is fixed by the soils into unavailable forms. Nutrient use efficiency of N applied to the soils through chemical fertilizers is said to be 50 – 60% in the first year.

Chemical Phosphatic Fertilizers

The fact that plants easily take up P in its water soluble form has lead the scientists of Rothamsted Experimental Station (England) in the year 1840 to the development of [4] Single Super Phosphate (SSP) that contains water soluble P. Development of more complex phosphatic fertilizers such as Di Ammonium Phosphate (DAP), Mono Ammonium Phosphate and NPK mixtures followed. Some rock phosphate minerals of sedimentary origin containing good amounts of citric soluble P are directly applied to acidic soils as P fertilizers after grinding to fine size say 90% of the particles passing through 150 micron IS sieve. The world production/consumption of rock phosphate was estimated [5, 6] at 171.4 million tons during 2005 and 167.8 million tons during 2006, 166 million tons during 2009 and 176 million tons during 2010. Around 90% of the rock phosphate produced is consumed by the chemical phosphatic fertilizer industry.

Chemicalisation of agriculture by the introduction of chemical fertilizers has improved world agricultural production greatly by three to four folds leading to green revolution and securing food to the world population. However excessive application of chemical fertilizers (that include N containing and other fertilizers) over long periods has also destroyed natural properties of soils by killing soil micro flora and fauna leading to reduced agricultural production. Thus chemical phosphatic fertilizers pose two fold problems in that on the one hand almost 85% of the applied P is lost forever which is from a non- renewable resource and destroys soil micro flora and fauna leading to soil ill health and poor quality of agricultural products.

Phosphate Rich Organic Manure

In experimental studies [7, 8] it was noticed that high grade rock phosphate in fine size along with well composted organic manure showed agronomic efficiency as high as that of DAP in alkaline soils and also showed equal residual effect whereas DAP fails to show such residual effect. This idea was pursued by M/s Rajasthan State Mines and Minerals Ltd through extensive testing by agricultural scientists in different agro climatic conditions throughout India. The scientists involved in this research formed Phosphate Rich Organic Manure Society (PROM Society) to keep up the research efforts and to popularize the technology. Government of India recognized PROM as P fertilizer by including PROM in the Fertilizer Control Order. Microorganism in the organic matter, slowly dissolve P from the fine sized rock phosphate mineral by releasing organic acids which is further enhanced by the organic acids released by the plant roots. Addition of phosphate solubilizing microorganism (*bacillus megatherium var. phosphaticum*) to PROM greatly enhances the dissolution of P from fine sized rock phosphate mineral particles. Table 1 shows the comparative results of agronomic efficiency of Phosphate Rock as PROM and DAP. It may be noted from treatment 7 that PROM shows equal residual effect. More interestingly high grade rock phosphate mineral in fine size along with urea @ 18 Kg of N per hectare gave the best output in the first crop. It is also noted that the quantity of organic manure applied along with phosphate rock played an important role and that 4 tons of organic manure (farm yard manure) per hectare gave the best result within the treatments studied.

Table 1

Effect of PROM* and DAP on the Output of *Cyamopsis tetragonoloba* (Linn.), Ref: 8

Treatment No.	Treatment	Seed Output per Plant (g)	Seed Output per Plant (g) (residual effect)
0	PR(34/23-d80) @40 kg P_20_5 ha^{-1}	6.69(+44.8)	8.63 (+25.43)
1	Control (Soil)	4.62	6.88
2	PR(34/23-d80) @40 kg P_20_5 ha^{-1} + Urea @ 18 kg N_2 ha^{-1}	7.76(+67.96)	7.69 (+11.77)
3	DAP @ 40 Kg P_20_5 ha^{-1}	7.09(+53.46)	7.61 (+10.61)
4	PR(34/23-d80) @ 40 kg P_20_5 ha^{-1}+ FYM @ 0.5ton ha^{-1}	5.29(+14.50)	7.92 (+15.11)
5	PR(34/23-d80) @ 40 kg P_20_5 ha^{-1}+ FYM @ 1ton ha^{-1}	5.28(+14.28)	8.58 (+24.70)
6	PR(34/23-d80) @ 40 kg P_20_5 ha^{-1}+ FYM @ 2 ton ha^{-1}	6.52(+41.12)	8.60 (+25.00)
7	PR(34/23-d80) @ 40 kg P_20_5 ha^{-1}+ FYM @ 4 tons ha^{-1}	7.17(55.19)	10.75 (+56.25)
8	DAP @ 40 kg P_20_5 ha^{-1}+ FYM @ 4 tons ha^{-1}	7.59 (+64.28)	9.76 (+ 41.86)

* The description of rock phosphate 1T, used in these tests is given in Table 2

PHOSPHATE ROCK CHARACTERISTICS

It may be noted[9] from figure-1 and table 2 that, rock phosphates of different geological origin show a characteristic curve of increasing content of P soluble in 2% citric acid (Y axis) as the particle size decreases (X axis). Interestingly citric acid (2%) soluble P_2O_5 content of even the

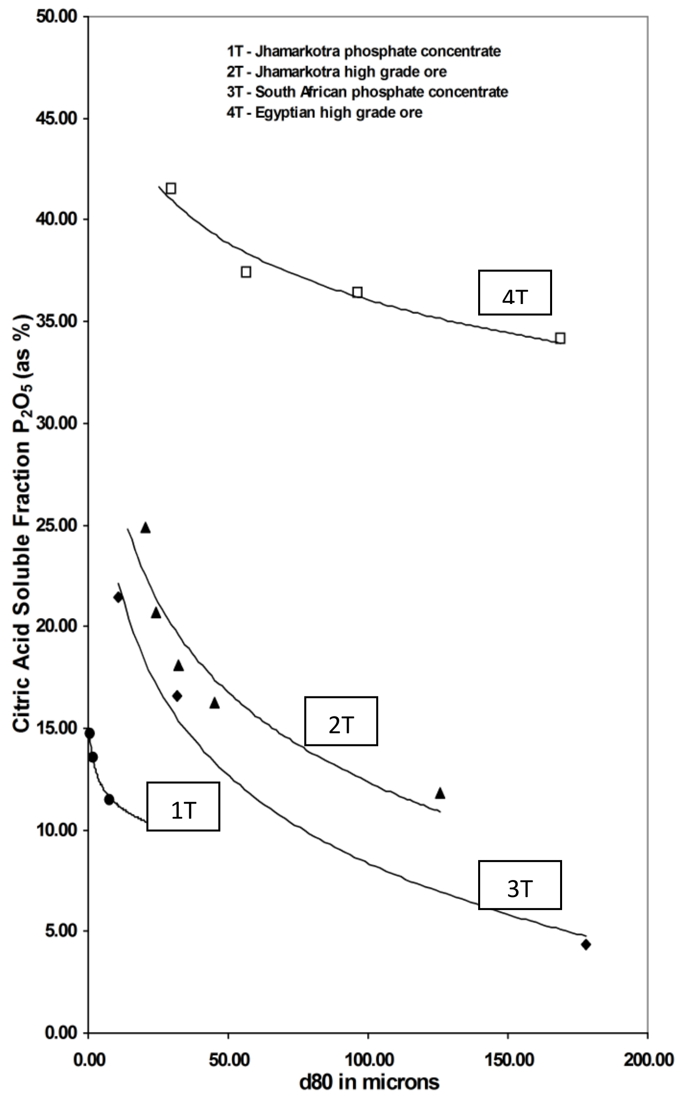

Figure1 - Increasing fraction (as %) of P_2O_5 soluble in 2% citric acid of rock phosphate mineral (from Egypt, India and South Africa) as the particle size decreases.

Table 2

Chemical Analysis of Phosphate rocks: Ref: 9

S. No.	Source & type	Percent by weight						
	Place of origin/detail	d80 in microns	Total P_2O_5	P_2O_5 soluble in 2% citric acid	CaO	MgO	SiO_2	Loss on ignition
1.	Jhamarkotra concentrate, 1T	23.14	34	3.5	47.7	2.3	6.29	4.85
2.	Jhamarkotra High-Grade Ore, 2T	24.43	33.8	7	46.6	1.5	9.1	3.42
3.	Phalaborwa (SA) Concentrate, 3T	31.84	36.8	6.1	51.5	0.6	2.78	3.35
4.	Egyptian High-Grade Ore, 4T	29.43	31.3	13	46.9	2.5	5.6	7.42

rock phosphate of igneous origin (Phalaborwa, South Africa) increases substantially as the mineral is ground to finer sizes.

Rock Phosphates of different geological origin in PROM

Studying three types of phosphate minerals [10] in PROM from South Africa (3T), India (2T) and Egypt (4T)Pareek *et.al*., report comparable yield of *Vigna unguiculata (L) walp*, to that of DAP on equal P_2O_5 basis. A comparison of the performance of the rock phosphates of Jhamarkotra (India) High-Grade Ore (2T), Phalaborwa, SA Concentrate (3T), Egyptian High-Grade Ore (4T) as PROM with DAP showed the following order:

$$3T\ (1.125) > 2T\ (1.115) > DAP\ (1.05) \approx 4T\ (1.002) > Control\ (0.465)$$

The seed output per plant in grams is shown in parenthesis. Control is without application of phosphate in any form.

A comparative study of PROM made with concentrate analyzing 34.31% P_2O_5 in 765 microns d80 size, discarded slimes containing 24.48% P_2O_5 in 79 microns d80 size with DAP in highly saline soil of Eshidiya mines, show that even slimes otherwise discarded as waste works very efficiently as P fertilizer where DAP completely fails. The discarded slimes are more efficient than the concentrate probably because of its fine size which may be noted from Table 3.

Table 3

Results of the Lettuce (*Lactuca sativa*) biomass production, Ref: 11

SN	Treatment	Average biomass per plant in grams	Percent survival of the saplings
1	32.4 gms of P_2O_5 from concentrate (PR 34. 31/765), 132.4 gms oil cake, 2253.5 gms of FYM - per M^2.	67.12	100
2	32.4 gms of P_2O_5 from waste slimes (PR 24.48/79), 132.4 gms oil cake, 2253.5 gms of FYM - per M^2.	69.15	100
3	Absolute control [Nothing added]	0.64	21
4	32.4 gms of P_2O_5 from DAP.	0.74	31

Rock Phosphates accompanied with N fertilizers

During NaRMA – IV, seminar organized at Bikaner during 19 -21, December 2012 interesting results were presented studying [12 – 14] the agronomic efficiency rock phosphate applied to soils along with N containing fertilizers such as Urea, Ammonium Sulphate and Ammonium Nitrate which showed higher agronomic efficiency compared to DAP. Though these results are of preliminary nature there is no reason why they cannot be demonstrated at large scale. Magesh *et al* studied [19] low grade rock phosphate analyzing 20% P_2O_5 (discarded slimes of Eshidiya plant, Jordan) with d80 at 14.74 microns along with ammonium sulphate and ammonium nitrate and compared with DAP applied alone. Their results the order of efficiency PR (20/14.74) with ammonium sulphate P_2O_5> PR (20/14.74) with ammonium nitrate > DAP on equal P_2O_5 basis at doses of N 16 Kg per hectare. Sashank *et al* studied [20] low grade rock phosphate (discarded slimes of Eshidiya beneficiation plant) analyzing 19.6% P_2O_5 along with Urea. Their results show that PR (19.6/14.74) with urea ≥ DAP at equal P_2O_5 (60 Kg per hectare) and N (16 Kg per hectare) basis. Sandeep and Murthy studied Morocco rock phosphate analyzing 31.5% P_2O_5 with d80 at 74 microns along with ammonium sulphate and compared with DAP on equal P_2O_5 (60 Kg per Hectare) and N (16 Kg per hectare) basis. Agronomic efficiency as indicated by their results is PR (31.5/74) with ammonium sulphate > DAP. The pH of soils studied by Magesh (Vellore), Sashank (Delhi) and Sandeep (Vizag) are 8, 8.8 and 7.56 respectively.

Discussion

High grade rock phosphate in fine size with organic manure (PROM) has been proved as effective as DAP by several scientists [15] in different agro climatic conditions in India. Integrating PROM production with bio gas generation is also envisaged [16] to be profitable. Further studies [11] on PROM showed that even low grade rock phosphate as low as 20% in P_2O_5 content but in very fine size is as effective as high grade phosphate rock in coarse size. This observation (Table 3) shows that the finer size of the rock phosphate is important in PROM technology. Further fine grinding of phosphate mineral increases 2% citric acid soluble P2O5 content of the phosphate rocks. However the importance of grade cannot be ignored [9, 10] as may be noted from Table 2 and the observation of Pareek *et al* which show that phosphate rock from South Africa performed better than that from Egypt which are almost of equal size when applied on equal P_2O_5 basis. Higher LOI that indicates the presence of carbonate minerals in Egyptian rock probably reduces the effectiveness of mild acidity produced by soil microorganism and plant roots there by hindering the dissolution of P from rock phosphate particles. Addition of N *via* chemical sources along with rock phosphate applied to the soils is effective in improving the agronomic efficiency of phosphate rock which is anomalous observation. Probably N applied to the soils in the chemical form boosts the growth of soil microorganism which assists the dissolution P naturally present in the soil or added advertently to the soil.

Summary

(1) The research on PROM shows that rock phosphate in fine size along with organic matter applied to alkaline soils works as efficiently as any other phosphatic fertilizer. PROM works even in saline soils where chemical fertilizers are most ineffective.

(2) Rock phosphates of even low grades are effective in PROM provided the phosphate particles are sufficiently fine in size say 80% passing through 74 microns. Rock phosphates of any geological origin are effective in PROM provided their particles are in fine size. Thus size of the particles is the most important factor for the effectiveness of PROM. Certain rock phosphates with high citric soluble P2O5 such as Egyptian or Jordanian rocks may be effective in PROM even at coarse sizes. However the finer the size of rock phosphate the better for PROM.

(3) N containing materials of chemical or organic origin applied along with fine sized phosphate rock improve the agronomic efficiency of rock phosphate in alkaline soils. Thus organic manure can be replaced partly or fully by Nitrogen containing fertilizers such as Urea or Ammonium Sulphate.

(4) The real advantage of PROM is that it works for two consecutive crops with the same efficiency unlike chemical fertilizers. Most importantly the quality of the harvest is

natural in that the size of the grains/fruit does not increase but the number of grains/fruits per plant increases. The PROM produced harvest has natural taste.

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PROM Production by Farmers

Chemical phosphatic fertilizer was first produced by the scientists of Rothamsted Experimental Station (England) in the year 1840 as Single Super Phosphate that contains P in water soluble form. Fertilizers that contain water soluble P, work well in alkaline soils. Since then a variety of phosphatic fertilizers that contain water soluble p such as DAP, MAP and mixed fertilizers were developed.

It was published in the year 2001 that rock phosphate in fine size (the raw material for DAP) along with organic manure (Phosphate Rich Organic Manure/ PROM) works more efficiently than DAP. Phosphorous in the rock phosphate is dissolved and taken up by the plants through the action of the organic acids released by the plant roots and soil bacteria. This technology was approved by the Govt. of India in the year 2012 but subsidy is not yet provided as in the case of DAP and SSP. Farmers can make PROM by mixing Phosphate Rock (30% P_2O_5, in fine size (@ 90 Kg P_2O_5 per hectare or six 50 Kg bags of rock phosphate) with Farm Yard Manure (FYM) @ 4 metric tons per hectare and use.

Today a 50 Kg bag of DAP (46% P_2O_5) costs around Rs 1300 after a Govt subsidy of Rs 557 (approx.). One Kg of unpacked, 30% P_2O_5 rock phosphate costs Rs 7.3 (at Udaipur)plus Rs 4 for transportation making it to Rs 11.3 per Kg at Ongole. Thus using rock phosphate directly as Phosphate fertilizer in alkaline soils is cheaper than DAP. The bottle neck is providing rock phosphate to the farmers in smaller quantities. Hopefully this problem can be solved by the farmer's cooperatives.

DAP Vs PROM Approximate Cost Analysis

[1] cost of 50 Kg DAP after Govt subsidy	
@ Rs 557 per bag.	= Rs 1250
[2] cost of DAP per hectare @ 90 Kg P2O5 per hectare (4 bags)	= Rs 5000

[3] Govt subsidy on DAP per hectare = Rs 1228

[4]

a) cost of rock phosphate (30% P_2O_5) per hectare @ 90 P_2O_5 (6 bags) = Rs 3750

b) cost of 1 ton of rock phosphate = Rs 7300

c) transportation cost of rock phosphate per ton Udaipur to Andhra = Rs 4000

d) Taxes plus bagging (if any) per ton = Rs 1200

e) cost of one tractor load of FYM/manure (Rs 400) plus application cost (Rs 400) = Rs 800

[5] cost of PROM per hectare (4a+ 4e) = Rs 4550

[6] If Govt provides subsidy directly to the farmers @ Rs 1228 per hectare

instead of giving to the fertilizer industry, the cost of PROM per hectare

to the farmer then is = Rs 3322

(Cost estimates are as on 13/7/2014. Cost of DAP is likely to go up as the Govt. of India has announced further cut in fertilizer subsidy, FYM cost as at Pernamitta)

Specifications of Rock Phosphate for use in PROM

Beneficiated Rock Phosphate for making PROM:

Total P_2O_5 content	: + 30%
Size of particles	: 80% passing through 74 microns (200 mesh)
Moisture Content	: Maximum 12% but to be billed on the basis of 3% moistrure.

Source of supply:

M/s Rajasthan State Mines and Minerals Ltd.

4 Meera Marg, Udaipur 313 001, Rajasthan, India

Tel: +91-294-2428763/4/5/6/7 Fax: +91-294-2428770

Website of RSMM Ltd: http://www.rsmm.com/ , email: info@rsmm.com

For any guidance: Er. MK Katewa, Senior Manager, RSMMLtd, 4 – Meera Marg, Udaipur,

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PROM as a Commercial Product:

Phosphate Rich Organic Manure (PROM) is approved by Government of India as organic fertilizer in the year 2014 and is included in the Fertilizer Control Order (FCO). The specifications of PROM as per FCO 2014 are as follows:

[1] Particle Size = 90% passing through 4 mm

[2] Bulk Density (g/cm^3) = less than 1.6

[3] Total organic carbon = minimum 7.9%

[4] Total Nitrogen as N = 0.4%

[5] Total P_2O_5 = 10.4%

[6] C:N ratio = less than 20:1

[7] pH of 1:5 solution = maximum 6.7

[8] conductivity (dSm^{-1}) = 8.2

[9] Moisture maximum = 25%

Upper limits of toxic heavy metals mg/Kg, As_2O_3 = 10.00, Cd = 5.00, Cr = 50, Cu = 300, Hg = 0.15, Ni = 50, Pb = 100, Zn = 1000.00 .

One metric ton of rock phosphate (30% P_2O_5) mixed with 1.75 tons of well composted manure will give a product of 2.75 tons of PROM of the above specifications.

Note: Production of PROM for commercial purpose needs permission from the Department of Agriculture of respective state governments without which the producer may be prosecuted. Please refer to FCO 2014.