Discarded Phosphatic Slimes as Fertilizer in Alkaline Soils

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Summary

Phosphate concentrator at Eshidiya, of Jordan Phosphate Mines Co. Plc, Jordan treats two different types of ores. Both these ores are de slimed to remove clay minerals and the slimes are discarded as tailings. The discarded slimes contain P_2O_5 as high as 20%. Tests were conducted to use these slimes as direct P fertilizer in alkaline/saline soils both in Jordan and India. It is noted that the slimes along with N containing materials either of organic or inorganic origin work as efficiently as known phosphatic fertilizers.

Keywords: phosphate, slimes, alkaline soil

Introduction

The element P plays an important role [1, 2] in living systems in the formation of DNA/RNA and as biological energy transfer molecules Adenosine Tri Phosphate / Adenosine Di Phosphate.Thus P is an important fertilizer element. Plants takeup P in water soluble forms such as $(PO_4)^{-3}$, $(H_2PO_4)^{-1}$, $(HPO_4)^{-2}$. Phosphates soluble in 2% citric acid are also taken up by plants by natural mechanisms. Forms of phosphates soluble in water and 2% citric acid are known as available forms. Chemical phosphatic fertilizer was first produced [3] 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. Rock phosphate mineral is directly used as P fertilizer in acidic soils. P uptake by plants is best facilitated in the soil pH range from 5.5 to 7. P is locked up as unavailable to plants [2] below5.5 pH by soil cations of Al, Fe and Mn and above 7 pH by cations of Ca and Mg. Thus the use efficiency of P from chemical fertilizers is reported [4] to be just 15% and the rest of it goes as unutilised waste.

Natural mechanism of soil P dissolution

Plants dissolve [1] and take up P from the soil by exuding organic acids such as citric and malic acids from their roots. It is also known that certain soil micro organism play an important role in dissolving P present in the soil. Bacteria such as *bacillus Megatherium var. phosphaticum, bacillus polymixa*, fungi such as *Aspergillus awamoori, A. cadidus, Penicillum digitatum* and actinomycetes such as S*treptomyces sp*. are known P solubilisers. These micro organism thriving on soil organic matter release organic acids that help in dissolving P minerals of the soil. Thus organic acids released by plant roots and soil micro organism help in making soil P available to the plants. It is also known that P up take by plants is high from the soils that contain higher amounts of organic matter.

Phosphate Rich Organic Manure

It was reported [5, 6] that high grade rock phosphate mineral in fine size applied along with well matured (composted/ fermented) organic manure shows (Table 1) agronomic efficiency comparable to any chemical phosphatic fertilizers in alkaline soils. The finer the grind of rock phosphate mineral the higher is the 2% citric acid soluble content of P_2O_5 in the rock phosphate [7] irrespective of its geological origin as may be noted from Fig 1. PROM has been tested on a variety of crops in different agro climatic conditions in India.

Studying three types of phosphate minerals in PROM from South Africa (3T), India (2T) and Egypt (4T) Pareek *et.al.*, reported [8] comparable yield of

Table 1. Effect of PROM* and DAP on the Output of *Cyamopsis tetragonoloba* (Linn.)

Tabela 1. Rezultat stosowania PROM* (PROM – Phosphate rich organic manure, odpady organiczne bogate w fosforany) oraz DAP (Diamonnium phospahate, wodorofosforan amonu) na uzysk Cyamopsis tetragonoloba

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 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
* Opis fosforytów 1T, stosowany w tych próbach, podano w tabeli 2

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:

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

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

Discarded phosphatic slimes in PROM

Low grade phosphatic ores are beneficiated first by de sliming the ore to remove clay gangue minerals. Substantial quantities of phosphate minerals are misplaced into the slimes stream which goes to waste/ /tailings. The discarded slimes at Eshidiya phosphate concentrator, Jordan contains P_2O_5 as high as ≥ 20%. Further recovery of P from the slimes by conventional techniques was proved futile. Trials were made [9] to see if the slimes containing P can be used for making Phosphate Rich Organic Manure that can compete chemical phosphatic fertilizers. Indeed the low grade phosphatic slimes (analysing 24.48% P_2O_5 and in the size d80 at 79 microns) are as effective as high grade concentrate as may be noted from Table 2 and DAP failed as the soil was highly saline (Electrical Conductivity 15320.00 µs/cm and soil pH 7.22).

Further studies were conducted [10, 11] using the low grade slimes in India at Vellore and New Delhi. Interestingly rock phosphate mineral of even low grade in fine size (discarded slimes of Eshidiya plant) shows comparable agronomic efficiency with DAP provided it is associated either with organic manure or with nitrogen containing inorganic chemicals such as urea or ammonium sulphate or ammonium nitrate. Thus the particle size of phosphate rock is of prime importance for use in phosphate rich organic manure to obtain comparable agronomic efficiency with DAP so although higher grades of phosphate rocks will further improve agronomic efficiency. More interestingly the organic manure may be replaced partly or fully with nitrogen containing fertilizers such as urea or ammonium sulphate or ammonium nitrate.

The research efforts made so far on the direct ap-

Table 2. Results of the Lettuce (*Lactuca sativa*) biomass production, Ref: 11

Tabela 2. Wyniki produkcji biomasy z sałaty (Lactuca sativa); 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

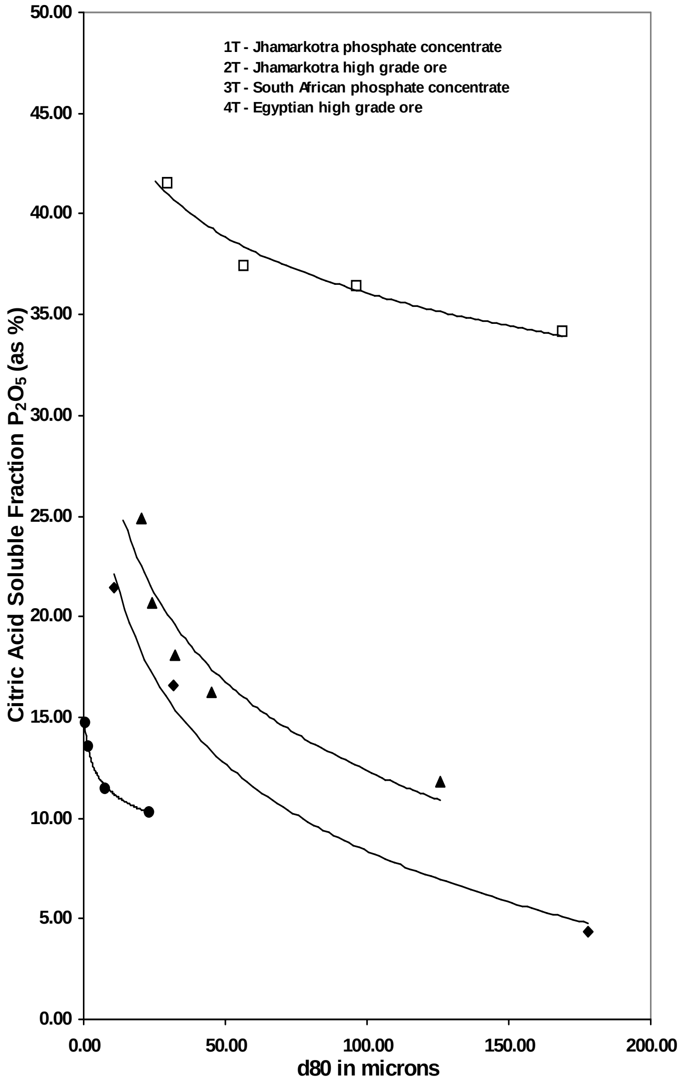

Fig. 1. Increasing fraction (as %) of P_2O_5 soluble in 2% citric acid of rock phosphate mineral (from Egypt, India and South Africa) as the particle size decreases.
3T = PR (36.8% P_2O_5, d80 = 31.84 microns), 2T = PR (33.8% P_2O_5, d80 = 24.43 microns),
4T = PR (31.3% P_2O_5, d80 = 29.43 microns).
These results suggest that at comparable particle sizes phosphate rocks of higher grade show higher agronomic efficiency in PROM

Rys. 1. Wzrost udziału (%) P_2O_5 rozpuszczalnego w 2% kwasie cytrynowym minerału fosforanowego (z Egiptu, Indii i Południowej Afryki) przy jednoczesnym zmniejszaniu rozmiarów cząsteczki.
3T = PR (36,8% P_2O_5, d80 = 31,84 mikronów), 2T = PR (33,8% P_2O_5, d80 = 24,43 mikronów),
4T = PR (31,3% P_2O_5, d80 = 29,43 mikronów).
Wyniki te sugerują, że przy porównywalnych rozmiarach cząsteczki skały fosforanowe wykazują wyższą wydajność agronomiczną w PROM

plication phosphate rock along with organic manure or nitrogen containing fertilizers in alkaline soils [12] clearly proves that direct application is far more superior than chemical phosphatic fertilizers as P use efficiency in direct application is double to that of chemical phosphatic fertilizers due to the equal residual effect. Even low grade ores are effective provided they are ground to finer sizes. The implications of these findings are far reaching in terms of (a) conservation of phosphate mineral resources which are non renewable (b) and food security.

Discussion

No doubt the introduction of chemical (phosphatic) fertilizers which began 163 years back has contributed to the improved agricultural production world over. The problem of low use efficiency of nutrient elements by the plants from the applied nutrients through chemical fertilizers how ever remained unsolved so far. Direct application of phosphate rock via PROM and related products indeed improves the use efficiency of applied nutrient elements which is bound to reduce the cost of agricultural production of food materials. Some phosphate rocks contain toxic heavy metals and radio active elements which are harmful if excess rock phosphate is used. Thus Government of India included upper limits of heavy metals in the specifications of PROM which is recently approved as a fertilizer. Integrating PROM Technology with bio gas technology [13] improves the financial viability of both these technologies. As on date chemical phosphatic fertilizers are heavily subsidised. If similar subsidies are extended to PROM to put it on equal playing ground the costly chemical phosphatic fertilizers can be slowly phased out. All concerned should realise that the chemical phosphatic fertilizers out lived their purpose.

Closing Remarks

As it can be seen that the introduction of PROM Technology and the related research/products demands review of our understanding of the principles of the soil and plant nutrition. Nitrogenous materials organic or inorganic applied to the soils probably blasts the growth of soil bacteria which in turn dissolve the soil P naturally present or applied. The finer the phosphate rock particles the greater the availability of P to the plants. The principles of phosphatic fertilization based on the current research are summarised as follows.

1. Phosphate Rock in fine size applied to soils along with N containing organic/inorganic materials also work as P Fertilizers even in alkaline soils more effectively than P fertilizers that contain water soluble P.
2. Phosphate rocks of even volcanic origin can work in acidic as well as alkaline soils as P fertilizers provided they are ground to finer sizes for 2% citric acid soluble content increases as the grind is finer. For alkaline soils the phosphate rock is to be applied with N containing materials either of organic or inorganic origin.
3. Phosphate Rocks in fine size if applied to alkaline soils along with organic manure works for two crops in sequence with equal agronomic efficiency comparable to chemical phosphatic fertilizers and hence P use efficiency is above 30% compared to ≈ 15% in the case of chemical phosphatic fertilizers. Organic manure may be replaced with N containing inorganic chemicals fully or partly.
4. Phosphate Rich Organic Manure enhances the growth of soil microorganism that assist the dissolution of P either applied to the soil or naturally present in the soil.

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Odpadowe szlamy fosfatowe jako nawóz dla gleb zasadowych

Zagęszczacz fosforanowy w Eshidiya (Jordańskie Kopalnie Fosforanu) jest stosowany przez Jordanię w przypadku dwóch typów rud. Obie rudy są odszlamowane aby usunąć gliny, natomiast szlam jest odrzucany. Odrzucony szlam zawiera do 20% P_2O_5*. Przeprowadzono testy nad wykorzystaniem tego szlamu jako głównego nawozu zawierającego fosfor w przypadku gleb zasadowych/zasolonych w Jordanii i Indiach. Należy zauważyć, że szlam wraz z materiałami zawierającymi N pochodzenia organicznego lub nieorganicznego funkcjonuje jako znany nawóz fosforowy.*

Słowa kluczowe: fosfaty, szlamy, gleba zasadowa