Phosphate rich organic manure as fertilizer

D.M.R. Sekhar *, Y. Dassin *, Lutfi Momani ** and Abu-Hamatteh †

* Eshidiya Mines Box 30, Amman,11118, Jordan.
** Maaden Phosphate Company, P.O.Box: 32001, Al Khobar 31952, Saudi Arabia
† Al-Balqa' Applied University, Al-Salt, P.O.Box: 7064 (19117) Jordan

Certain types of rock phosphates of sedimentary origin are applied to acidic soils as fertilizer directly. Recent research in India showed that high grade rock phosphate in fine size when used as a mix with organic manure works as efficiently as di-ammonium phosphate (DAP) in alkaline soils. The rock phosphate from Jhamarkotra, India (sedimentary origin), Egypt (sedimentary origin) and South Africa (volcanic origin) showed good agronomic efficiency when used as Phosphate Rich Organic Manure (PROM). Further PROM shows equal residual effect. The results of efficiency of PROM made using two grades (+ 24% P_2O_5 and 34% P_2O_5) of rock phosphate mineral from Jordan show that low grade rock phosphate slimes are as effective as high grade phosphate concentrate when used in PROM. Also PROM is very effective even in the saline soils where DAP completely fails.

The world today consumes around 150 million tones of high grade phosphate mineral, 90% of which goes into the production of chemical phosphatic fertilizers such as di-ammonium phosphate (DAP), single super phosphate (SSP) *etc* which contain P in water soluble form.

Phosphorous is an important nutrient element for plants. The element P is a constituent of DNA and RNA molecules as well as ADP and ATP, the molecules that transfer energy, facilitating biochemical processes in the plants. Plants exude [1] organic acids (*e.g.* malic and oxalic acids) through their roots that dissolve phosphates naturally present in the soil, into their water soluble forms *viz*. $(H_2PO_4)^-$, $(HPO_4)^{-2}$, $(PO_4)^{-3}$ which in turn are taken up by the plants. A variety of microorganism present in the soil organic matter release organic acids that can dissolve soil phosphates. Single Super Phosphate (SSP) that contains P in water soluble form was produced [2] by the scientists of Rothamsted Experimental Station (England) in the year 1840 by reacting rock phosphate and sulfuric acid, with the idea of providing readily available P to the plants. This is followed by production of more complex phosphatic fertilizers that contain water soluble P. Increased agricultural production world over is partly due to the introduction of chemical fertilizers that contain NPK. Unfortunately 60% to 70% of the P applied to the soils, in the water soluble forms is unavailable to the plant [3] as applied phosphorous is fixed by Fe, Al, Mn ions in acidic soils and by Ca, Mg ions in alkaline soils into complexes that plants cannot take up. Phosphorous availability to the plants is maximum in the narrow soil pH range between 5.5 and 7. Excessive and indiscriminate application of chemical fertilizers show adverse impact on the soils in that soil micro flora and fauna (which impart natural properties to the soils) are destroyed thereby resulting into decreased agricultural production after years of application.

The phosphate rocks having high content of P soluble in 2% citric acid are considered for direct application in acidic soils. Phosphate rocks of sedimentary origin, that has PO_4^{3-} partly replaced by CO_3^{2-} isomorphically (carbonate apatites), show [4] high content of P soluble in 2% citric acid. On the other hand phosphate rocks of igneous origin show less solubility of P in 2% citric acid and hence they are not considered for direct application in acidic soils.

Often organic manures are assessed in terms of their content of nutrient elements such as N, P, K, *etc*. Microorganism that decay organic matter produce a variety of useful compounds such as gibberlins, auxins, vitamins, fulvic and humic acids that are vital for the plant growth, therefore fertilizers and minerals cannot replace manure in agriculture. Peat or lignite can partly replace organic manures or composts for they also contain humic acids. Organic matter in the soil greatly enhances the water holding capacity of the soil in addition to facilitate the aeration by keeping the soil loose.

PHOSPHATE RICH ORGANIC MANURE

It is observed [5,6] that farm yard manure (FYM) enriched with high grade (+34% P_2O_5) rock phosphate in fine size (d80 at 23 microns) shows better agronomic efficiency than di-ammonium phosphate when applied on equal P_2O_5 basis. Some initial results using Jhamarkotra rock phosphate (1T) are shown in Table 1. Few companies in India are now producing and marketing PROM on commercial scale. The advantage with PROM is that it shows equal residual effect, that is it works for two consequent crops. The dissolution of P from PROM is slow and is due to the organic acids released by the plant roots and microorganism hosted (naturally present or advertently added) by the soil and the soil organic matter. Further organic matter (that matrixed rock phosphate particles) complexes soil cations thereby preventing fixation of P.

Table 1

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

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 AND PROM

As it may be seen [7] from figure-1 and table 2 (Sekhar *et.al*., 2005) that, each type of rock phosphate shows a characteristic curve of increasing content of P soluble in 2% citric acid (Y axis) as the particle size decreases (X axis). More interesting is the fact that citric acid (2%) soluble P_2O_5 content of even the rock phosphate of igneous origin (Phalabora, South Africa) increases substantially. Studying these three types of phosphate minerals [8] in PROM, 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.

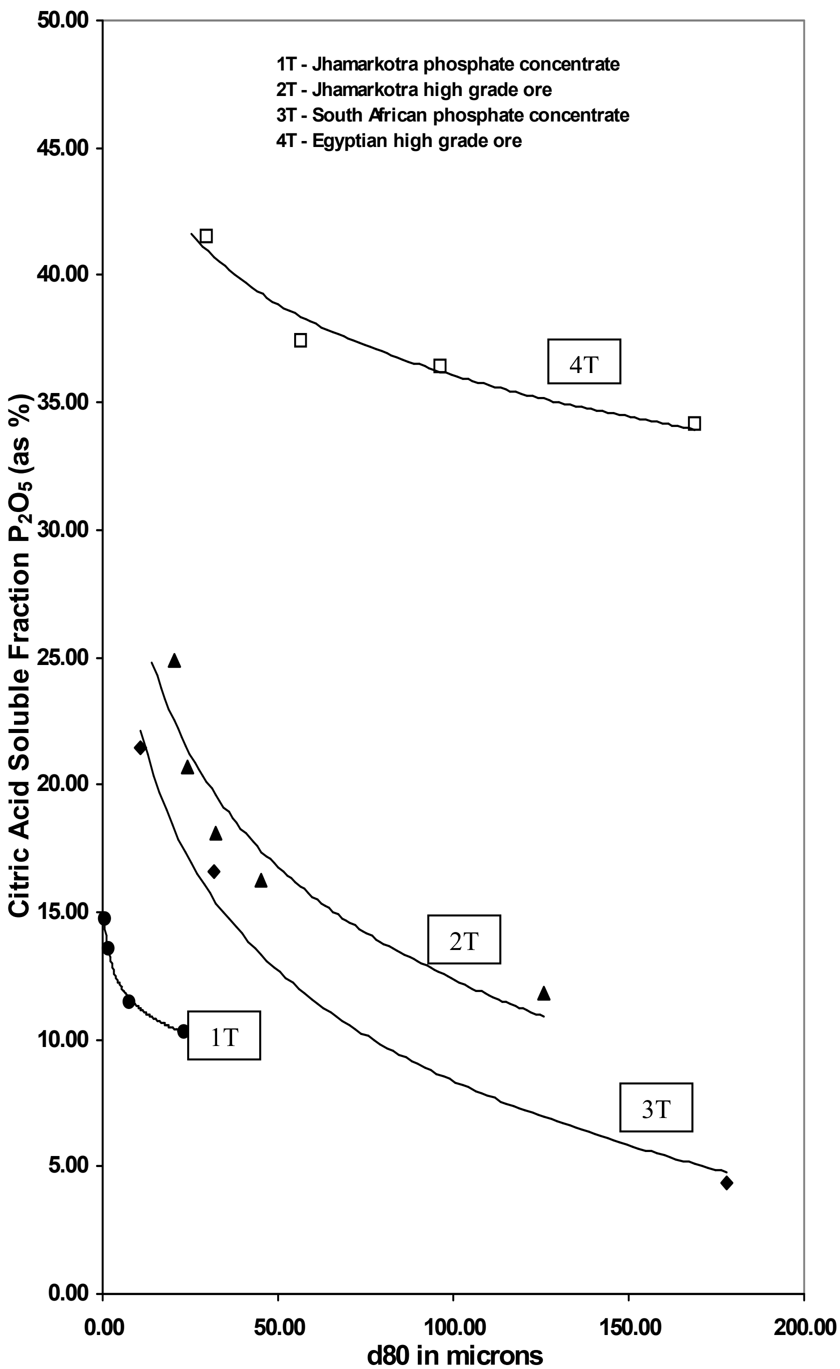

Figure1 - Increasing fraction (as %) of P_2O_5 soluble in 2% citric acid of rock phosphate mineral (from Egypt, India and South Africa) as the particle size decreases.

Table 2

Chemical Analysis of Phosphate rocks

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

PROM TRIALS WITH JORDAN PHOSPHATE ROCK

The flotation concentrate produced from Eshidiya plant analyzing 34.31 % P_2O_5 and the waste slimes from the same plant analyzing 24.48 % P_2O_5 are tested in the present study for use in PROM. The phosphate minerals are predominantly carbonate apatites. The description of these materials is given in table 3. DAP analyzing 46 % P_2O_5 and 18 % N from Aqaba Fertilizer complex of JPMC is used for the purpose of comparison.

Table 3

Chemical Analysis of Rock Phosphates used in the present study

S. No	Source & Type	Percent by weight									
	Place of origin / detail	d80 in µm	Total P_2O_5	Acid Insolubles	LOI	CaO	Al_2O_3	Fe_2O_3	MgO	Na_2O	K_2O
1.	Eshidiya Plant, Phosphate Concentrate	765	34.31	7.38	4.49	49.0	0.16	0.18	0.19	0.47	0.029
2.	Eshidiya Plant, Slimes going to waste after de-sliming the ore	79	24.48	27.12	5.90	35.1	3.29	2.23	0.77	0.50	0.194

335 grams of flotation concentrate analyzing 34.31 % P_2O_5 is mixed with 470 grams of oil cake [from an olive oil expeller] initially, the mix is further diluted in 8 kilograms of farm yard manure which is t_1 (treatment one). 470 grams of slime phosphate analyzing 24.48 % P_2O_5 is mixed with 470 grams of oil cake, the mix is further diluted with 8 kilograms of farm yard manure for t_2 (treatment two). 250 grams of DAP analyzing 46 % P_2O_5 is used in t_4 (treatment four). Treatment three, t_3 is blank *i*.e., absolute control. The nutrients (PROM or DAP) in treatments t_1, t_2 and t_4 are applied to the soil and the soil is turned and irrigated. Plots of size 1.45 meters x 2.45 meters were ploughed manually, PROM as t_1, $t_{2,}$ and DAP as t_4 were applied to the plots and watered. After 7 days Lettuce (*Lactuca sativa*) saplings of approximately equal size of 10 centimeters height were transplanted into the plots, each plot having sixteen saplings. The biomass production of lettuce after 60 days of transplantation of the saplings as a response to P nutrition from different sources is shown in table 4.

Table 4

Results of the Lettuce (*Lactuca sativa*) biomass production

SN	Treatment	Average biomass per plant in grams	Percent survival of the saplings
1	32.4 gms of P_2O_5 from concentrate, 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, 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

RESULTS AND DISCUSSION

The biomass production of lettuce per plant due to treatments t_1 and t_2 is almost the same that is the low grade slimy phosphate of Jordan in PROM showed equal agronomic efficiency to that of high grade rock phosphate concentrate. We expect the agronomic performance of DAP in treatment t_4 to be equal to PROM, that is treatments t_1, t_2 which surprisingly is not the case. This is noted to be due to high salinity of the desert soil of Eshidiya as indicated by electrical conductivity. The description of the soils is given in Table 5, where the electrical conductivity (EC) of the agricultural soils [9] of lower reaches of Zerka river (central Jordan valley) is also given The poor performance of DAP may be attributed to Ca and Mg ions which are known to fix water soluble phosphates into insoluble forms. Soil of Eshidiya where the tests are conducted contains around 5% water soluble salts [of Na, K, Ca, Mg, Fe as chlorides, fluorides, sulphates *etc*] by weight.

Table 5

Soil properties: Eshidiya (study area) and Central Jordan Valley (reference area)

S. No.	Parameter (average values of sample extract at 1:5 soil/water ratio }	Desert soil of Eshidiya	Central Jordan Valley
1.	pH	7.22	7.98
2.	EC (Electrical Conductivity in µs/cm)	15320.00	2215.15

We also note from our recent study [10] that the survival of the plants is 100% due to the application of PROM. Indeed composted manure is known [11] to improve even highly polluted tailings surfaces of the abandoned tailing impoundments of lead –zinc ore processing plants.

CONCLUSIONS

1. We show here that the low grade phosphate (slimes) separated from siliceous phosphate ore of Eshidiya mine, Jordan, is as effective in PROM, as the high grade phosphate concentrate produced from the same ore.
2. We further show that PROM is very effective as phosphatic fertilizer even in saline soils where DAP completely failed.
3. The use of PROM will reduce the cost of fertilization to the farmers and will also result into the conservation of phosphate mineral a non renewable resource due to the high residual effect.

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The phosphate samples are analyzed in the central research laboratory of JPMC located at Rusaifa (Jordan). The pH and EC are measured in the laboratory of Al-Balqa applied University, Jordan according to the method cited by Alaeddin *et al* [2007].

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