Wheat response to partially acidified phosphate rock, triple super phosphate and their combinations in Vertisols in Sudan

Abdelmoniem M.A. EITilib, Mubarak A. Abdalla and Mahgoub E. Abdelhafeez

Department of Soil Science, Faculty of Agriculture, University of Khartoum, Shambat, Sudan

.

ABSTRACT

Conventional water soluble phosphorus fertilizers(PF) such as triple super phosphate (TSP) is expensive because it is an imported commodity. Therefore, it is wise to substitute it by a cheap local material where possible. Phosphate rock (PR) was found to be a suitable material as a source of phosphorus (P) for plants. To investigate this, a two year(Novermber1999 and 2000) field experiment with wheat (*Triticum aestivum* L.), was carried out on a clay soil, in the Research Farm of the College of Agricultural Studies, University of Sudan. This was meant to test the agricultural value of using partially acidified phosphate rock (PAPR). Treatments consisted of two P sources (TSP and PAPR) applied at the rates of O, 43.0, 64.5 and 86.0 kg P_20_5 ha^{-1} Inoculation of wheat seeds with *Vesicular arbuscular* mychorrhiza (VAM) was also tested to determine its effects on release of P from PAPR. Results showed that P APR, alone or in combination with TSP، significantly increased grain and straw yield over those of TSP alone by 31 to 41% and 9 to 18% in the two seasons, respectively. Phosphorus residual effect on yield of grain and straw of wheat was significantly higher in plots treated with PAPR compared to those treated with TSP. Inoculation of the seeds with VAM fungus did not show any significant effects on yield. It could be concluded that, mixing PAPR with TSP increased its effectiveness relative to PAPR alone، and therefore PAPR is proposed as a source of P for irrigated wheat in the Vertisols of the Sudan.

INTRODUCTION

One of the major problems that limit economically successful agricultural production worldwide, is poor soil fertility. Addition of fertilizers is necessary to correct poor soil fertility by supplying the nutrients needed for optimum plant growth. Phosphorus, classified as a macronutrient, is an essential element for plant nutrition and oftentimes is deficient and of low solubility and therefore, has to be added as a fertilizer.

Studies conducted in Sudan indicated a positive response to phosphate fertilization (Mohammed, 1989; Ibrahim, 1995). However the use of conventional water soluble phosphorus fertilizers such as TSP by the local farmers is limited by its high cost. Finely ground PR ore had been used, as a direct application fertilizer or as an alternative to TSP (Chien and Menon,1995). Low reactivity and solubility of the PR limit its use for direct application (Goenadi et al., 2000).

Many efforts were exerted to enhance the effectiveness of PR. These included partial acidification (Goenadi et al., 2000), mixing with a water soluble P source (Chien et al., 1987); decreasing particle size (Babare et al., 1997) and by biological approaches such as inoculation by mychorrhiza (Barea, 1999).

Large quantities of PR deposits were discovered in Sudan and were investigated for their mineralogy, chemical composition and phosphorus content (Eltahir, 1999). Under the supervision of the Sudan Atomic Energy Commission (SAEC), Eltahir (1999) was able to produce a locally PAPR of low cost which met the universal safety measures of radioactivity in phosphate fertilizers. Moreover, he reported that the

transfer factor from soil to plant was inefficient which indicated a slow movement rate of radio-nucleotides from soil to plant. There are limited data on the use of PR of western Sudan as P source (Eltahir, 1999). Therefore, the aim of this work is to investigate the possibility

of substituting partially or completely, the imported TSP fertilizer by

the locally produced PAPR and also to test the effectiveness of P release by *Vesicular arbuscular* mychorrhiza (V AM) fungus on the cropping system of wheat.

MATERIALS AND METHODS

Field experiments were conducted during November 1999 and 2000 in the Research Farm of the College of Agricultural Studies University of Sudan for Science and Technology at Shambat (15˚ 36' N, 32˚ 32' E). The soil was Aridic Haplusterts, fine. smectitic, isohy perthermic. The climate of the study area lies within the semi-arid dry tropics with total annual rainfall of about 300 mm, maximum and minimum temperatures of 44C0 and

13.5Co, respectively, and average relative humidity during the study period of about 24%

A randomized complete block design (RCBD) with three replications was used to test the following treatments:

Treatment	Description
Op(T1)	TSP
IP(T2)	TSP
1.5P(T3)	TSP
2P(T4)	TSP
IP(T5)	PAPR
1.5P(T6)	PAPR
2P(T7)	PAPR
OP+VAM(T8)	
IP(T9)	PAPR+ VAM
1.5P(T10)	PAPR+ VAM
2P(T11)	PAPR+ VAM
IP(T12)	15% TSP+ 85% PAPR
1.5P(T13)	15% TSP+ 85% PAPR
2P(T14)	15% TSP+ 85% PAPR
1P(T15)	25%TSP +75% PAPR
1.5P(T16)	25%TSP +75% PAPR
2P(T17)	25%TSP +75% PAPR
1P(T18)	50%TSP +75% PAPR
1.5P(T19)	50%TSP +75% PAPR
2P(T20)	50%TSP +75% PAPR

The plot size was 3 x 4m. The part cropped for the first season was used in the second season to study the residual of P from TSP and The PAPR .

The field was disced, harrowed, leveled and then divided into 60 plots. Each plot was separated from the adjacent plot by 0.5 m in all directions. During the second season, each of these 60 plots was prepared manually to study the residual effect of P applied in the first season on yield of grain and straw of wheat.

Partially acidified phosphate rock (0.3% Na, 0.14% Mg, 1.15% K, 3.15% Ca, 3.65% Fe, 0.02% Ni, 375ppm Mn, 356ppm co, 447 ppm Cu, 1306 ppm Zn, 184 ppm Cd and 211 ppm Pb) was supplied by the Sudan Atomic. Energy Commission (SAEC). The original phosphate rock ore was obtained from Jebel Kurun (l1˚31'N and 31˚ 26' E). Nuba Mountains area of western Sudan. The acidification of the rock was conducted according to the procedure outlined by Eltahir (1999) who stated that in order to produce the highest percentage of available P, 100g of Kurun rock phosphate was soaked in water and 5 cm of commercial H_2S0_4 was added to each 100g (50 dm^3 t^{-1} rock phosphate). The containers were closed and left in the sunlight for seven days ،opened and allowed to dry. The TSP fertilizer was purchased from the local market. The rate of 43 kg P2 05 ha- was considered as the recommended dose. Phosphorus fertilizer from both sources (TSP and P APR) was placed with the seeds in the same lines. Nitrogen at the rate of 86 kg N ha^{-1} was applied before the second irrigation in the form of urea as a basal dressing.

Inoculation of wheat seeds with the mychorriza fungi for the treatments of PAPR + VAM was carried out at the Department of Botany and Biotechnology of the Faculty of Agriculture, University of Khartoum. The seeds were inoculated with *Vesicular arbuscular* myc -horriza (VAM) fungi using 250 g of inoculum of Sudan grass rhizo -sphere soil and root debris kg - of wheat seeds (Mahdi and Atabani, 1992).

In both seasons, wheat (*Triticunz aestivuna* var. Elneilien) was broadcast in November, 1999 and 2000, at the rate of 60 kg ha^{-1} and covered manually. The crop was irrigated at an interval of 12 days Weeding was carried out manually whenever needed. The crop was harvested in February 2000 and 2001 for the first and second seasons respectively.

After harvest, the straw from an area of 2 m^2 from each plot was weighed in the field and a sub-sample was taken for moisture content determination. Accordingly, straw dry matter (DM) was recorded in t ha^{-1} . Similarly, from the same area ($2m^2$), grain yield (kg ha^{-1}) from each plot was collected, dried at 60- 70˚C for 48 hrs, ground and analyzed for P content.

RESULTS

In the two seasons, treatments had significant effects on grain and straw yield (Table l). Yield from plots that received a combination of 50% TSP and 50%PAPR at 1.5 P level (T19) had significantly (P≤ (0.05) more grain yield than that of treatments l, 4 and 5. Treatment 9 resulted in the highest grain yield, whereas treatments I and 4 resulted in the lowest. There were no significant differences between the other treatments.

Table l. Effects of treatments on grain and straw yield of wheat (1999 And 2000).

Tr. no.	Grain yield (kg ha^{-1})		Straw yield (t ha^{-1})	
	1999	2000	1999	2000
1	1714.1 b	1700.3 bc	6.59 ghi	6.89 h
2	2065.4 ab	1943.7 abc	7.43 bcde	7.46 f
3	2120.7 ab	1828.6 abc	8.68 a	8.57 a
4	1614.1 b	1603.1 c	6.14 ij	6.69 i
5	1614.1 b	1691.8 bc	6.98 fgh	7.51 f
6	1937.5 ab	1900.3 abc	7.66 bc	7.10 g
7	1742.7 ab	2013.9 abc	5.86 jk	5.29 i
8	1766.8 ab	1800.9 abc	6.43 hi	6. 30 j
9	1916.0 ab	2151.0 a	7.48 bcd	7.45 f
10	1826.3 ab	1800.7 abc	6..97 efg	7.10 g
11	1750.2 ab	1805.3 abc	5.65 k	5.69 k
12	2069.9 ab	2060.6 ab	7.43 bcde	7.74 e
13	1969.2 ab	1813.9 abc	6.13 ij	6.19 j
14	1753.5 ab	1802.6 abc	6.85 fgh	6.90 h
15	1786.9 ab	1778.8 abc	7.11 def	7.72 e
16	2092.3 ab	1803.9 abc	7.81 b	8.30 b
17	1750.7 ab	1808.1 abc	7.75 b	7.70 e
18	2015.9 ab	1912.8 abc	7.18 cdef	7.89 d
19	2340.7 a	2091.4 ab	7.56 bcd	8.11 c
20	1798.0 ab	1976.8 abc	6.70 fgh	7.40 f

Means in the same column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test (DMRT).

Straw dry matter (SDM) yield in the first season was significantly (P≤ 0.05) affected by treatments (Table 2). The highest yield was observed in plots that received TSP at 1.5 P level 3) while the lowest was observed in PAPR + VAM plots at 2 P rates. In the second season, similar observations were recorded. It was also observed that the combination of TSP and PAPR had almost similar yield to TSP alone.

Table 2. Effects of treatments on straw and grain yield (phosphorus residual effect study).

Tr. no.	Grain yield (Kg ha^{-1})	Straw yield (t ha^{-1})
1	1779.7 b	8.82 o
2	20131.5 ab	9.27 n
3	1988.4	9.41 m
4	1732.5	12.97 g
5	1794.3	12.21 j
6	2064.6	11.44 k
7	2083.7	12.22 j
8	1856.6	9.04 o
9	2164.3	10.94 l
10	2004.8	11.50 k
11	1937.7	12.36 l
12	2161.9	12.48 d
13	1870.9	14.84 a
14	1883.5	13.82 d
15	1859.8	13.84 d
16	2096.4	13.10 f
17	1810.2 ab	13.99 c
18	2061.7 ab	12.44 l
19	2222.2 a	13.28 e
20	1844.6 ab	14.16 b

Means in the same column followed by the same letter(s) are not significantly different according to DMRT.

The concentration of leaf P at harvest of the first season and its content in the plots of the residual effect study are shown in table (3) Results showed that the addition of 25% TSP and 75% PAPR at 2 p had the highest leaf P in the first, second and third seasons (residual P). The lowest leaf P values were recorded with treatment 11 in the first season and treatment 5 in the second season.

In the first season, it was observed that if 75% or 85% of the p fertilizer was applied as P APR, the level of leaf P was similar of that TSP at IP level. Almost a similar trend was observed in the second season. The residual P experiment showed that, combining PAPR(75%) at 2 P level or adding PAPR alone at I .5 P level supplied the plants with significantly ($P<0.05$) more P than supplying by 2P level as TSP.

Table 3. Leaf phosphorus content (00) at harvest of the first (1999) and second (2000) seasons and phosphorus residual effect.

Tr. no.	First season	Second season	Phosphorus Residual effect
1	0.255 g	0.235 p	0.443 l
2	0.328 a	0.385 e	0.517 e
3	0.370 ab	0.362 d	0.523 d
4	0.328 c	0.322 i	0.481 g
5	0.255 ef	0.261 l	0.462 h
6	0.328 c	0.338 g	0.557 a
7	0.326 c	0.334 h	0.518 e
8	0.326 c	0.320 j	0.518 e
9	0.293 d	0.287 k	0.368 k
10	0.275 de	0.278 n	0.338 j
11	0.229 g	0.234 p	0.481 g
12	0.271 de	0.261 n	0.517 e
13	0.231 g	0.234 p	0.538 b
14	0.388 a	0.388 b	0.538 b
15	0.355 b	0.356 e	0.536 c
16	0.264 fg	0.261 n	0.507 f
17	0.388 a	0.391 a	0.557 a
18	0.351 b	0.348 f	0.538 b
19	0.246 fg	0.248 o	0.518 e
20	0.275 de	0.281 i	0.518 e

Means in the same column followed by the same letter(s) are not significantly different according to DMRT.

DISCUSSION

The results of the grain yield, for the first and second seasons and the P residual effect study, manifested an increased grain yield due to P application. The TSP treatments, at IP and 1.5 P levels, gave a higher grain yield than that of the PAPR at the same P levels; while PAPR treatment at 2 P out-yielded it's TSP counterpart. Mixing PAPR with TSP at the different percentages , resulted in similar, and sometimes higher yield than that of treatments receiving the TSP. Plots sown with VAM inoculated seeds gave about equal grain yield as that of the control. However, the plots sown with the inoculated seeds gave a decreased grain yield as the P level was increased. This reflected an adverse effect of high levels of P on the activity of the VAM fungus inreducing root infection.

Generally, the results showed an increased grain yield in response to P application, regardless of the P source, i.e., TSP, PAPR+ VAM and mixtures of PAPR+TSP at different percentages. Also, the results showed that acidification of PR and mixing of PAPR with TSP were as effective in increasing grain yields as a corresponding TSP level The increased grain yield in response to PAPR, as P source was investigated by many workers (Khasawnch and Doll, 1978; Alexakhin, 1999; Casanova and Salas, 1999). Positive effect of PAPR was earlier reported by Chien and Menon (1995) working on sulfuric acid based phosphate rock at 40% acidulation (SAB-PAPR 40%). They found that finely ground PR was less effective than PAPR and TSP, and that the PAPR was as effective as TSP.

In the present study, the noticeable effect of mixing PAPR and TSP، on grain yield was in accordance with the results obtained by Chien *et al*. (1987) who reported that mixing PR and TSP was similar to TSP in increasing grain yield. According to Mclean and Logan (1970), the increased effectiveness of PR in the presence of TSP could be due to the fact that the dissolved TSP probably reacted more with PR and less with A1 an Fe minerals in soils, thus increasing the water-soluble pool of P. They added that the TSP in the PR mixture, possibly stimulated early plant growth and root development. This was confirmed by Chien *et al*. (1987) who postulated that the increased effectiveness of mixing PR and TSP was probably due to the dissolution action of the monocalcium phosphate component of TSP on PR and stimulation of early root development.

Generally, most of the treatments showed a higher straw yield relative to the control in the first and the second seasons and also for the P residual effect study. The data (Table l) indicated that PAPR at I P and 1.5 P gave slightly lower straw yield than that of their corresponding levels of TSP, but higher than that of the control. mixing the PAPR and TSP resulted in straw yields which were about equal to or greater than that of the TSP at the different P levels. The plots that were previously treated with P gave higher straw yield than that of the control. This indicated a noticeable residual effect of the early applied P which resulted in increased solubility of P sources with time. Each of the plots receiving I P and 1.5 P as PAPR and sown with VAM inoculated seeds gave higher straw yield compared to that of the control. This was in conformity with the results of Kucey (1987) who found that inoculation of wheat and beans seeds with VAM gave a higher straw yield than that of the control. Also, he reported that in the solubilization of P was as effective as TSP. The present study showed that over the two seasons, the 2 P treatments as TSP or PAPR gave lower straw yield compared to that of the control. However, generally straw yield obtained from plot receiving a mixture of PAPR and TSP at different percentage gave higher straw yield over that of the control. The effect of P in increasing straw yield was in line with (he findings of Ibrahim and Adlan (1989).

Leaf P content at harvest showed low values than those of midseason, for the first and second seasons and residual effect study (data not shown). This decrease in P was expected, since most of the P absorbed by plants was usually translocated to the grains at maturity. Wild (1988) reported that, with wheat crop, at harvest only 17% of P was present in the straw whereas 83% of P was found in the grain. This study showed a general trend of higher P content of leaf at harvest from TSP treatments at any level of P for the two seasons compared to their counterparts of PAPR treatment (Table 4). However, PAPR at 2 P gave higher leaf P at harvest compared to that of their counterparts of TSP treatments for the two seasons. The PAPR alone and mixing of PAPR and TSP reflected a higher leaf P content than that of the control throughout the duration of the study.

Since the present study showed that mixing PAPR with TSP at different percentages invariably increased the effectiveness of PAPR and that PAPR proved to have a noticeable residual effect on the yield of grain and straw of wheat, it can be proposed that P fertilization of wheat in the irrigated Vertisols of Sudan can cheaply be achieved by' mixing PAPR of Jebel Kurun with TSP. The recommended percentage of PAPR and that of TSP should be based on economic evaluation.

ACKNOWLEDGEMENT

The authors are thankful to Dr. A. A. Mahadi for the supply of VAM fungus and also to the staff member of the SAEC for supplying the PAPR.

REFERENCES

Alexakhin, R. 1999. Studies of the effectiveness of rock agricultural countermeasure in soils contaminated by radionuclides, final repolt of the joint FAO/IAED, No. Dl 50.30, Vienna, Austria.

Babare, A. M., P. W. G. Sal, N. Fleming, D. 1. Graden and D. John- son. 1997. The agroncmic effectiveness of reactive phosphate rocks 5. The effect of particle size of a moderately reactive rock. Australian Journal of Experimental Agriculture 37 : 969-984.

Barea, J. M. 1999. The use of nychorrhiza and phosphate solubilizing microorganisms to improve the agronomic effectiveness of natural sources of rock phosphate. In the final report of the FAO/IAEA coordinate research project. Dl 50.30, Vienna, Austria.

Casanova, E. A. M. and M. T. Salas. 1999. The use of nuclear and related techniques for evaluating the agronomic effectiveness of phosphate fertilizers, in particular rock phosphate in Venezuela. Final report on the FAO/IAEA coordination research project, Dl- ‹50.03Vienna, Austria.

Chien, S. H. and R. G. Menon. 1995. Agronomic evaluation of modi- fied phosphate rock products. Fertilizer Research 41: 179-209.

Chien, S., H. F. Adams, F. E. Khasawneh and J. Jenao. 1987. Effect of combination of triple superphosphate and a reactive phosphate rock on yield and phosphorus uptake by corn . Soil Science Society of America Journal 51: 1656-1658.

Eltahir, M. A. 1999. Evaluation of some Sudanese rock phosphate and production of single superphosphate fertilizer. M. Sc. Thesis, Dept. of Chemistry, Faculty of Education, University of Khartoum‹ Sudan.

Goenadi, D. H. , S. Sugiarto and Y. Sugiarto. 2000. Bioactivation of poorly soluble phosphate rocks with a phosphorus solubilizing fun- gus. Soil Science Society Ainerica Journal 49: 927-932.

Ibrahim, H. S. 1995. Nutrition of wheat. In: Proceedings of wheat production and improvement in the Sudan. National Research Workshop, 27-30 August, 1995. ARC, Wad Madani, Sudan.

Ibrahim, H. S. and M. A. M. Adlan. 1989. Effects of time and rate of N application with P on the yield and uptake of N and P by wheat under two soil types in Northern Region. NV RP Annual National Wheat Co-ordination Meeting, 4-7 Sept., ARC, Wad Madani، Sudan.

Khasawnch, F. E. and E. C. Doll. 1978. The use of phosphorus for direct application to soils. Advances in Agronotny 30: 159-201.

Kucey, R.M.N. 1987. Increased phosphorus uptake by wheat and field beans inoculated with a phosphorus-solubilizing Penicillilll)l hilaji strain and with Vesicular arbuscular mychorriza fungi. Applied Environmental Microbiology 53:2699-2703.

Mahdi, A. A. and A. Atabani. 1992. Response of brady rhizobiunl inoculated soybean and lablab bean to inoculation with *Vesicular arbiscular* mychorriza. Experimental Agriculture 28: 390-407.

Mclean, E. O. and T. J. Logan. 1970. Sources of phosphonts for plants grown in soil with different phosphorus fixation tendencies. Soil Science Society of America Journal 34: 907-91 1.

Molvanuned, E. G. 1989. Effect of N level and time of application and P fertilizer on wheat grain yield under two different soil types in Shendi Area. Nile Valley Regional Programme, Annual National Coordinating Meeting 4-7, Sept., 1989. ARC, Wad Medani, Sudan.

Wild, A. 1988. The sources of plant nutrients in soil. Phosphorus. pp -742- .
695In: E. W. Russell (ed.). soil Conditions and Plant Growth,
I1th Edition. London Group Limited, UK.