Use of Gypsum and Sulphur for Improving Rock P Efficiency and Their Effect on Wheat Productivity and Soil Properties

Ghada F.H. El-Sheref, Hamed A. Awadalla, Gihan A. Mohamed
Soil, Water and Environment Res., ARC, Giza, Egypt.

ABSTRACT: Two field experiments were conducted in the Experimental Farm of Sids, Agricultural Research Station, ARC, Beni-Suef Governorate, Egypt on wheat (*Triticum aestivum* L.) to evaluate the effect of gypsum (0.0, 2.5 and 5.0 ton/fed) and sulphur (0.0, 200 and 300 kg/fed) on the efficiency of natural rock P at rate of (0.0 and 400 kg/fed), under the slightly alkaline soil and their effect on wheat productivity and some soil properties and fertility after wheat harvest. The results show that added 400kg rock P increased wheat growth (plant height and dry weight/plant), yield components (number of spikes/m^2, number of grains/spike and 1000-grain weight), yields (grain and straw), nutrients uptake (N, P and K uptake in grains and/or straw) and soil available P after harvest. Increasing gypsum levels improved all studied growth parameters, yields and yield components, nutrients uptake as well as improved soil reaction , salinity and soil available P after harvest . Sulphur application increased plant height, dry weight/plant, number of spikes/m^2, nutrient uptake, soil reaction and soil available P. Mixed gypsum or sulphur with natural rock P enhanced its effect on increasing wheat productivity and some soil properties and phosphorus availability after wheat harvest. The treatment of 400 kg rock P + 5.0 t/fed gypsum seems to be the favorable treatment for maximizing the wheat productivity and enhancing soil properties.

Key words: wheat, feldspar, gypsum, sulphur, nutrients uptake and soil properties.

INTRODUCTION

Directly applied of phosphate rock (RP) has increased in recent years. This is principally due to RP is usually the cheapest fertilizer and it can be efficient than soluble fertilizer in term of recovery of phosphate by plants even from short-term, where soluble P readily leached in sandy soils and possibly for long-term in other soils. The effectiveness of RP depended on its properties including particle size as well as chemical properties and type of soil on which RP is applied. The rock phosphate is less effective in direct application compared with ordinary calcium superphosphate, triple-superphosphate or di-ammonium phosphate. In this connection many authors reported that direct application of RP materials may be agronomical more useful and environmentally more feasible than soluble P such as Ranawat *et al.* (2009),Ali *et al.* (2012), Chaudhary *et al.* (2017) and Khan *et al*. (2017). In addition, Zapata and Roy (2004) mentioned that rock P materials are cheaper sources of P, however, most of them are not readily available to plants because the materials released slowly and their use as fertilizer often causes insignificant yield increases of current crops. Therefore, it could be improved the efficiency of RP as P source by using some methods such as microbial solubilizing of phosphate, organic manure, sulphur or gypsum.

Gypsum has used for reclamation of saline sodic soils. Yu *et al.* (2003) observed that spreading gypsum on the soil surface doubled the final water infiltration rate compared to that of control. Rashid *et al.* (2008) indicated that gypsum improved the wheat productivity and the moisture content in soil profile at sowing of wheat. Sulphur, as a constituent of gypsum, is essential for plant growth as it is involved in protein synthesis and is a part of some amino acids. It is required for nitrogen fixation by leguminous plants.

Sulphur management is an important issue in crop nutrition. Sulphur has a role in fundamental processes such as electron transport, structure and regulation. It also associated with photosynthetic oxygen production, abiotic and biotic stress resistance and secondary metabolism. Sulphur uptake, reductive assimilation and integration into cysteine and methionine are the central processes that direct oxidized and reduced forms of organically bound S into their various functions (Capaldi *et al., 2015*). On the other hand, elemental S has used for the reclamation and improvement of sodic and calcareous soils (Wassif *et al., 1993). Saleh (2001)* reported that sulphur has a favorable effects on promoting nutrient availability in soils, use of S as a nutrient and soil acidifier under used of natural sources as RP has recently gained importance in agricultural production (Atilgan *et al*., 2008). Added S dropped soil pH in sodic and calcareous soil (Abbaspour *et al.,* 2004). However, application of S with nitrogen fertilizers increased availability of phosphorus and micronutrients (Erdal *et al*., 2004).

The current work aims to evaluate the effects of gypsum or sulphur on enhancing the efficiency of rock phosphate as phosphorus fertilizers and its effects on wheat productivity, some soil properties and fertility after wheat harvest.

MATERIALS AND METHODS

Two field experiments were conducted at Sids Agric. Res. Station, Beni-Suef Governorate, ARC, Egypt during the two successive seasons of 2016/2017 and 2017/2018 to study the effect of application of different levels of gypsum (0.0, 2.5 and 5.0 ton/fed) and sulphur (0.0, 200 and 300 kg/fed) on increasing the efficiency of rock phosphate (at rate of 0.0 and 400 kg/fed) as phosphorus source contain about 10.2%P and their effects on wheat *(Triticum aestivum L.)* growth (plant height and dry weight/plant), yield components, i.e., number of spikes/m^2, number of grains/spike and 1000-grain weight, yield (grain and straw yields) and N, P and K uptake by wheat *(Triticum aestivum L.)* as well as some soil properties, i.e., soil pH, EC and organic matter, soil available N, P and K. A representative soil sample was collected from the experimental site at the depth of 0.0-30 cm before planting to determine some physical and chemical properties according to Jackson (1973) and listed in Table (1) Also, at the end of each season representative soil samples were collected from each experimental plots to determine soil pH, EC and organic matter as well as soil available N, P and K according to (Jackson, 1973).

Table (1). Some physical and chemical properties of the experimental soil

Soil properties	2016/2017	2017/2018
Particle size distribution		
Clay %	52.19	54.35
Silt %	28.31	23.76
Sand %	19.50	21.89
Texture class	Clay loam	Clay loam
pH (1:2.5 soil-water suspension)	8.16	8.21
EC, dSm^{-1} (soil paste extract)	1.02	1.16
Organic matter (%)	2.11	2.35
$CaCo_3$ (%)	2.3	1.9
Soil available N (mg kg^{-1})	21.6	25.4
Soil available P (mg kg^{-1})	12.3	11.6
Soil available K (mg kg^{-1})	165	179
Soil available S (mg kg^{-1})	8.5	9.1

Some chemical attributes of rock phosphate used in the experiment according to (Jackson, 1973) are presentment in Table 2.

Table (2). Some chemical contents of rock phosphate used in the experiments

pH (1:2.5 rock P-water suspension)	7.61
EC, dSm^{-1} (1:5 rock P-water extraction)	1.11
Soluble (cations):	
Ca^{++} (mg/100g)	46.15
Mg^{++} (mg/100g)	57.66
Soluble K^{+} (mg kg^{-1})	0.45
Soluble Na^{+} (mg kg^{-1})	16.13
Available P (mg kg^{-1})	26.18
Total P (%)	11.30

Rock phosphate, gypsum and sulphur added before wheat sowing during the land preparation. The design of the experiment was factorial (three factors), rock P ,gypsum and sulphur in randomized complete block design in four replication.

Wheat grains, C.V. Beni-Suef 1 variety sown during the third week of November for the two seasons at rate of 60 kg/fed. Nitrogen fertilizer applied at rate of 75 kg/fed as ammonium nitrate (33.5% N) in two equal doses, the first one before the first irrigation and the second one before the second irrigation. All other cultural practices for wheat production in district applied.

Wheat plants harvested during the first week of May for the two seasons. Representative ten wheat plants taken from each plots to determine growth parameters and yield components. Grain and straw yields were determined for each plots and converted to ardab/fed and t/fed, for grains and straw, respectively.

Samples from grains and straw were taken and analysed to determine N, P and K concentrations (according to Chapman and Pratt, 1961) and the obtained data was converted to N, P and K uptake.

The data subjected to statistical analysis according to Snedecor and Cochran (1980). Significant of differences between treatments compared using the least significant differences at 0.05, probability level.

RESULTS AND DISCUSSION

Growth parameters:

Table 3 show that, irrespective of gypsum or sulphur, added 400 kg rock P/fed had a positive effect on plant height and dry weight /plant. The relative increasing of plant height and dry weight /plant over no rock P reached to 6.4 and 15.2% in the first season and 6.7 and 14.3% in the second one, respectively. The promotive affect of natural P rock may be due its phosphorus content (about 11.5% total P). In this concern, Abou- el-Seoud and Abdel-Mageed (2012*)* found that plants treated with rock P minerals alone have root length higher than without P rock application, consequently take up more nutrients than those with short roots. Similar results obtained by Corretti *et al*. (2005) and Ahmed (2017*)*.

With respect to the main effect of gypsum, the results in Table 3 indicate that wheat plant height and dry weight /plant significantly responded to gypsum application in both seasons. Increasing gypsum level from 0.0 up to 5.0 t/fed increased plant height and dry weight /plant by about 7.1 and 18.6 % in the first season, respectively. Same trends obtained in the second season. The positive effect of gypsum on wheat growth may be due to addition of gypsum improved the physical properties of the sodic soils (the experimental soil having pH of 8.16 and 8.21 in both seasons), consequently led to increase nutrients availability (Niazi *et al.,* 2003). These results are in line with many authors such as AbouBakr *et al.* (1994*) and* Rashid *et al*. (2008).

Table(3). Growth, yields and its components of wheat as affected by rock P under different levels of gypsum and sulphur

Rock P (kg/fed) (A)	Gypsum (t/fed) (B)	Sulphur (kg/fed) (c)	Plant height (cm)		Dry weight/plant (g)		Number of spikes/m^2		Number of grains/spike		1000-grain weight (g)		Grain yield (ardab/fed)		Straw yield (t/fed)	
			I	II	I	II	I	II	I	II	I	II	I	II	I	II
0.0	0.0	0.0	88.1	90.3	1.96	1.99	301.2	303.7	80.1	81.2	45.2	45.6	15.3	16.1	4.2	4.4
		200	88.3	90.3	1.97	1.99	301.6	303.8	80.3	81.4	45.3	45.7	15.4	16.2	4.2	4.4
		300	88.4	90.5	1.97	2.00	301.5	304.1	80.3	81.4	45.3	45.7	15.4	16.3	4.3	4.5
	average		88.27	90.37	1.97	1.99	301.43	303.87	80.23	81.33	45.27	45.67	15.37	16.20	4.23	4.43
	2.5	0.0	91.6	93.3	2.01	2.05	325.5	326.6	83.5	84.3	45.4	45.7	17.9	18.5	5.0	5.2
		200	91.8	93.5	2.02	2.07	325.6	326.8	83.7	84.3	45.4	45.8	17.9	18.6	5.0	5.2
		300	91.9	93.4	2.01	2.06	324.8	326.7	83.8	84.5	45.6	45.8	17.8	18.6	5.1	5.3
	average		91.77	93.40	2.01	2.06	325.30	326.70	83.67	84.37	45.47	45.77	17.87	18.57	5.03	5.23
	5.0	0.0	93.9	95.8	2.21	2.26	336.7	341.1	86.6	87.6	45.5	45.8	19.3	20.2	5.8	6.0
		200	94.0	95.8	2.23	2.27	336.0	340.9	86.5	87.7	45.5	45.7	19.4	20.3	5.8	6.1
		300	94.0	95.7	2.22	2.26	336.2	341.3	86.5	87.5	45.6	45.8	19.4	20.2	5.8	6.1
	average		93.97	95.77	2.22	2.26	336.30	341.10	86.53	87.60	45.53	45.77	19.37	20.23	5.80	6.07
Average of P (0)			91.34	93.18	2.07	2.10	321.01	323.88	83.48	84.43	45.42	45.74	17.54	18.33	5.02	5.24
400	0.0	0.0	91.4	93.3	2.00	2.04	316.1	319.8	82.2	83.3	46.3	46.5	16.8	17.7	4.7	4.9
		200	93.5	95.1	2.11	2.17	326.5	329.7	83.3	84.5	46.9	47.2	16.9	17.8	4.8	4.9
		300	95.5	97.0	2.22	2.28	336.7	339.6	84.5	84.6	47.3	47.8	16.9	17.8	4.8	5.0
	average		93.47	95.13	2.11	2.16	326.43	329.70	83.33	84.13	46.83	47.17	16.87	17.77	4.77	4.93
	2.5	0.0	95.2	97.2	2.20	2.26	328.0	330.5	85.5	86.7	47.2	47.6	18.6	19.6	5.6	5.8
		200	97.7	99.3	2.31	2.35	328.2	330.7	85.7	86.7	47.9	48.3	19.2	20.2	5.7	5.9
		300	99.9	101.5	2.45	2.49	328.4	330.8	85.9	86.5	48.3	48.9	19.9	21.3	5.7	5.8
	average		97.60	99.33	2.32	2.37	328.20	330.67	85.70	86.63	47.80	48.27	19.23	20.37	5.67	5.83
	5.0	0.0	100.7	103.6	2.61	2.66	341.1	343.6	87.1	87.8	49.3	49.9	21.6	22.7	6.3	6.6
		200	100.8	103.7	2.62	2.66	341.3	343.8	87.3	87.9	49.3	49.8	21.7	22.8	6.4	6.6
		300	100.7	103.7	2.62	2.67	341.2	343.8	87.1	87.9	49.4	49.8	21.7	22.8	6.5	6.7
	average		100.73	103.67	2.62	2.66	341.20	343.73	87.17	87.87	49.33	49.83	21.67	22.77	6.40	6.63
Average of P (400)			97.26	99.38	2.35	2.40	331.94	334.70	85.40	86.21	47.98	48.42	19.26	20.30	5.61	5.80
Average of gypsum		0.0	90.87	92.75	2.04	2.08	313.93	316.79	81.78	82.73	46.05	46.42	16.12	16.99	4.50	4.68
		2.5	94.69	96.37	2.17	2.22	326.75	328.69	84.69	85.50	46.64	47.02	18.55	19.47	5.35	5.53
		5.0	97.35	99.72	2.42	2.46	338.75	342.42	86.85	87.74	47.43	47.80	20.52	21.50	6.10	6.35
Average of sulphur		0.0	93.48	95.58	2.17	2.21	324.77	327.55	84.17	85.15	46.48	46.85	18.25	19.13	5.27	5.48
		200	94.35	96.28	2.21	2.25	326.53	329.28	84.47	85.42	46.72	47.08	18.42	19.32	5.32	5.52
		300	95.07	96.97	2.25	2.29	328.13	331.05	84.68	85.40	46.92	47.30	18.52	19.50	5.37	5.57
L.S.D at 0.05																
	A		1.52	1.57	0.12	0.11	2.67	2.75	1.06	1.04	0.66	0.68	0.56	0.54	0.08	0.07
	B		1.01	1.11	0.08	0.07	1.78	1.71	0.93	0.92	0.03	0.05	0.39	0.41	0.06	0.05
	C		0.50	0.59	0.03	0.03	1.25	1.28	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
	AB		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
	AC		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
	BC		1.60	1.67	0.18	0.16	3.01	3.12	1.25	1.26	N.S	N.S	N.S	N.S	N.S	N.S
	ABC		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

As for sulphur, the data in Table 3 reveal that sulphur application was significantly increased wheat growth. The tallest and heaviest wheat plants recorded under added 300 kg sulphur /fed. Comparing with no sulphur application, added 300 kg S/fed, tallest and heaviest plant of wheat plants were obtained under the plants received 400 kg rock P/fed + 2.5 or 5.0 ton gypsum /fed + 300 kg S/fed. On the other hand, the plants without natural rock P + without both sulphur and gypsum exhibited the lowest plant height and dry weight /plant. It is clear from the results of the interaction that both Cooretti (1996) gypsum and sulphur had a positive effect on enhancing the efficiency of natural rock P as a phosphorus fertilizer source. This is mainly due to added both gypsum and sulphur in wet soil produced mineral acids which affecting the dissolving *rock P and decreasing the soil pH (see Table 6). Similar results were obtained by Niazi et al.,* (2003*)* and Rashid *et al.* (2008) for gypsum, and Ahmed (2017*).*

Yield attributes:

The main effect of natural rock P on yield attributes of wheat given in Table 3. The obtained results exhibited pronounced increases in number of spikes/m^2, number of grains/spike and 1000-grain weight due to applied 400 kg rock P. The relative increases in these studied yield attributes resulted by added rock P reached to 3.4, 2.3 and 5.6% over without rock P application in the first season, respectively. The corresponding increases in the second season were 3.3, 2.1 and 5.9% in the same respect. The positive effect of rock P on wheat yield attributes mainly explained by its effect on wheat growth as mentioned before. These results are in agreement with those obtained by Al Mamun *et al. (2012) and* Ahmed (2017*).* As for the main effect of gypsum, the results show that all studied yield attributes were gradually increased as the gypsum dose increased up to 5.0 t/fed, which mainly due to its effect on improving soil properties and plant growth as discussed former. In this connection, Yu *et al*. (2003) mentioned that spreading gypsum at the soil surface doubled the final water infiltration rate compared to that of control. These results are similar to those obtained by *Rashid et al*. (2008).

With regard to sulphur, the data reveal that sulphur application had a positive effect only on number of spikes/m^2 in the two studied seasons. The values of number of spikes/m^2 due to added 0.0, 200 and 300 kg S/fed were 324.77, 326.53 and 328.13 in the first season and 327.55, 329.28 and 331.05 in the second one, respectively. It is worthy to observe that number of grains/spike and 1000-grain weight were slightly increased but not significant due to sulphur application. These results are in harmony with these obtained by Jaggi *et al. (2005)* and Kacar and Katkat *(*2007).

Considering the effect of the interaction, the data show that both number of spikes/m^2 and number of grains/spikes affected by the interaction between gypsum and sulphur treatments, where the sulphur was not affected these two wheat yield components under the high dose of gypsum. In general, the maximum wheat yield attributes were produced under the treatment of 400 kg rock P + 5.0 t/fed gypsum + 300 kg S/fed. On the other hand, the lowest values of wheat yield attributes obtained at the control treatment (without rock P + zero of both gypsum and sulphur). These results support the synergistic effect of gypsum or sulphur on increasing the efficiency of natural rock P on wheat growth as mentioned before, consequently improved wheat yield components. These results are in line with those obtained by Chaudhary *et al.* (2015) for mixed rock P with gypsum and Besharati *et al*. (2007) for mixed rock P with Z increased grain and straw yield as compared with control. The increases were 9.8 and 11.8 % for grain and straw yields, respectively over without feldspar treatment in the first season. Same trends obtained in the second season. These increases might attributed to the role of phosphorus in facilitating biochemical process in plant, in turn enhanced plant growth and yield components as mentioned before. These results are in accordance with those obtained by Abou-Hussien *et al.* (2002) and Ahmed (2017).

As for the main effect of gypsum, the data in Table 3 reveal that both grain and straw yields of wheat significantly affected by gypsum application. Increasing gypsum dose up to 5.0 t/fed increased grain and straw yields by about 27.3 and 35.5% over control, respectively in the first season. The corresponding increases in the second season were 26.5 and 35.7% in the same order. These increases may be due to gypsum made phosphorus and micronutrient more available to plant by creating acidic condition through the formation of sulphuric acid in the presence of sufficient soil moisture, in turn reduce soil pH and improved plant growth (Melean and Ssali, 1977). Similar results reported by Chaudhary *et al.* (2015). With regard to the main effect of sulphur, the results in Table 3 reveal that sulphur had insignificant effect on wheat grain and straw yields, which mainly due to sulphur improved only number of spikes/m^2, while the two other yield components not affected by sulphur application.

Concerning the wheat yields as affected by the interaction between any two treatments or among them, the results in Table 3 clearly show that wheat yields did not affect by these interaction. The highest grain or straw yields were recorded under the wheat plants treated with 400 kg rock P/fed + 5.0 ton gypsum/fed. On the other hand, the plants without both rock P and gypsum possessed the lowest wheat yields. These results indicate that gypsum had a positive effect on improving the efficiency of natural rock P as phosphorus fertilize source. Similar results obtained by Chaudhary *et al. (*2015).

Nutrients uptake:

The data in Table 4 represent the effect of rock P, gypsum, sulphur, and their interaction on N, P and K concentrations and Tables (5 and 6) represent the uptake by wheat grains and/or straw. As for the main effect of natural rock P, the results clearly show that, rock P application at rate of 400 kg/fed was significantly increased N, P and K uptake in grains and straw as well as total uptake. The relative increases of total N, P and K due to rock P application reached to 12.2, 28.8 and 12.0% when compared with control, in the first season, respectively. Similar trends obtained in the second season. The positive effect of rock P on nutrients uptake is mainly due to its effect on both grain and straw yields (Table 3), since nutrient uptake calculated as multiplying yield by nutrient concentration. In this concern, Abbasi *et al. (*2015*)* mentioned that application of rock P directly to the soil had shown positive effect on root dry matter, consequently improved nutrient absorption. Similar results obtained by Correa *et al.* (2005) and Abd El-Hafeez *et* al. (2013).

Table (4). The N, P and K concentration in wheat grains and straw as affected by rock P under different levels of gypsum and sulphur

Rock P (kg/fed) (A)	Gypsum (t/fed) (B)	Sulphur (kg/fed) (C)	Grains						Straw					
			N%		P%		K%		N%		P%		K%	
			I	II	I	II	I	II	I	II	I	II	I	II
0.0	0.0	0.0	1.42	1.46	0.30	0.31	0.60	0.62	0.31	0.32	0.10	0.10	1.30	1.31
		200	1.43	1.45	0.32	0.33	0.60	0.60	0.31	0.32	0.12	0.13	1.30	1.31
		300	1.43	1.46	0.33	0.35	0.61	0.61	0.30	0.31	0.14	0.15	1.31	1.30
	average		1.43	1.46	0.32	0.33	0.60	0.61	0.31	0.32	0.12	0.13	1.30	1.31
	2.5	0.0	1.43	1.46	0.39	0.39	0.65	0.60	0.31	0.32	0.15	0.15	1.39	1.39
		200	1.43	1.46	0.42	0.43	0.66	0.65	0.31	0.31	0.17	0.17	1.39	1.40
		300	1.42	1.45	0.45	0.46	0.66	0.66	0.31	0.32	0.14	0.20	1.40	1.39
	average		1.43	1.46	0.42	0.43	0.66	0.64	0.31	0.32	0.15	0.17	1.39	1.39
	5.0	0.0	1.42	1.46	0.42	0.43	0.70	0.71	0.31	0.32	0.20	0.20	1.46	1.47
		200	1.43	1.45	0.44	0.45	0.71	0.71	0.32	0.31	0.22	0.23	1.47	1.47
		300	1.43	1.46	0.47	0.48	0.71	0.70	0.31	0.32	0.24	0.25	1.47	1.48
	average		1.43	1.46	0.44	0.45	0.71	0.71	0.31	0.32	0.22	0.23	1.47	1.47
Average of P			1.43	1.46	0.39	0.40	0.66	0.65	0.31	0.32	0.16	0.18	1.39	1.39
400	0.0	0.0	1.44	1.46	0.39	0.39	0.60	0.61	0.32	0.32	0.14	0.15	1.31	1.32
		200	1.43	1.45	0.40	0.41	0.60	0.61	0.32	0.32	0.15	0.17	1.31	1.32
		300	1.44	1.46	0.42	0.44	0.61	0.60	0.31	0.32	0.17	0.19	1.32	1.31
	average		1.44	1.46	0.40	0.41	0.60	0.61	0.32	0.32	0.15	0.17	1.31	1.32
	2.5	0.0	1.44	1.44	0.48	0.49	0.66	0.67	0.32	0.33	0.16	0.17	1.40	1.41
		200	1.43	1.42	0.50	0.51	0.65	0.66	0.32	0.31	0.18	0.19	1.41	1.41
		300	1.44	1.43	0.53	0.54	0.65	0.66	0.33	0.32	0.20	0.21	1.41	1.42
	average		1.44	1.43	0.50	0.51	0.65	0.66	0.32	0.32	0.18	0.19	1.41	1.41
	5.0	0.0	1.44	1.44	0.54	0.56	0.71	0.71	0.33	0.32	0.19	0.20	1.47	1.48
		200	1.43	1.44	0.54	0.56	0.70	0.71	0.32	0.33	0.21	0.22	1.48	1.48
		300	1.44	1.43	0.55	0.57	0.71	0.70	0.33	0.31	0.23	0.24	1.48	1.49
	average		1.44	1.44	0.54	0.56	0.71	0.71	0.33	0.32	0.21	0.22	1.48	1.48
Average of P			1.44	1.44	0.48	0.49	0.65	0.66	0.32	0.32	0.18	0.19	1.40	1.40
Mean effect of gypsum		0.0	1.44	1.46	0.36	0.37	0.60	0.61	0.32	0.32	0.14	0.15	1.31	1.32
		2.5	1.44	1.45	0.46	0.47	0.66	0.65	0.32	0.32	0.17	0.18	1.40	1.40
		5.0	1.44	1.45	0.49	0.51	0.71	0.71	0.32	0.32	0.22	0.23	1.48	1.48
Mean effect of sulphur		0.0	1.43	1.45	0.42	0.43	0.65	0.65	0.32	0.32	0.16	0.16	1.39	1.40
		200	1.43	1.45	0.44	0.45	0.64	0.66	0.32	0.32	0.18	0.19	1.39	1.40
		300	1.42	1.45	0.46	0.47	0.66	0.66	0.32	0.32	0.19	0.21	1.40	1.40
L.S.D at 0.05														
A			N.S	N.S	0.02	0.02	N.S	N.S	N.S	N.S	0.01	0.02	N.S	N.S
B			N.S	N.S	0.03	0.03	0.03	0.02	N.S	N.S	0.02	0.01	0.03	0.02
C			N.S	N.S	0.02	0.02	0.01	0.01	N.S	N.S	0.01	0.01	0.02	0.02
AB			N.S	N.S	0.04	0.04	0.04	0.04	N.S	N.S	0.04	0.03	0.04	0.04
AC			N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
BC			N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
ABC			N.S	N.S	0.05	0.05	0.05	0.05	N.S	N.S	0.05	0.04	0.05	0.04

Table (5). The N, P and K uptake in wheat grains and straw as affected by rock P under different levels of gypsum and sulphur

Rock P (kg/fed) (A)	Gypsum (t/fed) (B)	Sulphur (kg/fed) (C)	Grains						Straw					
			N (kg/fed)		P (kg/fed)		K (kg/fed)		N (kg/fed)		P (kg/fed)		K (kg/fed)	
			I	II	I	II	I	II	I	II	I	II	I	II
0.0	0.0	0.0	32.59	35.26	6.89	7.49	13.77	14.97	13.02	14.08	4.20	4.40	54.60	57.64
		200	33.03	35.24	7.39	8.02	13.86	14.58	13.02	14.08	5.04	5.72	54.60	57.64
		300	33.03	35.70	7.62	8.56	14.09	14.91	12.90	13.95	6.02	6.75	56.33	58.50
	average		32.88	35.40	7.30	8.02	13.91	14.82	12.98	14.04	5.09	5.62	55.18	57.93
	2.5	0.0	38.40	40.52	10.47	10.82	17.45	16.65	15.50	16.64	7.50	7.80	69.50	72.28
		200	38.40	40.73	11.28	12.00	17.72	18.14	15.50	16.12	8.50	8.84	69.50	72.80
		300	37.91	40.46	12.02	12.83	17.62	18.41	15.81	16.96	7.14	10.60	71.40	73.67
	average		38.24	40.57	11.26	11.88	17.60	17.73	15.60	16.57	7.71	9.08	70.13	72.92
	5.0	0.0	41.11	44.24	12.16	13.03	20.27	21.51	17.98	19.2	11.60	12.00	84.68	88.20
		200	41.61	44.15	12.80	13.70	20.66	21.62	18.56	18.91	12.76	14.03	85.26	89.67
		300	41.61	44.24	13.68	14.54	20.66	21.21	17.98	19.52	13.92	15.25	85.26	90.28
	average		41.44	44.21	12.88	13.76	20.53	21.45	18.17	19.21	12.76	13.76	85.07	89.38
Average of P (0)			37.52	40.06	10.48	11.22	17.35	18.00	15.58	16.61	8.52	9.49	70.13	73.41
400	0.0	0.0	36.29	38.76	9.83	10.35	15.12	16.20	15.04	15.68	6.58	7.35	61.57	64.68
		200	36.25	38.72	10.14	10.95	15.21	16.29	15.36	15.68	7.20	8.33	62.88	64.68
		300	36.50	38.98	10.65	11.75	15.46	16.02	14.88	16.00	8.16	9.50	63.36	65.50
	average		36.35	38.82	10.21	11.02	15.26	16.17	15.09	15.79	7.31	8.39	62.60	64.95
	2.5	0.0	40.18	42.34	13.39	14.41	18.41	19.70	17.92	19.14	8.96	9.86	78.40	81.78
		200	41.18	43.03	14.40	15.45	18.72	20.00	18.24	18.29	10.26	11.21	80.37	83.19
		300	42.98	45.69	15.82	17.25	19.40	21.09	18.81	18.56	11.40	12.18	80.37	82.36
	average		41.45	43.69	14.54	15.70	18.84	20.26	18.32	18.66	10.21	11.08	79.71	82.44
	5.0	0.0	46.66	49.03	17.50	19.07	23.00	24.18	20.79	21.12	11.97	13.20	92.61	97.68
		200	46.55	49.25	17.58	19.15	22.79	24.28	20.48	21.78	13.44	14.52	94.72	97.68
		300	46.87	48.91	17.90	19.49	23.11	23.94	21.45	20.77	14.95	16.08	96.20	99.83
	average		46.69	49.06	17.66	19.24	22.97	24.13	20.91	21.22	13.45	14.60	94.51	98.40
Average of P (400)			41.50	43.86	14.14	15.32	19.02	20.19	18.11	18.56	10.32	11.36	78.94	81.93
Average of gypsum		0.0	34.62	37.11	8.76	9.52	14.59	15.50	14.04	14.92	6.20	7.01	58.89	61.44
		2.5	39.85	42.13	12.90	13.79	18.22	19.00	16.96	17.62	8.96	10.08	74.92	77.68
		5.0	44.07	46.64	15.27	16.50	21.75	22.79	19.54	20.22	13.11	14.18	89.79	93.89
Average of sulphur		0.0	39.21	41.69	11.71	12.53	18.00	18.87	16.71	17.64	8.47	9.10	73.56	77.04
		200	39.50	41.85	12.27	13.21	18.16	19.15	16.86	17.48	9.53	10.44	74.56	77.61
		300	39.82	42.33	12.95	14.07	18.39	19.26	16.97	17.63	10.27	11.73	75.49	78.36
L.S.D at 0.05														
	A		0.74	0.71	0.61	0.60	0.72	0.73	0.66	0.65	0.54	0.56	1.10	1.13
	B		0.53	0.50	0.55	0.53	0.57	0.52	0.48	0.49	0.50	0.49	0.86	0.89
	C		0.16	0.14	0.09	0.09	0.18	0.16	0.18	0.17	0.08	0.09	0.31	0.35
	AB		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
	AC		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
	BC		0.89	0.83	0.83	0.81	0.92	0.94	0.92	0.90	0.78	0.75	1.54	1.59
	ABC		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

Table (6). Total N, P and K uptake as affected by rock P under different levels of gypsum and sulphur

Rock P (kg/fed) (A)	Gypsum (t/fed) (B)	Sulphur (kg/fed) (C)	N (kg/fed)		P (kg/fed)		K (kg/fed)	
			I	II	I	II	I	II
0.0	0.0	0.0	45.63	48.31	11.07	11.87	68.37	72.60
		200	46.02	48.24	12.45	13.75	68.44	72.25
		300	45.90	48.61	13.63	15.30	70.40	73.39
	average		45.85	48.39	12.38	13.64	69.07	72.75
	2.5	0.0	53.89	56.03	17.95	18.60	86.97	88.95
		200	53.89	56.21	19.79	20.85	87.20	90.91
		300	53.73	56.29	19.15	23.41	89.00	92.07
	average		53.84	56.18	18.96	20.95	87.72	90.64
	5.0	0.0	59.07	62.20	23.77	25.05	104.97	109.69
		200	60.21	62.73	25.58	27.75	105.90	111.31
		300	59.59	62.20	27.58	29.77	105.89	111.47
	average		59.62	62.38	25.64	27.52	105.59	110.82
Average of P (0)			53.10	55.65	18.99	20.70	87.46	91.40
400	0.0	0.0	51.32	53.79	16.39	17.73	76.66	80.85
		200	51.59	54.09	17.35	19.25	78.07	80.99
		300	51.41	53.88	18.80	21.24	78.80	81.53
	average		51.44	53.92	17.51	19.41	77.84	81.12
	2.5	0.0	58.13	60.29	22.35	24.25	96.83	101.49
		200	59.40	61.25	24.65	26.66	99.11	103.21
		300	61.81	64.53	27.20	29.41	99.75	103.42
	average		59.78	62.02	24.73	26.77	98.56	102.71
	5.0	0.0	67.44	69.80	29.44	32.27	115.63	121.86
		200	67.01	69.75	31.05	33.66	117.51	121.99
		300	68.31	70.33	32.84	35.59	119.29	123.75
	average		67.59	69.96	31.11	33.84	117.48	122.53
Average of P (400)			59.60	61.97	24.45	26.67	97.96	102.12
Average of gypsum		0.0	48.65	51.15	14.95	16.52	73.46	76.94
		2.5	56.81	59.10	21.85	23.86	93.14	96.68
		5.0	63.61	66.17	28.38	30.68	111.53	116.68
Average of sulphur		0.0	55.91	58.40	20.16	21.63	91.57	95.91
		200	56.35	58.71	21.81	23.65	92.71	96.78
		300	56.79	59.31	23.20	25.79	93.86	97.61
L.S.D at 0.05								
A			1.03	1.16	0.95	0.97	1.23	1.36
B			0.91	0.93	0.86	0.88	1.36	1.42
C			0.20	0.23	0.18	0.19	0.31	0.34
AB			N.S	N.S	N.S	N.S	N.S	N.S
AC			N.S	N.S	N.S	N.S	N.S	N.S
BC			1.46	1.62	1.66	1.49	2.00	2.10
ABC			N.S	N.S	N.S	N.S	N.S	N.S

As for gypsum, the data in Tables (5 and 6) reveal that N, P and K uptake by grains and /or straw significantly affected by increasing the dose of applied gypsum. Added 5.0 t/fed gypsum increased total N, P and K uptake by about 30.8, 89.8 and 51.7% over the control in the first season, respectively and 29.4, 85.7 and 32.7% in the second one.

The increases in nutrient uptake due to gypsum application is mainly due to its effect on improving soil properties, especially soil pH, consequently enhanced nutrient absorption. These results are in line with those obtained by Niazi *et al*. (2003). Regarding sulphur effect, the data in Tables (5 and 6) reveal that nutrients uptake significantly enhanced by sulphur z values for the second season were 1.6, 19.2 and 1.8% in the above-mentioned order. It is obvious to observe that sulphur had a pronounced effect on phosphorus uptake than nitrogen or potassium. The promotive effect of sulphur on nutrient uptake may be due to its effect on improve the availability of nutrients in alkaline soil (Neilsen *et al*., 1993*).*These results are in accordance with those obtained by Kacar and Katkat (2007) *and* Shivay *et al.* (2014).

As for the interaction effect, the data clearly show that N, P and K uptake by grains and/or straw were significantly affected by the interaction between gypsum and sulphur treatments, where sulphur did not affect N, P and K uptake under the high level of gypsum (5.0 t/fed). The highest N, P and K uptake by grains and/or straw were recorded for the plants treated with 400 kg rock P + 5.0 t/fed gypsum + 300 kg/fed sulphur, while the plants without application of rock P, gypsum and sulphur achieved by the lowest nutrient uptake. The enhancement of the efficiency of rock P on nutrient (Muchovej *et al.,* 1989). uptake by addition of gypsum and sulphur is mainly due to the effect of acid forming substances such as gypsum and sulphur on produce sulphuric acid, which lower pH near plant roots, consequently increased P availability from rock P and nutrient absorption Similar results were obtained by Chaudhary *et al. (*2015) and Ahmed (2017).

Soil properties:

The data of the effect of rock P, gypsum, sulphur, and their interaction on some soil properties after wheat harvest given in Table (7). As for the main effect of rock P, the results clearly show that rock P was not affected soil pH, EC and organic matter. Similar results obtained by Ali *et al*. (2009), El-Sheref (2012) and Ahmed (2017) for soil pH, EC and organic matter, respectively.

Concerning the main effect of gypsum, the data in Table 7 reveal that gypsum application had a promotive effect on reducing soil reaction and salinity which mainly due to gypsum consider as acid forming substance, consequently reduce soil pH (Stamford *et al.,* 2015). Also, gypsum doubled the final water infiltration rate, in turn increased the salt leaching from the soil (Rashid *et al*., 2008). Soil organic matter did not respond to gypsum treatment .Similar result were obtained by Bairagi *et al.(2017) and* Andrade *et al*. (2018).

With regard to sulphur application, the data in Table (7) clearly show that sulphur was only affected soil reaction. Increasing sulphur dose from 0.0 to 300 kg/fed reduce soil pH from 8.00 to 8.01 in the first season and from 8.05 to 7.99 in the second season. In this connection, Neilsen *et al. (1993)* stated that oxidation of sulphur into H_2SO_4 is beneficial for alkaline soils by reducing soil reaction.

These results are in line with those obtained by *Ali et al. (2009) and Ahmed (2017).* Turan *et al. (2013)* mentioned that, the reduction in pH level due to sulphur application to increase in the solubilization of soluble compounds and microbial activities, Similar results were obtained by Ali *et al. (2009),* Abd El-Hafeez *et al. (2013) and* Kuben Kulov *et al. (2013)* for rock P*,* De and Basak (1997) and Chaudhary et al. (2015) for gypsum, and Hellal et al. (2009) and Ahmed (2017) for sulphur.

As for the interaction effect, the data clearly show that not all the studied soil properties after wheat harvest affected by the interaction between treatments. In general added 5.0 ton gypsum/fed produced the lowest values of soil pH and EC, while added 300 kg sulphur/fed exhibited the favorable soil pH. Also, the results in Table 7 show that soil available phosphorus was significantly affected by rock P, gypsum and sulphur and their interaction, while soil available nitrogen and potassium did not affected. Application of 400 kg rock P or 5.0 t/fed or 300 kg/fed sulphur exhibited the highest values of soil available P (16.77, 14.72 and 13.05 mg/kg, respectively in the first season and 16.97, 14.90 and 13.37 mg/Kg, respectively in the second season). On the other hand, the control treatments of without each of rock P, gypsum and sulphur produced the lowest soil available P in both seasons.

The increasing of soil available P due to rock P application may be due to release phosphorus through rock P mineralization in soil *(*Gowda *et al*., 2011). On the other hand, the effect of gypsum or sulphur may be due to chemical weathering caused by gypsum or sulphur, which produced acids, consequently help in solubilizing fixed phosphorus in soil (Duponnois *et al*., 2005). Moreover, the data of the interaction between treatments show that soil fertility (available N, P and K) after wheat harvest did not effect by the interaction between treatments. This means that the highest values of soil available P recorded under the treatment of 400 kg rock P + 5.0 t/fed gypsum + 300 kg/fed sulphur. On the other hand, the treatment of without rock P + without gypsum + without sulphur gave the lowest soil available P.

From the results of the interaction, it could observed that gypsum and sulphur had a positive effect on increasing the solubility of rock P and release soil available P. Similar results obtained by Badr (2006*)* and Chaudhary *et al*., (2015).

Table (7). Soil properties after wheat harvest as affected by rock P under different levels of gypsum and sulphur

Rock P (kg/fed) (A)	Gypsum (t/fed) (B)	Sulphur (kg/fed) (C)	pH		EC		Organic matter (%)		Soil available N (mg/Kg)		Soil available P (mg/Kg)		Soil available K (mg/Kg)	
			I	II	I	II	I	II	I	II	I	II	I	II
0.0	0.0	0.0	8.15	8.13	1.27	1.19	1.35	1.43	21.3	25.6	8.1	8.4	170.5	181.3
		200	8.13	8.10	1.27	1.18	1.35	1.42	21.5	25.5	8.7	8.9	170.5	181.0
		300	8.12	8.10	1.27	1.19	1.36	1.43	21.0	25.6	9.5	9.9	170.5	181.5
	average		8.13	8.11	1.27	1.19	1.35	1.43	21.27	25.57	8.77	9.07	170.50	181.27
	2.5	0.0	8.08	8.07	1.20	1.11	1.35	1.43	21.2	25.5	10.3	10.5	175.9	186.2
		200	8.04	8.03	1.20	1.10	1.35	1.43	21.4	25.6	10.7	11.0	175.3	186.6
		300	8.01	8.00	1.20	1.11	1.36	1.42	21.5	25.6	11.1	11.5	175.8	186.3
	average		8.04	8.03	1.20	1.11	1.35	1.43	21.37	25.57	10.70	11.00	175.67	186.37
	5.0	0.0	7.97	7.96	1.17	1.05	1.36	1.42	21.3	25.5	12.3	12.5	181.3	192.5
		200	7.93	7.92	1.18	1.05	1.35	1.43	21.4	25.5	12.7	12.8	181.5	192.6
		300	7.89	7.87	1.18	1.06	1.35	1.42	21.5	25.6	13.0	13.2	181.6	192.3
	average		7.93	7.92	1.18	1.05	1.35	1.42	21.40	25.53	12.67	12.83	181.47	192.47
Average of P			8.04	8.02	1.22	1.12	1.35	1.43	21.34	25.56	10.71	10.97	175.88	186.70
400	0.0	0.0	8.15	8.13	1.28	1.14	1.35	1.43	21.4	25.6	11.5	11.9	170.7	181.7
		200	8.13	8.11	1.27	1.19	1.36	1.43	21.5	25.7	11.9	12.4	170.5	181.3
		300	8.11	8.10	1.28	1.18	1.36	1.42	21.6	25.5	12.5	12.8	170.6	181.5
	average		8.13	8.11	1.28	1.17	1.36	1.43	21.50	25.60	11.97	12.37	170.60	181.50
	2.5	0.0	8.04	8.06	1.21	1.12	1.35	1.44	21.6	25.5	13.6	13.6	175.8	186.3
		200	8.05	8.03	1.20	1.11	1.35	1.43	21.4	25.5	14.2	14.6	175.5	186.4
		300	8.01	8.00	1.20	1.10	1.36	1.43	21.3	25.6	14.9	15.3	175.6	186.4
	average		8.03	8.03	1.20	1.11	1.35	1.43	21.43	25.53	14.23	14.50	175.63	186.37
	5.0	0.0	7.98	7.95	1.17	1.06	1.36	1.43	21.3	25.6	16.2	16.4	181.9	192.6
		200	7.94	7.91	1.18	1.05	1.35	1.43	21.4	25.6	16.8	17.0	181.6	192.6
		300	7.90	7.87	1.17	1.06	1.35	1.42	21.5	25.7	17.3	17.5	181.7	192.5
	average		7.94	7.91	1.17	1.06	1.35	1.43	21.40	25.63	16.77	16.97	181.73	192.57
Average of P			8.03	8.02	1.22	1.11	1.35	1.43	21.44	25.59	14.32	14.61	175.99	186.81
Mean effect of gypsum		0.0	8.13	8.11	1.27	1.18	1.36	1.43	21.38	25.58	10.37	10.72	170.55	181.38
		2.5	8.04	8.03	1.20	1.11	1.35	1.43	21.40	25.55	12.47	12.75	175.65	186.37
		5.0	7.94	7.91	1.18	1.06	1.35	1.43	21.40	25.58	14.72	14.90	181.60	192.52
Mean effect of sulphur		0.0	8.06	8.05	1.22	1.11	1.35	1.43	21.35	25.55	12.00	12.22	176.02	186.77
		200	8.04	8.02	1.22	1.11	1.35	1.43	21.43	25.57	12.50	12.78	175.82	186.75
		300	8.01	7.99	1.22	1.12	1.36	1.42	21.40	25.60	13.05	13.37	175.97	186.75
L.S.D at 0.05														
	A		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	1.05	1.13	N.S	N.S
	B		0.02	0.01	0.02	0.03	N.S	N.S	N.S	N.S	0.02	0.02	N.S	N.S
	C		0.01	0.01	N.S	N.S	N.S	N.S	N.S	N.S	0.01	0.02	N.S	N.S
	AB		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
	AC		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
	BC		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
	ABC		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

CONCLUSION

The benefits of using natural fertilizers under gypsum and sulphur demonstrated the validity and possibility of sustained agronomic performance of wheat and reduce the cost of cultivation using cheap rock phosphate. Therefore, it could recommended to increasing wheat productivity and improving soil properties by mixed 5.0 t/fed gypsum and 300 kg/fed with 400 kg rock P under the alluvial soil of Middle Egypt.

REFERENCES

Abbasi, M.K., N. Musa and M. Manzoor (2015). Mineralization of soluble P fertilizers and insoluble rock phosphate in response to phosphate-solubilizing bacteria and poultry manure and their effect on the growth and P utilization efficiency of chilli (*Capsicum annuum* L.). Biogeosciences Discuss, 12: 4607-4619.

Abbaspour, A., V.C. Baligar and H. Shariatmadari (2004). Effect of steel converters as iron fertilizer and soil amendment in some calcareous soils. J. Plant Nutr. 27: 377-394.

Abd El-Hafeez, A. M., H.A. Awadalla and S.A. Ismail (2013). Influence of different sources and levels of nitrogen and rock phosphate addition on maize productivity and soil fertility. J. Soil Sci. and Agric. Eng., Mansoura Univ., 4(11): 1313-1328.

AbouBakr, A.A., M.A. Mahdy, A.O. Osman and S.A. Ismail (1994). Effect of gypsum and phosphorus application on peanut yield and quality. Egypt, J. Appl. Sci., 9(10): 358-371.

Abou-el-Seoud, I.I and A. Abdel-Megeed (2012). Impact of rock materials and biofertilization on P and K availability for maize (Zea maize) under calcareous soil conditions. Saudi Journal of Biological Sciences, 19: 55-63.

AbouHussien, E.A., M.A. Abou El-Fadl, S.A. Ramadan and H. Khalil (2002). Response of wheat and broad bean plants to phosphorus under diffirent soil conditions. Egypt J. Agric. Res, 80(1): 41-55.

Ahmed, T.A.M. (2017). Studies on phosphorus fertilization for wheat plants. Ms.C. Thesis.Fac. of Agric.,Benha Univ. Egypt.

Ali, Sh. F., S. A. Ismail, M. A. Ali and M. Fayez (2009). Integrated organic and inorganic fertilization regimes are indispensable for appropriate canola growth and oil yield. J. Agric. Sci., Mansoura Univ., 34 (6): 5801-5817.

Ali, M. E., S. A. Ismail, A. H. Abd El Hameid, O. H. EL.Hussieny and Gh. F. H. El-Sherf (2012). Effect of nature fertilizers under different levels of nitrogen and farmyard manure on the productivity of maize. Fayoum J. Agric. Res.& Dev., 26 (1): 49-63.

Al Mamun, N., S. Rahman, N.M. Jahangir, M. S. Moula and K.N. Islam (2012). Effect of phosphate rock on the growth and yield of wheat (*Triticumaestivum* L.)under old brahmaputra floodplain soils. A Scientific Journal of Krishi Foundation, 10(1): 31-37.

Andrade, J.J., F.J.M. Oliveira, L.G.M. Pessoa, S.A.S. Nascimento, E.S. Souza, G.B. Junior, M.F.A. Miranda, A.C. Oliveira and M.B.G.S. Freire (2018). Effect of elemental sulphur associated with gypsum on soil salinity attenuation and sweet sorghum growth under saline water irrigation. Austoralian J. of Crop Sci., 12(02): 221-226.

Atilgan, A., A.Coskan, T. Alagoz and H. Oz (2008). Application level of chemical and organic fertilizers in the greenhouses of Mediterranean Region and its possible effects. Asian J. Chem., 20:3702-3714.

Badr, M.A. (2006). Efficiency of K-feldspar combined with organic materials and silicate dissolving bacteria on tomato yield. J. Appl. Sci. Res., 2(12): 1191-1198.

Bairagi, M.D., A.A. David, T. Thomas and P.C. Gurjar (2017). Effect of different level of NPK and gypsum on soil properties and yield of groundnut (*Arachishypogaea* L.)var. jyoti. Int. J. Curr. Microbiol. App. Sci., 6(6): 984-991.

Besharati, H., K. Atashnama and S. Hatani (2007). Biosuper as a phosphate fertilizer in a calcareous soil with low available phosphorus. African J. of Biotecnology, 6: 1325-1329.

Capaldi, F.R., P.L. Gratao, A.R. Reis, L.W. Lima and R.A.Azevedo (2015). Sulphur metabolism and stress defense responses in pants. Tropical Plant Biology, 8(3-4): 60-73.

Chapman, H.D. and P.F. Pratt (1961). Method of Analysis for Soils, Plants and Water.Univ. of California, Division of Agric. Sci.

Chaudhary, S.K., R. Kumar, A.K. Singh and R. Kumar (2015). Effect of acidulated rock phosphate on growth yield attributes and yield of wheat (*Triticum aestivum* L.). Indian J. Agric. Res., 49(6): 574-576.

Chaudhary, S.K., M. Hashim, M. Saquib and C.B. Singh (2017). Yield, NPK content and nutrient uptake of wheat as influenced by the application of acidulated rock phosphate. Bangladesh J. Bot., 46(1): 187-194.

Cooretti, S.P. (1996). Plant Nutrition Sulphur. A Review of Nutrient Balance, Environment Impact and Fertilizer. Fert., Res. 43: 117-125.

Correa, R.M., C.W.A. Nascimento, S.K. Souza, F.J. Freie and G.B. Silva (2005). Gufsa rock phosphate and triple superphosphate for dry matter production and P uptake by corn. Scienta Agricola, 62(2): 159-164.

De, G.K. and R.K. Basak (1997). Effect of partially acidulated rock phosphate on phosphorus availability in alkaline soil. Indian Agriculurist, 41: 131-138.

Duponnois, R., C. Aline, H. Victor and T.Jean (2005). The mycorrhizalfungs glomusintraradices and rock phosphate amendment influence plant growth and microbial activity in the rhizosphere of Acociaholosericea. J. Soil Biol. and Biochem., 37: 1460-1468.

El-Sheref, Gh. F.H. (2012). Minimizing pollution with inorganic fertilizers through some nutritional techniques. Ph.D. Thesis, Fac. of Agric., Benha Univ., Egypt.

Erdal, I., K. Kepenek and I. Kizilgoz (2004). Effect of foliar iron applications at different growth stages on iron and some nutrient concentrations in strawberry cultivars. Turk. J. Agric. Forest, 28: 421-427.

Gowda, A.M., A.A. El-Taweel and K.B. Eassa (2011). Studies on reducing the harmful effect of saline water irrigation on picual olive trees. Minufiya J. Agric. Res., 36(3): 623-645.

Habashy, N.R. and M.M. Bishara (2013). Effect of applied bio-fertlizers, seaweed extract and elemental sulphur on productivity of sunflower grown in Newly reclaimed slightly saline soil. Egypt J. Soil Sci., 53(1): 21-38.

Hellal, F.A., M. Abd El-Had and A.A.M. Ragab (2009). Influence of organic amendments on nutrient availability and uptake by faba been plants fertilized by rock phosphate and feldspar. American-Eurasian J. Agric., & Environ, Sci., 6(3): 271-279.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice-Hall of India, Private and LTD., New Delhi (2ndед). Indian.

Jaggi, R.C., M.S. Aulakh and R. Sharma (2005). Impacts of elementalsulpur supplied under various temperature and moisture regimes on pH and available P in acidic, natural and alkaline soils. Biol. Fertilizer Soils, 41: 52-58.

Kacar, B. and A.V. Katkat (2007).“Plant Nutrition”.3thEdn. Nobel Press, Ankara, Turkey.

Khan, K., M. Sharif, I. Azeem, A.A. Khan, S. Ali, I. Khan and A. Khan (2017). Phosphorus solubility from rock phosphate mixed compost with sulphur application and its effect on yield and phosphorus uptake of wheat crop. Open J. of Soil Sci, 7: 401-429.

Kubenkulov, K., A. Naushabayev and D. Hopkins (2013). Reclamation efficiency of elemental sulphur on the soda saline soil. World Appl. Sci. J., 23(9): 1245-1252.

Melean, E.O. and H. Ssali (1977). Effect of phosphorous rate and form of combination with lime and gypsum on yield and composition of German millet and alfalfa from highly weathered soils. Soil Sci., 123: 155-164.

Muchovej, R.M., J.J. Muchovej and V.H. Alvarez (1989). Temporal relations of phosphorus fractions in anoxisol amended with rock phosphate and Thiobacillusthiooxidans. Soil Science Society of America Journal, 53: 1096-1100.

Neilsen, D., E.J. Hogue, P.B. Hoyt and B.G. Drought (1993). Oxidation of elementalsulphur and acidification of calcareous orchard soils in Southern British Columbia Can. J. Soil Sci., 73: 103-114.

Niazi, B.H., I.U. Haq, M. Salim and M. Ahmed (2003). Use of gypsum to increase fertilizer efficiency on normal soils. Asian Journal of Plant Sciences, 2(9): 673-676.

Ranawat, P., K.M. Kumar and N.K. Sharma (2009).A process for making slow-release phosphate fertilizer from low-grade rock phosphate and siliceous tailings by fusion with serpentinite. Curr. Sci. 96(6): 843-848.

Rashid, M., M.N. Iqbal, M. Akram, M. Ansar and R. Hussain (2008). Role of gypsum in wheat production in rainfed areas. Soil & Environ., 27(2): 166-170.

Saleh, M.E. (2001). Some agricultural applications for biologically produced sulphur recovered from sour gases. I. Effect on soil nutrients availability in highly calcareous soils. In: “International Symposium on Elemental Sulphur for Agronomic Application and Desert Greening”. United Arab Emirates University, Feb. 24-25, 2001, Abu Dhabi, UAE.

Shivay, Y.S., R. Prasad and M. Pal (2014). Effect of levels and sources of sulphur on yield, sulphur and nitrogen concentration and uptake and S-use efficiency in basmati rice. Communications in Soil Science and Plant Analysis, 45(18): 2468-2479.

Snedecor, G.W. and W. G. Cochran (1980). Statistical Methods. 7^{th} (Ed.), Iowa State Univ., Press, Ames, Iowa, USA.

Stamford, N.P., M.V.B. Figueiredo, S.S. Junior, A.D.S. Freitas, C.E.R.S. Santos and M.A.L. Junior (2015). Effect of gypsum and sulphur with acidithiobacillus on soil salinity alleviation and cowpea biomass and nutrient status as affected by PK rock biofertilizer. Sci. Hortic-Amsterdam, 192: 287-292.

Turan, M.A., S. Taban, A.V. Katkat and Z. Kucukyumuk (2013). The evaluation of the elemental sulphur and gypsum effect on soil pH, EC, SO_4-S and available Mn content. Journal of Food, Agricultural & Environment, 11(1): 572-575.

Wassif, M.M,, A.M. Elgala, M.A. Mostafa and S.E. El-Maghraby (1993). Effect of elemental sulphur and water salinity in two calcareous soils.“2^{nd} African Soils Sci. Soc. Conf. Proc.,” Nov., Cairo, Egypt.

Yu, J., T. Lei, I. Shainberg, A.I. Mamedov and G.J. Levy (2003). Infiltration and erosion in soils treated with dry PAM and gypsum. Soil Science Society of America Journal, 67: 630-636.

Zapata, F. and R.N. Roy (2004). Use of phosphate rock for sustainable agriculture. In: Fertilizer and Nutrition Bulletin (FAO), 13: 148. FAO, Rome (Italy). Land and Water Development Div., International Atomic Energy Agency, Vienna (Ausria).

الملخص العربي

استخدام الجبس والكبريت لتحسين كفاءة صخر الفوسفات وتأثيرهما على إنتاجية القمح وبعض خواص التربة

غادة فتح الله حافظ الشريف حامد علي عوض الله جيهان عبد الرءوف محمد

معهد بحوث الأراضي والمياه والبيئه – مركز البحوث الزراعية – الجيزة – مصر

أجريت تجربتان حقليتان على القمح بالمزرعة البحثية بمحطة البحوث الزراعية بسدس/محافظة بنى سويف /مركز البحوث الزراعية لتقييم استخدام إضافة الجبس (٠ ، ٢.٥ ، ٥ طن/ فدان) والكبريت (٠ ، ٢٠٠ ، ٣٠٠ كجم/ فدان) لزيادة كفاءة صخر الفوسفات كسماد فوسفاتي بمعدلات (٠ ، ٤٠٠ كجم/ فدان) وتأثيرهم علي إنتاجية القمح وبعض خواص التربة وكانت أهم النتائج كما يلي:-

- أدي إضافة ٤٠٠ كجم/ فدان صخر فوسفات الي زيادة صفات النمو (طول النبات والوزن الجاف للنبات) ومكونات المحصول (عدد السنابل/ م^{٢}، عدد الحبوب في السنبلة ، وزن الألف حبة) ومحصول الحبوب والقش ، زيادة الممتص من عناصر النيتروجين والفوسفور والبوتاسيوم ، وتحسين كلا من حموضة التربة وملوحتها وصلاحية الفوسفور بعد الحصاد.

- أدي إضافة الجبس الي تحسين كل صفات النمو ومكونات المحصول والمحصول وامتصاص العناصر وحموضة التربة وملوحتها وصلاحية الفوسفور بعد الحصاد.

- أدي إضافة مستويات من الكبريت الي زيادة طول النبات والوزن الجاف للنبات وعدد السنابل/ م^{٢} وامتصاص العناصر وحموضة التربة وصلاحية الفوسفور بعد الحصاد ، ولم يؤثر الكبريت علي عدد الحبوب في السنبلة ووزن الألف حبة ومحصول الحبوب والقش.

- خلط الجبس والكبريت مع صخر الفوسفات أدي الي زيادة كفاءتة كمصدر للتسميد الفوسفاتي لزيادة إنتاجية القمح وبعض خواص التربة وصلاحية الفوسفور.

- كانت معاملة ٤٠٠ كجم/ فدان صخر الفوسفات + ٥.٠ طن/ فدان جبس + ٣٠٠ كجم/ فدان /تربة هي الأفضل لتعظيم إنتاجية القمح وتحسين خواص التربة بعد الحصاد.

من نتائج الدراسة يمكن التوصية بتسميد نبات القمح بمعدل ٤٠٠ كجم صخر فوسفات للفدان مع إضافة ٥ طن/ فدان جبس و٣٠٠ كجم/ فدان كبريت لزيادة إنتاجية القمح وتحسين خواص التربة بعد الحصاد.