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EFFICIENCY OF SULFUR, COMPOST AND PHOSPHOREEN AS A DIRECT AND RESIDUAL EFFECT IN SUSTAINABLE AGRICULTURE

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ABSTRACT: *A field experiment was conducted on calcareous soil at El- Nubaria Agriculture Research Station, El - Behera Governorate to study the efficiency of sulfur (mineral fert), compost (organic fert) and phosphoreen (bio fert) with two different sources of phosphorus (rock phosphate and superphosphate) on physiochemical soil properties and yields of wheat as direct and succeeded by maize as residual effect grown on a calcareous soil. To fulfill this objective, two field experiments were conducted on EI-Noubaria calcareous soil during two successive winter (2014 -2015) and summer seasons (2015). The treatments were : A- amendments factor as control, sulfur by rate, 1 ton fed^{-1} as mineral fertilizer, compost, 10 ton fed $^{-1}$ as organic fertilizer and phosphoreen seed inoculation with PDB as bio fertlizer and two sources of phosphorus (control , rock phosphate and superphosphate) . The experimental plots were distributed in a split-plot design. Wheat (Triticum aestivum L, cv. Sakha 93) was cultivated within the first half of November 2014 then harvested in May 2015. The second experiment was conducted to study the residual effect of the aforementioned treatments on maize (Zea maize L, c v. single cross 10) cultivated at the same experimental plots in the second half of May 2015 and harvested at the end of August (2015). The results indicated that: The treatment of sulfur combined with super phosphate treatment has the highest effect in lowering pH values followed by compost treat. Also bio fertilizer showed moderately values. EC values of soil were increased by sulfur application combined with super phosphate treatment wheres, compost caused reductions in the EC values as compared to the control. The highest values of OM were recorded by compost combined with super phosphate treatment over sulfur followed by bio fertilizer. An improvement in soil physical properties as affected by soil amendment was observed. Wherever a slight decreased in soil bulk density (BD), an increase in both soil total porosity (TP) and soil hydraulic conductivity (HC) with using compost (organic fert) than sulfur (mineral fert) followed by phosphoreen (bio fert) were occurred. Compost combined with super phosphate treatment achieved the highest biological, grain yield and 100 grains weight of wheat and maize plant followed by sulfur combined with super phosphate treatment. Compost treatments significantly increased NPK uptake of wheat and maize crop. Also data revealed the superiority of compost treatments over sulfur followed by biofertilizer combined with super phosphate, compared to that treatment combined with rock-phosphate. Generally, the different soil properties and crop yield of wheat and maize plant grown on calcareous soil were more affected by compost combined with super phosphate treatment than sulfur followed by bio fertilizer addition compared to rock phosphate treatment.*

Key words: *Compost, sulfur, bio fertilizer, superphosphate, rock phosphate, calcareous soil, wheat and maize crop.*

INTRODUCTION

Wheat, along with maize and rice, is one of the world's leading grain crops. Phosphorous is considered as the second macronutrient after nitrogen, which is essential for plant growth. Calcareous soils are frequently characterized by its low bioavailability of plant nutrients due to high base status and pH between 7.5 and 8.5 and the presences of carbonate minerals (Marschner, 1998). The level of available phosphorus in that soil decreases sharply after a short period since application. Under alkaline soil conditions, the available phosphorus in the added fertilizer is rapidly transformed to tricalcium phosphate which is unavailable to the plants Miller *et al.* (1990). The P concentration in the soil solution is the factor most closely related to P availability to plants. This concentration is related to the solid forms of P that dissolve to replenish soil solution P following its depletion by crop uptake. Many different solid forms of phosphorus exist in combination with Ca in calcareous soils. After P fertilizer is added, it undergoes a series of chemical reactions with Ca that decrease its solubility with time (a process referred to as P fixation) (Leytem and Mikkelsen, 2005), they also stated that The efficiency of P fertilizers in these soils is generally very low because P applied to the soil reacts with Ca forming minerals such as dicalcium phosphate dihydrate, octacalcium phosphate, and ultimately hydroxyl-apatite. Considering the low recovery of applied and native P and the high cost of chemical phosphatic fertilizers in addition to an increasing concern about environmental degradation, it is important to find solutions to increase P fertilizer use efficiency. Two management options can be effective: (i) increasing the recovery and solubility of applied P fertilizers and (ii) replacing the expensive chemical P fertilizers with cheaper and more ecologically friendly but nevertheless efficient P sources, such as indigenous rock phosphates. Rock phosphate is a raw material in the manufacture of chemical phosphatic fertilizers and during the last decade, has been recognized as an important alternative economical source of P for the crops. The high cost of single or triple super phosphate fertilizer production has generated considerable interest toward direct utilization of rock phosphate. However, direct application of rock phosphate is not a common practice because of its low solubility in calcareous soils Hence, application of sulphur to calcareous soil is known to convert the unavailable form of nutrients to available form through bio-chemical reactions and desorption process (Abdou, 2006). Rock phosphate is the main source for producing phosphate fertilizers. The direct application of apatite instead of phosphate fertilizers is not suitable, especially in soils with a high pH. However, using acidic materials such as sulphur and sulphuric acid, or using rock phosphate combined with phosphate dissolving bacteria (PDB) such as Pseudomonas which can produce some organic acids will release phosphorous from rock phosphate and can replace P-fertilizers . Therefore, rock phosphate is a good source of phosphorus if organic manure and powdered sulphur with phosphate dissolving bacteria are added Lotfollahi *et al.* (2001). More attention has been given to sulphur application to soils due to its favorable effects in promoting nutrient availability in soils (Saleh, 2001). Application of sulphur as amendment for alkaline and/or calcareous soils has received little attention, as an inhibitor for ammonia volatilization (Abdou *et al.,* 2011). The nutrient availability of soils can be increased with the application of S. Thus, there is a growing interest in S applications to improve availability of nutrients and overcome nutrient deficiencies in both alkaline and calcareous soils. The addition of compost to the soils improves their physical, chemical, and biological soil properties, which influence the growth and development of plants. Also, organic acids produced from decomposition of organic matter help to dissolve the rock phosphate and increase the availability of phosphorus. Khalil (2013) found that the use of rock phosphate in conjunction with different organic manures was similar to the use superphosphate. Sulphur oxidation in soils is an effective process in the reclamation of sodic soils in addition to providing the sulphur needs for plants. More importantly, this process will lower the pH of the soil resulting in an increased activity of some plant nutrients near the root zone and consequently resulting in an improvement in the yield and quality of agricultural crops.

Kumar *et al.* (1992) reported the superiority of rock phosphate and sulphur compared to rock phosphate alone in increasing macro- and micronutrients in soils and decreasing soil pH which may be due to the oxidation of sulphur to sulphuric acid. El-Sayed (1999) revealed that PDB plays an important role in releasing P from rock, tri-calcium, or other difficult P-forms through the production of organic and inorganic acids, as well as CO_2. These substances convert the insoluble forms of P into soluble ones. PDB also affects other nutrients in addition to phosphorus. For example, it was reported that seed inoculation with PDB generally increased number of total bacteria PDB in the rhizosphere zone and number of nodules and released ammonia from bound complex nitrogen compounds (Nassar *et al.,* 2000). The use of beneficial microorganisms (bio-fertilizers) such as phosphorus dissolving bacteria (PDB) as inoculants with the seed increases P availability and uptake by the plants (Mousavi *et al.,* 2004; Sharan *et al.,* 2008 and Nico *et al.,* 2012) because the beneficial microbes produce of organic acids which reduce soil pH (Chen *et al.,* 2006; Rodriguez *et al.,* 2006).The acids reduce the PH and bring the dissolution of bound forms of phosphate (Walpola and Yoon,2012). Beneficial microorganisms are important not only for the reduction of the quantity of chemical fertilizers and environment friendly (Hafeez *et al.,* 2002) but also increased crop productivity (Yasmin and Bano, 2011). Phosphate solubilizing microorganisms (PSM) play a significant role in making phosphorus available to plants by bringing about favorable changes in soil reaction in the soil microenvironment leading to solubilization of inorganic phosphate sources. It is generally accepted that the major mechanism of mineral phosphate solubilization is the action of organic acids synthesized by soil microorganism.

Therefore, the aim of this study was evaluate the direct and residual effect of two sources of phosphorous fertilizers (rock phosphate and super phosphate) and three sources of soil amendments (elemental sulfur, compost and phosphorus dissolving bacteria (PDB) on some physical and chemical soil properties and productivity of wheat *(Triticum aestivum L cv. Sakha 93*) at first season and maize (*Zea mayes L. c. v.* single cross 10) to be affected by residual fertilizers at second season, grown on a calcareous soil.

MATERIALS AND METHODS

Field experiment was conducted on calcareous soil at El- Nubaria Agriculture Research Station, El - Behera Governorate to study the efficiency of sulfur (mineral fert), compost (organic fert) and phosphoreen (bio fert) with two different sources of phosphorus (rock phosphate and superphosphate) on physio-chemical soil properties and yields of both grains and straw of wheat succeeded by maize grown on a calcareous soil. To fulfill this objective, two field experiments were conducted on EI-Noubaria calcareous soil on some calcareous soil properties, wheat (*Triticum aestivum L cv. c v*. Sakha 93*)* as affected by the direct and maize (*Zea mayes L. c. v.* single cross10) as residual effect during two successive winter (2014 - 2015) and summer seasons (2015). The studied treatments in this study may be listed as follows:

A- Amendments sources: control, sulfur at the rate 1 ton fed^{-1} (mineral fert), compost at the rate 10 ton fed $^{-1}$ (organic fert) and phosphoreen (seed inoculation with PDB just before sowing (bio fert).

P- Sources of phosphorus control, rock phosphate at the rate 250 kg fed^{-1} and superphosphate at the rate 200 kg fed^{-1}). The experimental plots were distributed in a split-plot design with three replicates with 3.5 × 3.0 m^2 plot area. The main plots were sources of phosphorus (P), sub plot were amendments factors (A). Compost was thoroughly incorporated with surface soil layer 25 cm at two weeks before cultivation) and phosphoreen (seed inoculation with PDB just before sowing). Wheat *(Triticum* *aestivum* L, Sakha 93) was cultivated within the first half of November 2014 then harvested in May 2015. The second experiment was conducted to study the residual effect of the aforementioned treatments on maize (Zea *maize* L, single cross10) cultivated at the same experimental plots in the second half of May 2013 and harvested at the end of August. Mineral fertilizers were added as 100 % of recommended doses from N and K (nitrogen added at the rate 400kg fed $^{-1}$ in three equal doses after 15, 30 and 60 days from planting in the form of ammonium sulfate (20 % N) while, potassium added at the form potassium sulfate (48 % K_2O) at the rate 50 kg fed $^{-1}$ in two equal doses at sowing and 30 days from planting).

Before planting surface soil sample (0- 30 cm) was taken from experimental field, air dried, ground, sieved through a 2 mm sieve and prepared for analysis. Some physical and chemical characteristics of the studied soil were determined and the obtained data were presented in Table (1). Some characteristics of compost were determined according to Page *et al.* (1982) and the obtained data were recorded in Table (2). Soil samples were also collected from the surface layers (0-30) from each plot separately before harvest. The soil samples were air- dried ground, sieved and analyzed for some chemical characteristics, i.e., soil pH, organic matter content, according to the methods described by Page *et al.* (1982). The total soluble salts were determined using electrical conductivity meter at 25 ^{o} C in soil paste extract (Jackson, 1973).

Particle size distribution was carried out by the pipit method description by Gee and Bauder (1986) using sodium hexametaphosphate as a dispersing agent. Soil bulk density was determined using the undisturbed soil column according to Richards (1954). Hydraulic conductivity was determined using the undisturbed soil samples according to the method of Richard (1954). At harvest stage after 150 day from planting, the yield of biological, grain and straw were weighted for each plot and estimated as ton fed^{-1} and weight of 100 grains. Represented samples were taken from grain and straw dried, ground and wet digested (0.2 g) in 10 ml H_2SO_4 and 1 ml $HClO_4$ to determine the content of N, P and K. according to Chapman *et al.,* (1961). Obtained results were subjected to statistical analysis according to Snedecor and Cochran (1980) and the treatments were compared by using the least significant difference (L. S. D at 0.05 level of probability).

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

Particle size distribution %			Textural class	$CaCO_3$ %	O M %	PH (1:2.5) soil sus	EC dS m^{-1}	B.D g cm^{3}	T.P %	H.C cm^{3}h^{-1}
Sand	Silt	Clay								
68.91	16.57	14.52	Silt loam	25.40	0.89	8.38	1.42	1.35	49.06	2.89

Table (2): Some properties of compost used in experiment.

OM %	pH 1:10	EC dSm^{-1}	Total C %	Total N %	C/N Ratio	Total P %	Total K %
45.75	7.50	2.75	26.54	1.70	15.61	0.65	0.75

RESULTS AND DISCUSSION

Soil chemical properties:-

Soil pH

Soil pH is an important chemical property because it affects the availability of nutrients to plants and the activity of soil microorganisms. Data in Table (3) revealed that, soil pH varied with amendment treatments. The treatment of sulfur application has the highest effect in lowering pH values followed by compost. Also bio fertilizer has a moderately values. The highest of soil pH value after wheat crop in the control plots was 8.37, the lowest value after treatment with sulfur decreased to 7.56, whereas the residual effect of sulfur application after maize crop soil pH decreased from 8.39 to 7.71. The decreasing in soil pH by sulfur application is attributed to biological S-oxidation to sulphuric acid, causing reduction in soil pH. Data also clear that application of compost showed a decreasing trend in soil pH in both two experiment soils (after wheat and maize crop) due to mineralization and release of hydrogen (H+) ions. Mbakaya *et al*., (2006) and Ali *et al.* (2014) reported that the use of RP composted organic materials slightly decrease the values of soil pH, which was due to the release of H$^+$ during the nitrification process of fertilizers. Data also indicated that the interaction effects of SP and sulfur application gave the lowest soil pH. Generally, the application of phosphorus had a positive effect on soil pH, similar results were obtained by Youssef *et al*. (2009) and Ali *et al.* (2011). This result is in agreement with (Ashraf, 2001; Vidyalakshmi *et al.* 2009; Mutowal *et al*., 2013 and Karimizarchi *et al.,* 2014

Table (3): Effect of applied treatments on pH, EC (dS m $^{-1}$) and O.M (%) of the tested soil.

Phosphorus treatments (P)	soil after wheat crop					soil after maize crop				
	Amendments (A)					Amendments (A)				
	Control	Sulfur	Compost	Bio	Mean	Control	Sulfur	Compost	Bio	Mean
pH										
Control	8.37	7.66	7.80	8.30	--	8.39	7.88	7.90	8.32	--
RP	8.32	7.63	7.78	8.26	--	8.30	7.74	8.05	8.29	--
SP	8.25	7.56	7.73	8.18	--	8.27	7.71	7.83	8.26	--
	--	--	--	--		--	--	--	--	
L.S.D$_{0.05}$	---------------					------------------				
EC (dS m $^{-1}$)										
Control	1.40	1.85	1.16	1.32	1.43	1.39	1.72	1.22	1.36	1.42
RP	1.44	1.99	1.12	1.34	1.47	1.42	1.84	1.26	1.42	1.49
SP	1.88	2.35	1.43	1.77	1.85	1.86	2.32	1.66	1.48	1.83
Mean	1.57	2.06	1.24	1.47		1.55	1.96	1.38	1.42	
L.S.D$_{0.05}$	P= 0.12 A= 0.14 P x A= ns					P= 0.20 A= 0.23 P x A= ns				
O.M (%)										
Control	0.90	0.96	1.09	0.92	0.97	0.88	0.92	0.99	0.89	0.92
RP	0.91	0.97	1.11	0.93	0.98	0.90	0.93	1.02	0.91	0.94
SP	0.92	0.98	1.15	0.95	1.00	0.90	0.94	1.09	0.93	0.97
Mean	0.91	0.97	1.12	0.93		0.89	0.93	1.03	0.91	
L.S.D$_{0.05}$	P= 0.035 A= 0.03 P x A= ns					P= 0.04 A= 0.04 P x A= ns				

Soil EC

The effect of phosphorus treatments and amendment applications on soil EC are shown in Table (3) Data clarified that elemental sulfur increased soil EC at both of direct effect (after wheat crop) and residual effect (after maize crop) as compared to control. Soil EC was elevated from 1.57 to 2.06 dS m^{-1} with sulfur application in soil after wheat plant whereas; the residual effect at soil after maize increased it from 1.55 to 1.96. This may be ascribed to the sulfur oxidation in soil that produce sulfuric acid which react with the calcium carbonate of calcareous soil and produce gypsum wherever, it was more soluble than calcium carbonate consequently, increased soil EC (Slaton, 1998 and Hashemimajd *et al.,* 2012). Soaud *et al.* (2011) reported that the EC of soil was increased by sulfur application. Data also showed that the application of compost caused pronounced reductions in the EC by values 21.02 and 10.96 % for soil after wheat and maize crop, respectively as compared to the control.

Beheiry *et al.* (2005) and Abd- Elrahman *et al.* (2012) reported that addition of organic manures decreased soil salinity and they attributed that to improving physical properties of the soil which in turn facilitate the leaching of salts outside from the root zone. Bio-fertilizer (PSB) slightly decreasing soil EC. As regard to the interaction effect between phosphorus and amendment application, the highest EC value was noted in the treatment where SP and sulfur was applied and the lowest one was found in the compost and control treatment in both two experiment soils (as direct and residual effect).

Soil organic matter

Organic matter plays an important role in soil. Data presented in Table (3) declare that the application of amendments influenced on the soil organic matter (SOM). Applied compost increased significantly soil organic matter content. The increment percentage was 23.08 % in the soil after wheat plant where and it was 15.73 at the soil after maize plant as relative to control according to mean results. Angelova (2013) stated that addition of compost was able to affect the soil organic matter content. Fortuna *et al.,* (2003) found that the vermicompost amendment could increase the carbon contents up to 45 g.kg^{-1} of the original levels, and thus contribute to increase the soil structural stability, particularly that of the macro-aggregates. Illmer *et al*. (2007) and El-Maghraby and Shaaban (2011) showed that, organic matter content distinctly to better within the plots treated with compost compared to the untreated samples. The elemental sulfur and bio-fertilizer had non-significant effect on SOM. The highest SOM was noted in the treatment where SP and compost was applied and the lowest one was found in the control at both of direct and residual effect.

Effect of applied treatments on soil physical properties:

Soil bulk density

Results of Table (4) pointedout that the soil physical properties were affected mainly by addition of compost. Results also show that P treatments had no significant effect on soil bulk density, Sultani *et al.* (2007) and El-Maddah *et al*. (2012) found that phosphorus application did not affect bulk density. Also Data in Table (4) show that the soil bulk density (BD) was significantly decreased under soil treated with compost. Average decrease was 8.21 % at soil after wheat plant whereas; it was 8.08 % as compared to untreated plots. The effect of organic substances on reducing soil bulk density may be attributed to the dilution effect of adding less dense organic matter to more dense mineral fraction of the soil (García-Orenes *et al.*, 2005) act as cementing agents which help in formation of soil aggregation on one hand beside of the lower density of the applied amendment on the other hand. Such a finding stands in well agreement with those of El-Sherbiny (2007) and Harvey *et al.* (2016).

Table (4). Effect of applied treatments on Bulk density (g cm^{-3}), Total porosity (%) and hydraulic conductivity (cm ^{3} h^{-1}) of tested soil:

Phosphorus treatments (P)	soil after wheat crop					soil after maize crop				
	Amendments (A)					Amendments (A)				
	Control	Sulfur	Compost	Bio	Mean	Control	Sulfur	Compost	Bio	Mean
Bulk density (g cm^{-1})										
Control	1.35	1.33	1.24	1.30	1.31	1.36	1.35	1.26	1.32	1.32
RP	1.34	1.31	1.21	1.29	1.29	1.36	1.34	1.23	1.31	1.31
SP	1.33	1.32	1.23	1.28	1.29	1.35	1.33	1.25	1.30	1.31
Mean	1.34	1.32	1.23	1.29		1.36	1.34	1.25	1.31	
L.S.D$_{0.05}$	P= 0.03 A= 0.03 P x A= ns					P= ns A= 0.029 P x A= ns				
Total porosity (%)										
Control	49.06	49.81	53.20	50.94	50.75	48.68	49.05	52.45	50.19	50.09
RP	49.43	50.57	54.34	51.32	51.41	48.68	49.43	53.58	50.56	50.56
SP	49.81	50.19	53.58	51.70	51.32	49.05	49.81	52.83	50.94	50.66
Mean	49.43	50.19	53.70	51.32		48.80	49.43	52.95	50.56	
L.S.D$_{0.05}$	P= 1.074 A=1.241 P x A= ns					P= ns A= 0.947 P x A= ns				
hydraulic conductivity (cm^3 h^{-1})										
Control	2.90	3.49	4.80	3.74	3.73	2.44	3.14	3.80	3.48	3.21
RP	3.35	3.84	5.19	4.01	4.10	2.79	3.49	4.59	3.63	3.62
SP	3.84	4.10	5.40	4.28	4.40	3.21	3.90	4.80	3.50	3.85
Mean	3.36	3.81	5.13	4.01		2.81	3.51	4.40	3.54	
L.S.D$_{0.05}$	P= 1.17 A= 1.033 P x A= ns					P= ns A= 0.462 P x A= ns				

Soil total porosity

Porosity or the part of soil volume occupied by pore space is inversely proportional to soil bulk density. It is in general; viewed as a good indicator of other soil physical properties such as compaction, air water relationship. Data presented in Table (4) revealed that soil total porosity values differed significantly by compost application. The increment percentage as a result of compost application 8.13 % at soil after wheat plant while, it was 8.5 % at soil after maize plant as relative to untreated soil. These results may be attributed to that organic compounds are important in binding soil particles (Caravaca *et al*., 2002 and Wilson *et al.,* 2009) into macro-aggregates and micro-aggregates (Singh *et al*., 2009). El-Sherbiny (2007) observed that a linear relation between soil porosity and the compost application rate. Harvey *et al.,* (2016) observed that application of farm yard manure increased soil porosity. Data also reveal that the sulfur and bio fertilizer appeared no significant effect on soil total porosity. Jalili (2015) observed that main effect of sulfur and interaction effect of sulfur and organic matters was not significant.

Hydraulic conductivity

Data in Table (4) manifest that compost addition was significantly increased saturated hydraulic conductivity as compared with another amendment treatments and unfertilized soil. These results may be due to the effect of organic materials on soil structure (El-Sherbiny, 2007; El-Kotb 2013 and Harvey *et al.,* 2016). According to Franzluebbers (2002) and Hamidpour *et al.* (2012) soil organic matter as a key index of soil quality impacts soil aggregation and accordingly increases hydraulic conductivity. Data also elucidated that sulfur application and interaction effect of P and amendments treatments showed no significant effect on saturated hydraulic conductivity. El-Edfawy *et al.* (2016) found that phosphorus application was not significant by affect saturated hydraulic conductivity.

Effect of applied treatments on yield and its components of wheat succeeded by maize crop:

The effect of phosphorus treatments and soil amendments application on wheat succeeded by maize crop are presented in Table (5). Application of RP and SP significantly increased yield and its components of wheat in direct effect as well as that of succeeding maize with residual P. The percent of increments were 10.12, 15.81 and 2.07 % in SP treatment and 6.01, 8.45 and 1.72 % in RP treatment for biological yield, grain yield and weight of 1000 grain of wheat, respectively. Taalab, *et al.,* (2008*)* reported that the application of single super phosphate gave higher effects on maize yield than the use of phosphate rock. khalill (2013) reported that the application of single super phosphate gave higher effects on faba bean yield than the use of phosphate rock. Regard to residual effect, the percent of increments were 26.54, 28.96 and 17.63 in RP treatment and 33.05, 37.7 and 29.45 in SP treatment for biological yield, Grain yield and Weight of 100 grain of maize respectively. The reduced effect of RP as compared to SP in grain yield and biomass among the treatments observed in present study reflected the slow dissolution of RP which probably replenished the soil solution with a steady rate of the P required at initial stages of wheat crop regardless of their levels. As cereals take up about 75% of their required P within 40 days after emergence (Ross & Middleton, 2013), increasing the level of a slow release P source (RP) above certain level could decrease the apparent P recovery in the first season of application. Naseer and muhammad (2014) reported that the P supplied by residual RP at low levels was not adequate for promoting crop growth but when does was enhanced to high level the residual RP supplied enough P to soil solution and produced increases at par with initial application to wheat. On the basis of these reports, there is good possibility that the residual release of P by RP may become effective in subsequent cropping. This observation is supported by earlier studies. Akande *et al.* (2010) and Ghosal *et al.* (2013) reported higher crop yields of subsequent second year crop than first crop with the application of un-amended RP. Tang *et al.* (2008) also reported that P fertilizers added to wheat crop can maintain higher yields in succeeding maize crops without further applications. Ndung *et al.* (2003) observed that one time application of rock phosphate at the rate of 60 kg ha^{-1} significantly increased maize yields up to the fourth season with the highest yield from first residual crop.

In general, amendment treatments significantly affected yield and its components of wheat in direct effect as well as that of succeeding maize with residual P. Compost treatments significantly increased yield and its components of wheat in direct effect. The values of increments were 27.59, 33.85 and 6.46 % for biological yield, grain yield and weight of 1000 grain of wheat. Khan *et al.* (2009*)* reported that total dry matter yield improved with the application of organic materials with super phosphate*.* Phiri *et al.* (2010) observed that application of organic materials with RP increased the maize grains yield. Sharife *et al.* (2013) reported that the composts were enriched with phosphorus significantly increased grains, total dry matter, straw yield and 1000 grains weight of wheat over control. As regard to residual effect of compost treatments, the values of increments were 33.54, 14.58 and 14.25 % for biological yield, grain yield and weight of 100 grain of maize. Khan (1993) stated that as a result of residual effect of composts of different organic materials with RP, total dry matter yield of crops enhanced significantly. Furthermore, the addition of organic manure significantly increased yield and its components of the studied plants as being a source for all essential macro- and micronutrients. It plays a direct role for meliorating soil hydro physical properties such as soil aggregation, bulk density, total porosity, aeration, hydraulic conductivity and available water range, soil chemical characteristics such as soil pH, released organic constituents of active groups such as fulvic and humic acids able to retain the essential plant nutrients in complex and available chelated forms are also impacted by the organic manure. Organic manure affects soil biological conditions. That is, a source of energy for the microorganism activities which enhance the release of necessary nutrients in available forms throughout their mineralization, in return improves soil fertility status (i.e., slow release of nutrients) which support root development among the different growth stages, and finally leads to higher yield and its content of studied plants. Similar results were gained by Subehia (2001) and khalill (2013).

Table (5). Effect of applied treatments on biological yield, grain yield and weight of grains of wheat and succeeding maize crop.

Phosphorus treatments (P)	wheat					Maize				
	Amendments (A)					Amendments (A)				
	Control	Sulfur	Compost	Bio	Mean	Control	Sulfur	Compost	Bio	Mean
biological yield (ton fed $^{-1}$)										
Control	8.22	9.73	11.516	8.48	9.48	5.52	5.79	7.06	5.60	5.99
Rock phosphate	9.076	9.916	11.543	9.786	10.05	6.69	7.34	8.99	7.29	7.58
Super phosphate	9.90	10.18	11.64	10.06	10.44	6.75	8.29	9.27	7.59	7.97
Mean	9.06	9.96	11.56	9.44		6.32	7.14	8.44	6.83	
L.S.D$_{0.05}$	P= 0.160 A= 0.156 P x A= 0.26					P= 1.075 A= 0.32 P x A=0.08				
grain yield (ton fed $^{-1}$)										
Control	2.362	2.665	3.312	2.528	2.72	2.413	2.51	2.633	2.536	2.52
Rock phosphate	2.538	3.034	3.334	2.901	2.95	3.043	3.315	3.515	3.125	3.25
Super phosphate	2.816	3.136	3.669	2.997	3.15	3.195	3.676	3.768	3.250	3.47
Mean	2.57	2.94	3.44	2.81		2.88	3.16	3.30	2.97	
L.S.D$_{0.05}$	P= 0.138 A= 0.065 P x A= 0.110					P= 0.218 A= 0253 P x A= 0.169				
	Weight of 1000 grain (gm)					Weight of 100 grain (gm)				
Control	42.71	45.97	46.50	45.87	45.26	27.61	31.94	32.27	30.72	30.63
Rock phosphate	44.50	46.43	46.83	46.40	46.04	33.47	38.14	36.77	35.75	36.03
Super phosphate	44.70	46.63	47.10	46.37	46.20	35.15	39.22	40.87	43.38	39.65
Mean	43.97	46.34	46.81	46.21		32.07	36.43	36.64	36.62	
L.S.D$_{0.05}$	P= 0.25 A=0 .52 P x A= 0.83					P= 2.49 A= 2.87 P x A= 4.98				

Sulfur treatments significantly increased yield and its components of wheat as direct effect. The values of increments were 9.93, 14.39 and 5.39 % for biological yield grain yield and weight of 1000 grain, respectively. The effective utilization of phosphate fertilizers in combination with sulphur was obvious by the S role in decreasing soil pH, which played an effective role in transformation of insoluble P to available form for plant uptake. Elemental sulphur, as a soil amendment, is of special interest to increase plant nutrient availability in the soil system since it possesses a slow release acidifying characteristic and is readily available. El-Syed *et al.* (2005) found that the dry matter yield of faba bean seeds, straw and the whole plant increased significantly due to application of S. As regard to residual effect of sulfur treatments, the values of increments were 12.97, 9.72 and 13.56 % for biological yield, grain yield and weight of 100 grain of maize. Rajan *et al.* (1996) reported that mixing of sulfur with RP or SSP resulted in increasing in the yield of permanent pastures compared to RP or SSP application alone. Taalab, *et al.* (2008) reported that maize yield improved remarkably through the solubilizing effects of sulfur. Karimizarchi *et al.* (2014) found that, application of elemental Sulphur at a rate of 0.5 g S kg^{-1} soil significantly increased total dry weight of maize by 45.06 %. Badawy *et al.,* (2011) reported that sulfur application in the range of 300-400 kg/fed, alone or with organic manures had significant beneficial effects on increasing wheat growth, and yields obtained (between 11.50 to 12.99 % increases in grain yields). PSB treatments significantly increased yield and its components of wheat in direct effect. The values of increments were 4.19, 9.34 and 5.09 %. While, the values of increments in residual effect were 8.06, 3.12 and 14.18 % for biological yield, grain yield and weight of 100 grain of maize. PSB inoculants play an important role in making P available to crop plants and thereby increase the yield of crop plants (khalid *et al.* (2004) and Hameeda *et al.* (2008). khalil. (2013) reported that seed inoculation with the PDB caused remarkable increases in most growth parameters as compared with rock phosphate fertilizer only. Ewais (2006) refer to the increases in growth parameters may be due to the inoculation with phosphate dissolving bacteria which solubilized unavailable phosphate by excreting organic acids and cause lowering the soil pH. PDB may also produce growth promoting substances which increase plant growth. Similar positive effects of PDB have been obtained on soybean, lentil, and mung bean. Data also indicated that the interaction effects of phosphorus treatments and applied soil amendments were significant. In direct effect and residual effect of compost with SP treatment that recorded the highest values of, biological yield, grain yield and weight of 1000 grain of wheat and maize crops.

The interaction between amendments and sources of phosphorus was found to be significant in both biological yield, grain yield and weight of 1000 grain of wheat and maize crops.

Effect of applied treatments on N, P and K uptake in grain and straw of wheat and maize crop:

The results in Tables (6 and 7) revealed significant increase in NPK uptake in grain and straw yield due to the effect of phosphorus treatments and soil amendments application on wheat and succeeding maize crop. The percent of increments of NPK uptake in grain yield were 21.93, 24.58 and 26.54 % with SP treatment and 10.84, 11.99 and 13.87 % with RP treatment for N, P and K, respectively. Regard to residual effect, the percent of increments of NPK uptake were 31.14, 40.42 and 35.94 % with RP treatment and 43.51, 62.39 and 52.64 % in SP treatment for N, P and K, respectively. Awaad *et al.* (2009) reported that the highest values of N, P and K uptake by straw or seeds were obtained by superphosphate application at two rates when compared to phosphate ore treatments. Similar results were also observed by Shafeek *et al.* (2005) who found that the chemical composition of green pea seeds tissues recorded the highest significant values with applying the chemical source of P (superphosphate) addition as compared with the natural source (phosphate ore). khalill (2013) reported that the application of single super phosphate gave higher effects on NPK uptake of faba bean yield than the use of phosphate rock.

In general, amendment treatments significantly affected NPK uptake of wheat as direct effect as well as that of succeeding maize with residual P. Compost treatments significantly increased NPK uptake of wheat and maize crop. Also data revealed that, superiority of compost treatments over sulfur followed by biofertilizer compared to control. Awaad *et al.* (2009) observed that plant N uptake improved by the application of RP mixed with organic materials. Jan *et al.* (2010) showed an increase in plant N uptake by the combined application of organic and inorganic sources of N. Erdal *et al.* (2000) noted that accumulation of plant P enhanced with combined application of P fertilizer and organic materials. Taalab *et al.* (2008) recorded that plants N and P uptakes were increased by the combination of RP with organic materials. Sulfur treatments significantly increased yield and its components of wheat in direct effect and maize as residual effect both grain and straw followed by PSB treatments for yield and its components of wheat in direct effect and maize as residual effect on both grain and straw.

Table (6). Effect of applied treatments on N, K and P uptake (kg fed $^{-1}$) in grain of wheat and maize crop.

Phosphorus treatments (P)	Wheat					Maize				
	Amendments (A)					Amendments (A)				
	Control	Sulfur	Compost	Bio	Mean	Control	Sulfur	Compost	Bio	Mean
N uptake (kg fed $^{-1}$)										
Control	29.76	34.11	43..05	32.61	*34.88*	26.78	28.36	30.28	28.40	28.45
Rock phosphate	32.48	39.44	45.01	37.71	*38.66*	34.38	38.12	41.12	35.62	37.31
Super phosphate	36.61	41.71	51.37	40.46	*42.53*	36.47	43.37	45.21	38.02	40.83
Mean	32.95	38.42	46.47	36.92		32.63	36.62	38.87	34.01	
L.S.D$_{0.05}$	P= 1.64 A=2 .17 P x A= 1.42					P =2.95 A=0 .69 P x A= 0.79				
P uptake (kg fed $^{-1}$)										
Control	6.61	7.99	10.93	7.83	8.34	4.82	5.77	6.58	5.58	5.69
Rock phosphate	7.36	9.40	11.33	9.28	*9.34*	6.69	8.29	9.49	7.50	7.99
Super phosphate	8.45	10.03	13.21	9.89	*10.39*	7.67	9.92	10.93	8.45	9.24
Mean	*7.47*	*9.14*	*11.82*	*9.0*		6.39	7.99	9.00	7.17	
L.S.D$_{0.05}$	P= 0.50 A=0 .76 P x A= 0.61					P= 1.15 A=0 .39 P x A= 0.38				
K uptake (kg fed $^{-1}$)										
Control	5.19	6.39	8.61	6.32	*6.63*	4.34	4.77	5.27	4.56	4.73
Rock phosphate	6.09	7.58	9.00	7.54	*7.55*	5.78	6.63	7.38	5.94	6.43
Super phosphate	7.04	8.15	10.27	8.09	*8.39*	6.39	7.72	8.29	6.50	7.22
Mean	*6.11*	*7.37*	*9.29*	*7.32*		5.50	6.37	6.98	5.67	
L.S.D$_{0.05}$	P= 0.46 A=0 .60 P x A= 0.56					P= 0.85 A=0 .085 P x A= 0.11				

Table (7). Effect of applied treatments on N, K and P uptake (kg fed $^{-1}$) in straw of wheat and maize crop.

Phosphorus treatments (P)	Wheat					Maize				
	Amendments (A)					Amendments (A)				
	Control	Sulfur	Compost	Bio	Mean	Control	Sulfur	Compost	Bio	Mean

N uptake (kg fed $^{-1}$)										
Control	22.26	28.26	34.46	23.81	27.20	8.70	9.84	14.17	8.90	10.40
Rock phosphate	26.15	28.92	36.12	28.22	29.85	10.92	13.68	19.71	13.33	14.41
Super phosphate	29.75	31.08	36.66	30.29	31.94	11.38	16.59	20.90	14.75	15.90
Mean	26.05	29.42	35.74	27.44		10.33	13.37	18.26	12.32	
L.S.D$_{0.05}$	P= 1.30 A= 0 .67 P x A= 0.75					P= 0.21 A=0 .97 P x A= 0.15				
P uptake (kg fed $^{-1}$)										
Control	4.57	5.65	6.73	4.76	*5.43*	1.64	1.83	2.57	1.68	1.93
Rock phosphate	5.23	5.64	6.89	5.57	*5.83*	2.00	2.33	3.28	2.33	2.48
Super phosphate	5.81	5.84	6.85	5.93	*6.11*	2.13	2.76	3.41	2.52	2.70
Mean	*5.20*	5.71	*6.82*	*5.42*		1.92	2.31	3.09	2.18	
L.S.D$_{0.05}$	P= 0.20 A=0 .11 P x A= 0.09					P= 0.27 A=0 .13 P x A= 0.05				
K uptake (kg fed $^{-1}$)										
Control	131.80	140.71	196.89	138.03	151.86	66.59	71.5	97.39	67.11	75.65
Rock phosphate	152.99	162.48	201.02	161.73	169.55	79.50	88.55	123.19	91.21	95.56
Super phosphate	166.47	169.51	199.27	167.65	175.72	80.63	104.18	126.5	97.65	102.24
Mean	150.42	157.56	199.06	155.80		75.57	88.08	115.69	85.32	
L.S.D$_{0.05}$	P= 6.07 A=2.63 P x A= 2.86					P= 5.96 A=2.76 P x A= 0.50				

CONCLUSION

The application of sulfur at the rate 1 ton fed^{-1} (mineral), compost 10 ton fed $^{-1}$ (organic) and phosphoreen seed inoculation as PDB (bio) combined with two sources of phosphorus (rock phosphate and superphosphate) appeared an obvious effect on chemical and physical properties of the tested calcareous soil. Generally the different chemical calcareous soil properties pH, EC and OM were more affected by the compost and sulfur, than bio fertilizer addition compared to the control. Superiority of compost combined with superphosphate to improve soil bulk density (BD), soil total porosity (TP), and soil hydraulic conductivity (HC) over sulfur and bioferilizer (phosphoreen) were considerable observed compared to control. Rock phosphate gave lower values than superphosphate. The highest biological, grain yield and 100 grains weight values were obtained as affected by compost applied, combined with superphosphate followed by sulfur application. Superiority of compost combined with superphosphate in promoting NPK uptake of wheat and maize crop was recorded.

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كفاءة الكمبوست والكبريت والفوسفورين فى التأثير المباشر و المتبقى على الزراعة المستدامة

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الملخص العربى

أقيمت تجربة حقلية في مزرعة محطة البحوث الزراعية – مركز البحوث الزراعية بالنوبارية بغرض دراسة تأثير الأسمدة العضوية الكمبوست بمعدل (10 طن للفدان) والمعدنية الكبريت بمعدل (1 طن للفدان) والسمادالحيوى (االفوسفورين) مع مصدرين للفوسفور (سوبر الفوسفات – صخر الفوسفات) علي بعض الخواص الكيميائية والطبيعية للأرض الجيرية بالنوبارية وإنتاجية محصول القمح (سخا 93) فى التجربة الأولى والتأثير المتبقى للمعاملات السابقة على نبات الذرة (فردى 10) فى التجربة الثانية خلال موسمين شتوى (2014 - 2015) وصيفى (2015) متتالين وذلك فى تصميم قطع منشقة مرة واحدة وكانت المعاملات تحت الدراسة كالأتى :-

1- مصدر الفوسفور (كنترول- سوبر الفوسفات – صخر الفوسفات) وتم وضعه فى القطع الرئيسية

2- المحسنات الكمبوست 10 طن للفدان والكبريت المعدنى 1 طن للفدان والسمادالحيوى (الفوسفورين) والكنترول وتم وضعه فى القطع تحت الرئيسية

وكانت أهم النتائج كالتالى :-

1- أوضحت النتائج أن المعاملات المستخدمة تحت الدراسة كان لها تأثيرا إيجابيا على بعض خواص االتربة الكيميائية والطبيعية حيث أدى إستخدام الكمبوست إلى خفض قيم كلا من نسبة الأملاح الذائبة (EC) ورقم الحموضة (pH) و زيادة محتوى التربة من المادة العضوية (OM) وكذلك أدت إلى خفض قيم الكثافة الظاهرية (BD) وزيادة المسامية الكلية (TP) والتوصيل الهيدروليكى (HC) خاصة مع إستخدام السوبر فوسفات كمصدر للفوسفور كما أدى إسخدام الكبريت إلى زيادة قيم EC خاصة مع إستخدام السوبر فوسفات كمصدر للفوسفور

2- تفوق التداخل بين المحسن العضوى مع سوبر الفوسفات على المعدنى والحيوى فى تحسين الخواص التربة الكيميائية والطبيعية تحت الدراسة

3- كان تأثير معاملات المحسنات عالي المعنوية سواء كانت عضوية أومعدنية او حيوية علي المحصول الكلى والحبوب وعلى قيم وزن 1000 حبة لمحصول القمح و 100 حبه للذرة كتأثير المتبقى وذلك مقارنة بالقطع الغير معاملة (الكنترول) وكذلك كانت معاملات صور الفوسفور عالى المعنوية على إنتاجية الحبوب وكان التفاعل بين صور الفوسفور والمحسنات أيضا معنوى

4- تفوق التداخل بين محسن الكمبوست مع سوبر الفوسفات على زيادة كلا من انتاجية المحصول الكلى والحبوب لمحصول القمح والذرة وكذلك قيم وزن 1000 حبه عن تأثير باقى المعاملات

5 - تفوق التداخل بين محسن الكمبوست مع سوبر الفوسفات على زيادة إمتصاص العناصر النتروجين والفوسفور والبوتاسيوم بواسطة النباتات تحت الدراسة.

أسماء السادة المحكمين

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