International Journal of Chem Tech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.10 pp 53-68, 2015

Studies on the Possible use of Rock phosphate in Agriculture

Mona, A. Osman

Soils, Water and Environment Research Inst., Agric. Res. Center, Giza, Egypt.

Abstract: A field experiment was carried out at El- Ismailia Agriculture Research Station Farm in Ismailia Governorate, Egypt. The institute farm is located at 30° 35´41.9" N Latitude and 32° 16´ 45.8" E longitude during two successive winter seasons cultivated with Green Pea (Pisum sativum L.) crop grown on sandy soil under drip irrigation system to evaluate the possible use of rock phosphate in agriculture through partially acidulation with different concentration (the organic and mineral acids were added with three concentrations i.e. 5 ,10 and 20 %) (C1, C2 and C3). Acidulation with organic acids (humic, fulvic and citric) as compared to mineral acids (sulfuric), sulfur and compost extract on phosphorus release from rock phosphate(15 % P_2O_5) as compared to super phosphate(15 % P_2O_5) and their reflection on soil chemical properties and yield production of Green Pea. Results show that acidulation both of rock phosphate and super phosphate caused a significant decrease in soil pH as compared to control treatments (superphosphate only without acidulation) or rock phosphate only , also acidulated rock phosphate was superior for decreasing the soil pH as compared to superphosphate . Moreover, pH values decreased significantly along with increasing the concentration of acids, while all applied treatments increased the soil EC and nutrient availability (N, P and K) as compared to control treatment. This trend was more pronouns for rock phosphate as compared to superphosphate. With respect to the different acidulates, for both super and rock phosphate the sulfuric and fulvic acid were superior for securing a maximum availability of nutrient (N, P and K) as compared to the control and other treatments .The treatments arranged as follow ; sulfuric acid, fulvic acid, humic substance , sulfur ,citric acid and compost extract. Data also indicated that yield components (straw, pods and biological yield) of green pea crop increased significantly due to application of different acidulated treatments for superphosphate and rock phosphate as compared to control treatment at both tested season. Generally, acidulated rock phosphate was superior as compared to super phosphate in dry matter yield. Acidulation both of rock phosphate and super phosphate with sulfuric and fulvic acid was the superior for increasing the nutrient uptake and yield components. Also, phosphorus uptake increased with each increase in concentration of acids, also both yield and P- uptake for rock phosphate were higher when the pH decreased. Generally, Positive relationship was responded between the availability of nutrients in the soil and the uptake of nutrients with acidulation. Also, acidulation of both super phosphate and rock phosphate enhance the Phosphorus use efficiency of Pea yield especially for rock phosphate. Generally increasing the concentration of acids cause a significant increase in phosphorus use efficiency, the highest phosphorus use efficiency was obtained in presence of sulfuric and fulvic acid for both P- sources super phosphate and rock phosphate as compared to the other treatments, the opposite trend was obtained in presence of citric acid and compost extract. Finally, we can concluded that uses of acidulated rock phosphate became a pronounce alternative phosphate fertilizers because of its effect on increasing the availability of P, nutritional status and yield of green pea on certain Egyptian soil.

Key Words: Acidulation, natural minerals, superphosphate, rock phosphate, pea yield.

Introduction

Green Pea (*Pisum sativum L.*) is a leguminous crop contains higher amount of protein and is an excellent human food. Improving yield per unit area is dependent on increase in fertilizer rates. Phosphorus is an essential element for plant nutrition, so phosphorus is the most limiting nutrient after nitrogen in most of the Egyptian soils.

The heavy fertilization policy has an adverse effect on the environment due to the large quantities of chemical residues remaining. [1] mentioned that, improving food security by increasing crop production is primary objective. Poor soil fertility and inadequate utilization of chemical fertilizers have often resulted in poor crop yields and that has exacerbated the problems of poverty and hunger in the country. Local phosphate deposits and indigenous phosphate resources could provide less expensive phosphate fertilizers that could help farmers to increase crop production with low cost of phosphate fertilizers. Phosphate rock is the only economical source of P for production of Phosphate fertilizers. In Egypt, there are large commercially mine deposits of rock phosphate, they have been mined for over a century.

Rock phosphate is successfully used in acid soils as a source of P for plants. In Egypt, direct application of rock phosphate is not well suited[2]. So, ground phosphate rocks treated with different acidulates at varying degrees of acidulation increase the effectiveness of phosphate rocks in alkaline soils[3,4]. In addition, Partially Acidulated Phosphate Rock (PAPR) produced using phosphate rock is just as agronomical effective as superphosphate fertilizers on food crops in Egypt. The process of producing PAPR is therefore less expensive in terms of acid consumption. The agronomic effectiveness of PAPR largely depends on the percentage of soluble phosphate (available P_2O_5) content in the PAPR, particle size of phosphate rock, degree of acidulation and acid concentration. These variables differ from one phosphate rock to the other. The authors added that, the percentage of available P_2O_5 in PAPR increased with the increase in the degree of acidulation (i.e. 40%, 50%, 60%, 70%, 80%, and 100%). Low acid concentrations, 50% to 70% H_2SO_4 gave high levels of water-soluble P_2O_5. Acid concentration below 40% and above 70% lowered the percentage of water-soluble P_2O_5.

[5] found that partially acidulated phosphate rock (PR) at five levels (0, 40, 60, 80, 100%) was superior for increasing the Relative Agronomic Effectiveness (RAE) of canola. The Partially acidulated Phosphate Rock (PAPR) was compared with standard fertilizer (triple superphosphate) in two levels (50 and 100 mg P/kg). Results indicated that the relative effectiveness of fertilizers as based on dry mater (DM) and phosphorous (P) uptake, significantly increased was recorded with each increase in acidity level. In no application of acidulated PR, the relative effectiveness based on DM and P uptake was very low. In 100% acidulated PR (in match with single superphosphate) the relative DR and P uptake were low as against standard fertilizer application but very high against no PR application. Increased soil acidity in the rhizosphere can enhance PR dissolution and its availability to plants. This has been observed directly as increased PR dissolution but more often indirectly as increased P uptake by those plants that acidify the rhizosphere [6]. [7] have also found enhanced PR dissolution by the rhizosphere of some crop species in alkaline soils. Proton secretion by roots occurs when the equivalent sum of cation uptake by plants (K^+, Ca^{2+}, Mg^{2+} and Na^+) exceeds that for anions (usually, NO_3^-, $H_2PO_4^-$ and SO_4^{2-}). As the H_2SO_4 produced on oxidation of S affects the dissolution of PR in PR/Ss, it is logical to conclude that increasing the S content in PR/Ss would increase their agronomic effectiveness. Results from early studies show that PR/Ss could be as effective as SSP.

Acidulation of phosphate rock is usually necessary to break the apatite bond to render the contained phosphate more soluble, Wet process sulfuric acid acidulation is the most commonly used technique for improving the agronomic suitability of phosphate rock. Increasing the concentration of acids ,the polarity acid will increase leading in a decrease in the acid reaction with phosphate, with a corresponding increase in the%P_2O_5 recovery. Increase in acidulation time, led to increase in P_2O_5 content. [8] added that in an alkaline soil (pH 8.2) the PR-SSP mixture tended to be as effective as SSP. Moreover, based on a sequence of three crops, the product was economically equal to SSP. It was calculated that the dissolution of PR increased by 55 percent when applied in combination with SSP compared with that of an application of PR only.

[2]reported that, the use of acidulated rock phosphate increased the availability of P and consequently increases P uptake by plants and their yields in alkaline soil.

Partial acidulation with H_2SO_4 results in a decrease in total P because of the formation of calcium sulphate in the product. However, the water-soluble P increases with the increasing degree of acidulation [9]. Partial acidulated phosphate rock can be agronomical and economically effective in crop production as compared with conventional, fully acidulated fertilizers, e.g., single superphosphate (SSP), also, acidulation with 50 % sulphoric acid can be as effective as SSP for plants [10]

[11] mentioned that, acidulated rocks showed some promising agronomic results. So, for acidulation of rocks various acidulation at varying degrees of success. They may be broadly grouped into three categories as under: Strong acid (phosphoric acid, nitric, sulfuric and hydrochloric acid), Weak acid, (oxalic, citric acid and sulfur). Among these, however, strong acids particularly phosphoric, nitric acid appear to be most popular promising and suitable for use under widely different soil conditions.

Organic acids may affect mineral weathering rates by at least three mechanisms: by changing the dissolution rate through decreasing solution pH or forming complexes with cations at the mineral surface; by affecting the saturation state of the solution with respect to the mineral; and by affecting the speciation in solution of ions such as Al^{+3} that themselves affect mineral dissolution rate. The levels of organic acids are affected by a number of independent variables such as pH and redox potential influence on the dynamics of K release from silicate rocks[12].[13] added that humic, fulvic and other organic acids have been shown to be aggressive weathering agents in soils, especially with respect to the dissolution of clay minerals.

[14]mentioned that various organic acids can effectively dissolve minerals and chelate metallic cations. Generally, the great effect of organic acid on dissolution rocks and minerals is attributed to the presence of hydrogen ions and the formation of cation- complexes. The structural cations, released from minerals as a result of the attack of hydrogen ions, tend to form cation-organic complexes with oxalic acid, which has OH^{-1} and $COOH^{-1}$ groups in the ortho position. The chemisorptions of the cation- organic complexes on the mineral surface cause a shift of electron density toward the frame work of the mineral. This charge transfer increases the electron density of the cation- oxygen bonds and makes them more susceptible to hydrolysis. Generally organic acids such as citric, gluconic acids can also led to the weathering of rocks through acidic attack and chelating [15].

The objective of the present study is to discuss the features of alternative phosphate fertilizers through partially acidulated rock phosphate with different concentration of acidulation on availability of P , nutritional status and yield of green pea on certain Egyptian soil.

Materials and Methods

To achieve the objectives of the present study, a field experiment was carried out in sandy soil at El-Ismailia Agriculture Research Station Farm in Ismailia Governorate, Egypt. The institute farm is located at 30° 35´41.9" N Latitude and 32° 16´ 45.8" E longitude . Some physical and chemical characteristics of the studied soil are presented in Table (1).

Table (1): Some characteristics of soil samples representing the studied location

Soil characteristics	Values
Particle size distribution %	
Coarse sand	50.4
Fine sand	40.4
Silt	3.20
Clay	6.00
Texture class	Sandy
Chemical properties	
$CaCO_3$ %	1.35
pH (suspension 1:2.5)	8.00
EC dSm^{-1} (Saturated paste extract)	0.37
Organic matter %	0.45
Soluble cations and anions (meq L^{-1})	
Ca^{++}	0.94
Mg^{++}	0.89
Na^{+}	1.45
K^{+}	0.45
CO_3^{--}	-
HCO_3^{-}	1.42
CL^{-}	1.02
SO_4^{--}	1.29
Available nutrients (mg L^{-1})	
N	45.0
P	15.0
K	50.6

The experiments were carried out during two successive winter seasons cultivated with green pea (*Pisum Sativum* L.) crop grown on sandy soil under drip irrigation system. to evaluate the effect of partially acidulation with different concentration of organic acids (humic and fulvic) as compared to mineral acids (sulfuric, phosphoric and citric) sulfur and compost extract on phosphorus release from rock phosphate as compared to super phosphate and their reflection on soil chemical properties and yield production of pea. The experiment was designed in a randomized split- split plot design with three replications. The organic and mineral acids were added with three concentrations i.e. 5 ,10 and 20 % (C1, C2 and C3), while sulfure was applied with three rates i.e. 50, 75 and 100% from the recommended dose.

The soil under study was analyzed according to [16] and described in (Table 1) while organic acids and rock phosphate constituents analysis were described in Table (2).

All treatments received mineral fertilizers ammonium sulphate (20.6 % N), potassium sulphate (48%) were added at recommended dose of green pea , two treatments of super phosphate (15 % P_2O_5) and natural mineral (rock phosphate 15 %) were added separately in bands and mixing with the soil surface before pea cultivation at the rate of 15 % P_2O_5 fed^{-1}. and acidulated with different concentration of acidulates under investigation.

At maturity, Green Pea was harvested to determine yield components (straw, pods and biological yield) and nutritional status. Plant samples were oven dried at 70 C for 48 hours, up to constant dry weight, then ground and digested using H_2SO_4 and H_2O_2 mixture to the evaluation of nutrients (N, P and K) according to procedures described by [16]. Soil chemical properties along with analyses of natural minerals were evaluated according to [16].

Obtained results were subjected to statistical analysis according to [17]. the treatments were compared by using L.S.D. at 0.05 level of probability.

Phosphorus use efficiency (PUE) was calculated as:

$$PUE= ((Pf-Pc)/P) \times 100$$

Where: Pf and Pc are the total P uptake for fertilized treatment and check (control) plots, respectively, and P is the applied P in kg fed^{-1} [18] .

Table (2): Some chemical properties of humic substance, fulvic acids, compost extract and rock phosphate used in the experiment

Characteristics	Rock phosphate	Humic acid	Fulvic acid	Compost extract
pH	7.80	5.56	1.23	5.20
EC (dSm^{-1})	3.05	61.5	64.6	6.00
	Total macronutrients %	**Available macronutrients (ppm)**		
N	-	1.29	0.42	2380
P	15.0	0.25	0.15	2450
K	0.04	2.00	2.00	1960

Results and Discussion

Soil chemical properties:

Data presented in Table (3) show the changes of some soil chemical properties as affected by the tested treatments of partially acidulation of rock phosphate and superphosphate.

1- Soil reaction (pH)

It is well known that the pH values is important for healthy plant growth and nutrients availability, thus data presented in Table (3) indicated that application of acidulation both of rock phosphate and super phosphate caused a significant decrease in soil pH as compared to control treatments (superphosphate only without acidulation) or rock phosphate only , also obtained data clear that, acidulated rock phosphate was superior for decreasing the soil pH as compared to superphosphate [19]. Moreover, pH values decreased significantly along with increasing the concentration of acids due to the changes occur in soil pH as a result of treatment application. This reflected on the initial pH of the amendments which has a low pH especially in sandy soil which has a low buffering capacity [20].

2- Electrical conductivity (EC)

With regard of electric conductivity (EC) statistical analysis showed that all applied treatments increased significantly the soil EC as compared to both control treatments; this trend was true for both season. This trend was more pronouns in R.P as compared to superphosphate. This may be due to the improvement of nutrients availability due to the presence of different acids, which causes more solubility of nutrients. Moreover, HA, FA and compost extract contains more nutrients, different elements and function groups with high molecular weight and carbon contents[21]. Also , organic acids play an important role in improving bioavailability of soil nutrients which cause a significant increase in the EC of the soil for both tested seasons.

Table(3) : Effect of partially acidulation of rock phosphate as compared to superphosphate on nutrient availability (ppm).

Treatments	Conc.	First Season					Second Season				
		pH	EC	N	P	K	pH	EC	N	P	K
Superphosphate											
Control		8.10	0.60	190	18.2	51.2	8.02	0.64	186	17.8	52.4
Humic Substance	C1	7.84	0.63	196	20.5	57.5	8.00	0.65	186	18.3	54.2
	C2	7.81	0.70	199	28.6	69.2	7.86	0.68	194	20.5	63.0
	C3	7.81	0.70	210	31.0	84.8	7.82	0.70	198	28.6	72.2
Mean		7.82	0.68	202	26.7	70.5	7.89	0.68	193	22.5	63.1
Fulvic acid	C1	8.05	0.80	189	26.8	55.6	7.92	0.75	170	23.2	54.3
	C2	7.95	0.87	198	30.7	74.1	7.85	0.77	182	26.4	72.2
	C3	7.74	1.10	203	48.0	78.0	7.75	0.78	194	39.7	74.5
Mean		7.91	0.92	197	35.2	69.2	7.84	0.77	182	29.8	67.0
Citric acid	C1	7.88	0.72	189	20.9	57.5	7.91	0.70	176	18.8	52.4
	C2	7.79	0.77	193	27.5	63.4	7.88	0.74	182	20.9	59.8
	C3	7.78	0.90	199	28.7	65.3	7.79	0.75	194	26.5	60.5
Mean		7.82	0.80	194	25.7	62.1	7.86	0.73	184	22.1	57.6
Sulfuric acid	C1	7.83	1.03	200	26.9	48.8	7.82	0.72	178	25.7	48.2
	C2	7.77	1.10	203	39.4	63.4	7.80	0.72	186	26.9	62.5
	C3	7.68	1.20	203	48.6	79.5	7.77	0.74	198	39.4	80.4
Mean		7.76	1.11	202	38.3	63.9	7.80	0.73	187	30.7	63.7
Sulfure	C1	7.95	0.70	189	23.3	57.5	7.89	0.74	165	20.2	52.6
	C2	7.89	0.87	193	26.6	60.5	7.80	0.75	165	23.3	59.4
	C3	7.65	1.20	198	38.7	66.3	7.75	0.79	178	27.2	62.4
Mean		7.83	0.92	193	29.5	61.4	7.81	0.76	169	23.6	58.1
Compost extract	C1	7.91	0.98	189	19.6	60.5	7.91	0.70	198	16.9	50.2
	C2	7.80	1.10	203	22.5	63.4	7.83	0.72	201	19.6	59.8
	C3	7.80	1.14	203	28.1	71.2	7.68	0.77	204	22.5	62.8
Mean		7.83	1.07	198	23.4	65.0	7.81	0.73	201	28.1	57.6
Mean of super p.		7.83	0.92	198	29.8	65.4	7.85	0.73	186	24.7	61.2
Rock phosphate											
Control		8.02	0.70	197	11.14	50.7	8.01	0.71	182	10.2	49.2
Humic Substance	C1	7.93	0.75	195	33.14	80.0	7.98	0.72	194	30.9	80.2
	C2	7.85	0.80	202	36.49	82.9	7.93	0.79	198	34.6	84.4
	C3	7.72	1.10	202	47.40	88.7	7.85	0.80	198	35.8	86.5
Mean		7.83	0.88	199	39.01	83.9	7.92	0.77	198	33.7	83.7
Fulvic acid	C1	8.07	0.70	196	33.80	79.7	8.00	0.70	189	30.2	74.2
	C2	7.96	0.72	196	42.67	75.1	7.83	0.70	196	39.6	76.3
	C3	7.88	0.92	200	45.27	85.8	7.72	0.82	197	49.9	82.4
Mean		7.92	0.78	197	40.58	80.2	7.85	0.73	194	39.9	77.6
Citric acid	C1	8.01	0.80	195	32.20	52.7	7.94	0.78	184	29.8	59.2
	C2	7.97	1.10	199	36.00	58.5	7.89	0.87	192	32.2	62.0
	C3	7.86	1.20	199	47.13	82.9	7.75	0.99	196	39.2	74.4
Mean		7.95	1.03	197	38.44	64.7	7.86	0.88	191	33.7	65.2
Sulfuric acid	C1	7.89	0.72	191	35.03	62.4	8.01	0.74	192	33.8	60.3
	C2	7.74	0.74	196	42.60	77.0	7.95	0.76	197	39.2	70.2
	C3	7.71	1.20	198	51.87	77.0	7.71	0.88	200	49.4	77.9
Mean		7.78	0.89	195	43.17	72.2	7.89	0.79	196	40.8	69.5
Sulfure	C1	7.91	0.70	196	32.60	68.3	7.97	0.74	190	30.2	66.2
	C2	7.89	0.87	198	41.93	68.3	7.78	0.86	196	33.4	67.8
	C3	7.89	1.03	199	45.5	75.1	7.74	0.99	202	42.5	70.4
Mean		7.90	0.87	198	39.98	70.5	7.83	0.86	196	35.4	68.1
Compost extract	C1	7.97	0.98	196	32.50	75.2	7.97	0.89	200	30.2	75.0
	C2	7.94	1.10	196	37.27	79.5	7.89	0.90	202	32.1	77.4
	C3	7.89	1.14	200	44.60	97.3	7.88	1.00	205	34.0	85.2
Mean		7.93	1.07	197	38.12	84.0	7.91	0.93	202	32.1	79.2
Mean of rock p		7.89	0.92	197	39.88	75.9	7.88	0.83	196	35.9	73.9
LSD 0.05%											
A (P- Source)		0.147	0.001	0.821	0.116	0.375	0.01	0.002	0.062	0.025	0.402
B (different acidulation)		0.068	0.026	0.807	0.174	0.487	0.064	0.022	0.770	0.133	0.338
C (Conc. acid)		0.084	0.029	0.461	0.104	1.103	0.078	0.026	0.097	0.098	0.982
A*B		0.097	0.038	1.023	0.245	0.689	0.095	0.033	0.990	0.235	0.258
A*C		0.206	0.042	0.633	0.147	1.560	2.040	0.040	0.038	0.166	1.225
B*C		0.206	0.072	1.031	0.255	2.702	2.002	0.068	0.069	0.276	2.198
A-C		0.119	0.103	1.160	0.360	3.822	0.113	0.110	0.112	0.289	3.724

3- Nutrient availability in soil after harvesting of Pea

The data representing the availability of nutrients (N, P and K) in the soil after green pea harvesting, statistical analysis show the application of acidulated superphosphate and rock phosphate cause a significant increase in nutrient availability (N, P and K) as compared to the control treatments (superphosphate) this trend was true for both tested seasons for green pea yield. Moreover, P acidulation of Rock phosphate with different treatment was superior for increasing the availability of N,P and K as compared to superphosphate this may be due to convert the rock phosphate to superphosphate by acidulation [15] in addition the presence of P as rock phosphate promoted the diffusion of P away from the root zoon.

With regard to the concentration of different acidulates, available N, P and K increased gradually by increasing the concentration of acid. Generally, the dilution is more effective than the concentrated acids this agree with the finding of [15]. With respect to the different acidulates, for both super and rock phosphate the sulfuric and fulvic acid were superior for securing a maximum release of N, P and K as compared to the control and other treatments this can be attributed to larger CO_3^{-2} substitution for(PO_4) crystal lattice which renders to be un stable and more reactive [22] because of the control treatment (P- rock) low soluble in alkaline soils, especially calcareous soil, the direct application of rock phosphate has not been effective. The treatments arranged as follow ; sulfuric acid, fulvic acid, humic , sulfur ,citric acid , compost extract, this may be due to the presence of organic acids such as humic, fulvic, citric which lower the soil pH as a result of calcium and magnesium ion chelating process and boost the availability of P- from rock [23,24].

Also, the addition of sulfuric acid cause a decreasing in soil pH so, increasing the P-rock effectiveness and rock phosphate dissolution was also shown to be linearly correlated with reserve acidity of the tested treatments, the similar trend was observed for both tested seasons. Generally the availability of P with addition of different acids to rock and superphosphate was differ, this may be due to the differences in stability and to the amount of CO_3^{-2} release during $CaCO_3$ dissolution to Ca and CO_3. Also , depending on the supplies of H^+ from acid to another [25].

2- Response of yield components and biological yield

Data presented in Table (4) reveal that yield components (straw, pods and biological yield) of pea crop at both tested season increased significantly due to application of different acidulated treatments for superphosphate and rock phosphate as compared to control treatment. In case of rock phosphate only without acidulation the yield components (straw, pods and biological yield) of green pea crop decreased significantly as compared to acidulated rock phosphate and super phosphate treatments, this may be due to the relatively low solubility of phosphorus in rock phosphate and hence , the level of P in the root sorption zone is low , particularly, in early growth stages. It may also be due to attributed to the low development of plant compared with its rapid growth when soluble form of P is applied [26] .

In case of superphosphate, phosphorus can be release and diffusion immediately for uptake directly after amended, after that P reverse from available to an un available form [27].

With respect to yield of straw , pods and biological yield , data presented indicated that acidulated rock phosphate was superior as compared to super phosphate due to the partially acidulation of P-rock cause a significant increase the uptake of P and K in dry matter yield [28] . Generally, acidulation of rock phosphate and super phosphate with sulfuric and fulvic acid was the superior treatments which recorded high values of biological yield components .

On the other hand, the most inferior treatments for both acidulated rock phosphate and super phosphate were observed for compost extract. Therefore, we can conclude that partially acidulation of non reactive rock phosphate with sulfuric acid can improve the agronomic value of the p-rock, this agrees with the finding of [28]. Also, [29] mention that addition of sulfur to rock phosphate increase yield of ground nuts. On the other hand , the most inferior treatments for both yield components were recorded for the application of both super and rock phosphate with compost extract and citric acid, the oboist trend was recorded by [22] how found that 2% citric acid resulted from higher reactivity rather than the other acid. Again, organic, strong or weak acids and sulfur can improve the agronomic value of the P-rock [28].

Generally, rock phosphate was superior as compared to superphosphate (Fig. 1) due to reverse ion of unavailable to available form by slow release of P from rocks and affecting the development of the root system at the initial developmental stages of the plant which increase the uptake of other nutrient such as N, P and K and secure a good biomass and yield productivity, this agree with the finding of [28].

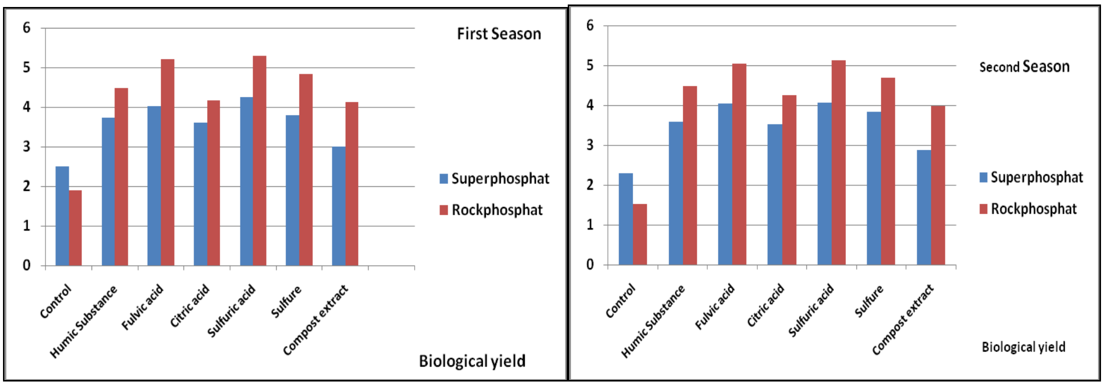

Fig.(1) : Effect of partially acidulation of rock phosphate as compared to super phosphate on biological yield of green pea crop

Table (4): Response of yield components of pea crop to the partially acidulation of rock phosphate as compared to super phosphate.

a) First season

Treatments	Conc.	Yield components (ton fed^{-1})		Biological yield (ton fed^{-1})
		Straw	Pods	
Superphosphate				
Control		1.10	1.20	2.30
Humic Substance	C1	1.31	1.97	3.28
	C2	1.47	2.20	3.67
	C3	1.58	2.25	3.83
Mean		1.45	2.14	3.59
Fulvic acid	C1	1.70	1.86	3.56
	C2	1.81	2.28	4.09
	C3	1.86	2.60	4.46
Mean		1.79	2.25	4.04
Citric acid	C1	1.00	1.90	2.90
	C2	1.25	2.02	3.27
	C3	1.94	2.46	4.40
Mean		1.40	2.13	3.52
Sulfuric acid	C1	1.71	1.87	3.58
	C2	1.75	1.89	3.64
	C3	1.99	2.96	4.95
Mean		1.82	2.24	4.06
Sulfure	C1	1.44	1.86	3.30
	C2	1.52	1.97	3.49
	C3	2.02	2.69	4.71
Mean		1.66	2.17	3.83
Compost extract	C1	1.06	1.15	2.21
	C2	1.14	1.31	2.45
	C3	1.53	2.43	3.96
Mean		1.24	1.63	2.87
Total Mean		1.56	2.09	3.65
Rock phosphate				
Control		0.70	0.82	1.52
Humic Substance	C1	1.41	2.50	3.91
	C2	1.54	2.79	4.33
	C3	2.24	2.93	5.17
Mean		1.73	2.74	4.47
Fulvic acid	C1	1.89	2.45	4.34
	C2	2.06	3.08	5.14
	C3	2.13	3.51	5.64
Mean		2.03	3.01	5.04
Citric acid	C1	1.27	2.12	3.39
	C2	1.65	2.62	4.27
	C3	2.07	3.00	5.07
Mean		1.66	2.58	4.24
Sulfuric acid	C1	1.77	2.82	4.59
	C2	2.17	3.13	5.30
	C3	2.34	3.16	5.50
Mean		2.09	3.04	5.13
Sulfure	C1	1.55	2.75	4.30
	C2	1.75	2.76	4.51
	C3	2.19	3.08	5.27
Mean		1.83	2.86	4.69
Compost extract	C1	1.24	2.32	3.56
	C2	1.44	2.48	3.92
	C3	1.50	2.92	4.42
Mean		1.39	2.57	3.97
Total Mean		1.79	2.80	4.59
LSD 0.05%				
A (P- Source)		0.078	0.074	0.004
B (different acidulation		0.026	0.027	0.019
C (Conc. acid)		0.029	0.029	0.014
A*B		0.038	0.038	0.026
A*C		0.042	0.042	0.021
B*C		0.073	0.072	0.036
A-C		0.103	0.063	0.031

b) Second season

Treatments	Conc.	Yield components (ton fed^{-1})		Biological yield (ton fed^{-1})
		Straw	Pods	
Superphosphate				
Control		1.20	1.31	2.51
Humic Substance	C1	1.40	2.05	3.45
	C2	1.50	2.30	3.80
	C3	1.66	2.30	3.96
Mean		1.52	2.21	3.73
Fulvic acid	C1	1.67	1.90	3.57
	C2	1.80	2.21	4.01
	C3	1.95	2.55	4.50
Mean		1.80	2.22	4.02
Citric acid	C1	1.10	1.86	2.96
	C2	1.32	2.17	3.49
	C3	1.84	2.52	4.36
Mean		1.42	2.18	3.60
Sulfuric acid	C1	1.80	1.98	3.78
	C2	1.90	2.00	3.90
	C3	1.95	3.11	5.06
Mean		1.88	2.37	4.25
Sulfure	C1	1.50	1.82	3.32
	C2	1.60	2.00	3.60
	C3	1.90	2.60	4.50
Mean		1.66	2.14	3.80
Compost extract	C1	1.10	1.20	2.30
	C2	1.20	1.41	2.61
	C3	1.60	2.50	4.10
Mean		1.30	1.70	3.00
Total Mean		1.34	1.77	3.11
Rock phosphate				
Control		0.90	1.00	1.90
Humic Substance	C1	1.47	2.60	4.07
	C2	1.60	2.71	4.31
	C3	2.20	2.90	5.10
Mean		1.75	2.73	4.48
Fulvic acid	C1	2.00	2.50	4.50
	C2	2.11	3.20	5.31
	C3	2.20	3.61	5.81
Mean		2.10	3.10	5.20
Citric acid	C1	1.20	2.20	3.40
	C2	1.72	2.50	4.22
	C3	2.00	2.90	4.90
Mean		1.64	2.53	4.17
Sulfuric acid	C1	1.84	2.90	4.74
	C2	2.20	3.22	5.42
	C3	2.41	3.30	5.71
Mean		2.15	3.14	5.29
Sulfure	C1	1.62	2.86	4.48
	C2	1.80	2.90	4.70
	C3	2.20	3.11	5.31
Mean		1.87	2.95	4.83
Compost extract	C1	1.32	2.40	3.72
	C2	1.50	2.60	4.10
	C3	1.60	3.00	4.60
Mean		1.47	2.66	4.13
Total Mean		1.83	2.85	4.68
LSD 0.05%				
A (P- Source)		0.068	0.057	0.014
B (different acidulation)		0.024	0.028	0.017
C (Conc. acid)		0.026	0.026	0.015
A*B		0.027	0.036	0.023
A*C		0.039	0.050	0.026
B*C		0.063	0.062	0.029
A-C		0.114	0.065	0.036

3- Total content of macronutrients for pea crop

The statistical interaction analysis in Table (5) showed that all applied treatments increased significantly the total content of macronutrient over the control treatments; this trend was true for both straw and seeds of green pea crop at both tested seasons. Application of super phosphate and rock phosphate in presence of different acidulates recorded a significantly superior for nutrient N, P and K uptake as compared to the control for both straw and seeds , these results are of similar trend to those of yield components discussed before. Organic acid (fulvic) and inorganic acid (sulfuric) enhancing the fertilizer use efficiency by slow release of applied nutrients and reduced nutrient losses [30] through chelation. Data also clear that, the application of both acidulated SP and RP with different concentration of acidulates show positively increase in N, P and K total contents of both straw and seeds compared to control treatments.

Positive relationship was responded between the availability of nutrients in the soil and the uptake of nutrients, the absorption of these elements by plant increase with increasing the availability of nutrients in the soil, these results confirmed the findings of [31, 32].

Moreover , phosphorus uptake increased with each increase in concentration of acids, also both yield and P- uptake for rock phosphate were higher when the pH decreased[22] . [33] mentioned that partially acidulation of rock phosphate can be release P immediately for crop uptake and synergist the nitrogen uptake.

Table (5) : Effect of partially acidulation of rock phosphate as compared to super phosphate on uptake of some macronutrients of pea Straw and Seeds
a) first season.

Treatments	Conc.	Uptake (kg fed^{-1})					
		Straw			Seeds		
		N	P	K	N	P	K
Superphosphate							
Control		22.00	3.00	12.00	9.10	2.09	8.11
Humic Substance	C1	30.94	4.46	20.10	16.95	2.95	8.96
	C2	36.83	6.65	22.83	21.81	3.01	9.84
	C3	40.33	7.59	24.09	22.00	4.06	10.13
Mean		36.03	6.23	22.47	20.30	3.37	9.64
Fulvic acid	C1	36.86	5.73	20.53	18.65	3.11	10.68
	C2	41.54	7.85	25.87	21.00	3.39	11.30
	C3	47.17	9.40	34.01	22.66	4.71	13.74
Mean		41.86	7.66	26.80	17.16	3.76	11.90
Citric acid	C1	22.29	3.25	12.50	9.31	2.44	8.80
	C2	27.10	3.76	16.51	11.74	2.43	9.22
	C3	38.01	5.19	18.91	17.72	3.83	9.61
Mean		29.13	4.07	15.97	12.76	3.02	9.21
Sulfuric acid	C1	38.05	6.30	27.16	22.17	3.45	10.28
	C2	41.32	6.98	29.59	22.80	4.17	12.27
	C3	51.69	10.2	32.07	25.75	4.51	15.27
Mean		43.68	7.83	29.61	23.61	4.05	12.52
Sulfure	C1	35.35	4.70	21.81	15.05	3.47	10.65
	C2	41.99	6.12	22.40	16.47	3.50	11.02
	C3	38.44	8.42	23.56	19.81	3.73	12.22
Mean		38.59	6.42	22.60	17.11	3.59	11.34
Compost extract	C1	22.73	3.05	13.28	13.29	2.09	6.27
	C2	26.30	3.64	15.60	13.69	2.12	6.94
	C3	35.22	4.47	16.27	14.00	2.16	8.02
Mean		28.09	3.72	15.03	15.29	2.29	7.95
Mean of super p.		42.37	5.99	22.08	17.71	3.35	8.54
Rock phosphate							
Control		30.20	2.05	16.00	11.20	2.00	6.00
Humic Substance	C1	51.54	4.75	23.37	20.69	2.75	9.85
	C2	40.85	6.89	25.87	31.21	3.35	10.52
	C3	32.71	9.09	27.00	36.50	3.93	11.39
Mean		41.70	6.91	25.39	24.86	3.04	10.59
Fulvic acid	C1	35.34	4.72	26.39	18.97	3.52	10.80
	C2	45.29	6.67	28.30	22.52	3.83	12.47
	C3	35.34	10.2	32.40	27.99	4.28	14.00
Mean		43.57	7.21	29.03	23.16	3.96	14.42
Citric acid	C1	29.05	3.43	16.14	17.05	2.25	9.20
	C2	38.41	5.64	18.60	18.00	3.02	10.23
	C3	49.32	7.75	19.05	19.63	3.15	11.30
Mean		38.93	5.61	17.91	18.23	2.81	10.25
Sulfuric acid	C1	36.72	5.10	28.88	22.40	3.12	14.46
	C2	47.42	8.18	30.48	23.00	4.04	15.25
	C3	52.96	11.6	34.06	26.20	4.86	15.29
Mean		45.70	8.29	31.07	23.87	4.01	15.00
Sulfure	C1	51.80	4.68	26.50	11.41	2.36	11.61
	C2	40.24	7.59	28.22	19.69	3.05	13.89
	C3	38.35	9.31	29.60	20.18	5.50	14.50
Mean		43.46	7.20	28.11	17.56	3.64	13.33
Compost extract	C1	25.40	3.90	12.87	14.31	2.36	7.57
	C2	39.48	5.39	18.39	16.00	2.62	9.04
	C3	39.58	6.67	19.40	17.00	3.21	11.37
Mean		34.82	5.32	16.87	15.77	2.73	9.32
Mean of rock p.		47.25	6.76	24.73	20.58	3.37	12.15
LSD 0.05%							
A (P- Source)		0.114	0.099	0.534	0.552	0.065	0.034
B (different acidulation)		0.756	0.154	0.512	0.277	0.153	0.116
C (Conc. acid)		1.540	0.375	0.427	0.571	0.455	0.077
A*B		1.070	0.217	0.727	0.393	0.217	0.164
A*C		2.178	0.177	0.603	0.808	0.644	0.109
B*C		3.772	0.307	1.045	1.400	1.116	0.189
A-C		3.266	0.266	1.477	1.979	1.578	0.268

b) second season.

Treatments	Conc.	Uptake (kg fed^{-1})					
		Straw			Seeds		
		N	P	K	N	P	K
Superphosphate							
Control		32.0	3.20	17.0	15.0	2.00	8.00
Humic Substance	C1	34.00	4.30	20.30	18.2	3.11	8.40
	C2	38.70	5.80	21.60	16.6	3.50	9.00
	C3	36.00	7.21	22.20	15.4	3.71	9.30
Mean		36.23	5.77	21.37	16.7	3.44	8.90
Fulvic acid	C1	35.00	5.90	23.70	19.3	3.70	10.6
	C2	40.00	7.40	28.30	22.0	4.32	11.2
	C3	44.00	9.65	33.40	24.0	5.00	12.0
Mean		39.67	7.65	28.47	21.8	4.34	11.3
Citric acid	C1	24.00	3.70	13.40	14.0	2.93	8.00
	C2	29.70	4.52	18.00	15.2	3.21	9.00
	C3	37.00	6.03	19.20	16.0	4.00	9.50
Mean		30.23	4.75	16.87	15.1	3.38	8.83
Sulfuric acid	C1	40.20	6.24	26.30	21.0	4.00	11.0
	C2	43.60	8.00	30.00	23.0	5.30	12.2
	C3	54.70	11.30	34.50	24.0	6.00	13.6
Mean		46.17	8.51	30.27	22.7	5.10	12.3
Sulfure	C1	31.20	5.60	21.70	18.2	3.00	10.0
	C2	37.00	7.00	24.50	22.5	3.52	11.3
	C3	41.00	8.30	26.00	24.0	4.12	12.0
Mean		36.40	6.97	24.07	21.6	3.55	11.1
Compost extract	C1	23.30	3.71	13.00	10.2	2.21	6.50
	C2	26.00	4.40	14.80	12.5	2.50	7.20
	C3	28.00	5.30	15.70	16.4	2.63	8.40
Mean		25.77	4.47	14.50	13.0	2.45	7.37
Mean super p.		35.75	6.35	22.60	18.5	3.71	9.96
Rock phosphate							
Control		30.0	4.10	15.0	15.0	2.20	8.00
Humic Substance	C1	35.0	4.90	22.0	16.3	3.00	9.50
	C2	42.8	8.40	24.5	18.0	3.70	10.8
	C3	53.0	9.00	26.8	19.2	4.51	11.0
Mean		43.6	7.43	24.4	17.8	3.74	10.4
Fulvic acid	C1	37.4	6.35	25.6	24.4	3.61	12.2
	C2	46.0	8.20	29.5	26.8	4.70	13.1
	C3	50.6	11.81	35.0	28.2	5.50	14.0
Mean		44.7	8.79	30.0	26.5	4.60	13.1
Citric acid	C1	35.0	4.30	15.8	12.2	2.86	9.00
	C2	41.8	6.40	18.0	18.7	3.35	10.2
	C3	50.6	8.20	18.7	21.0	4.00	10.8
Mean		42.5	6.30	17.5	17.3	3.40	10.0
Sulfuric acid	C1	45.3	6.35	28.2	21.9	4.27	12.6
	C2	50.0	8.50	31.3	30.4	5.80	14.0
	C3	48.5	12.4	35.2	32.5	6.45	14.2
Mean		47.9	9.08	31.6	28.3	5.51	13.6
Sulfure	C1	40.8	5.82	25.0	22.0	3.00	11.4
	C2	42.2	7.51	27.2	25.7	3.86	11.8
	C3	48.0	10.0	28.6	29.0	4.00	12.5
Mean		43.7	7.78	26.9	25.6	4.42	11.9
Compost extract	C1	30.0	4.20	14.0	15.0	2.40	8.00
	C2	38.6	5.62	17.8	16.3	2.80	9.00
	C3	42.2	7.20	18.2	18.5	3.11	10.0
Mean		36.9	5.67	16.7	16.6	2.77	9.00
Mean of rock p		43.2	7.51	24.5	22.0	4.07	11.2
LSD 0.05%							
A (P- Source)		0.102	0.012	0.324	0.322	0.042	0.043
B (different acidulation)		0.632	0.111	0.340	0.253	0.147	0.109
C (Conc. acid)		1.420	0.262	0.326	0.562	0.451	0.068
A*B		0.921	0.170	0.650	0.374	0.213	0.156
A*C		1.854	0.168	0.557	0.720	0.598	0.112
B*C		2.004	0.145	1.300	1.350	1.110	0.168
A-C		2.358	0.233	1.354	1.890	1.320	0.242

4- Phosphorus use efficiency

Phosphorus use efficiency from both rock phosphate and superphosphate can be calculated in terms of P-uptake per unit of fertilizer sources. The calculated values of P - use efficiency by green pea crop are presented in table (6).

Table (6): Effect of partially acidulation of different P-sources on P-use efficiency.

Treatments	Conc.	Phosphorus use efficiency			
		First season		Second season	
		Straw	Seeds	Straw	Seeds
Superphosphate					
Control					
Humic Substance	C1	6.49	3.82	4.89	4.93
	C2	16.2	4.09	11.6	6.67
	C3	20.4	8.76	17.8	7.60
Mean		14.3	5.56	11.4	6.40
Fulvic acid	C1	12.1	4.53	12.0	7.56
	C2	21.6	5.78	18.7	10.3
	C3	28.4	11.6	28.7	13.3
Mean		20.7	7.30	19.8	10.4
Citric acid	C1	1.11	1.56	2.22	4.13
	C2	3.38	1.51	5.87	5.38
	C3	9.73	7.73	12.6	8.89
Mean		4.70	3.60	6.89	6.13
Sulfuric acid	C1	14.7	6.04	13.5	4.44
	C2	17.7	9.24	21.3	14.7
	C3	32.0	10.7	36.0	17.8
Mean		21.5	8.66	23.6	12.3
Sulfure	C1	7.55	6.13	10.7	4.44
	C2	13.9	6.27	16.9	6.76
	C3	24.1	7.29	36.9	9.42
Mean		15.2	6.56	21.5	6.87
Compost extract	C1	0.22	0	2.27	0.93
	C2	2.84	0.13	5.33	2.22
	C3	6.53	0.31	9.33	2.80
Mean		3.20	0.15	5.64	1.99
Mean super p.		13.3	5.31	14.8	7.35
Rock phosphate					
Control					
Humic Substance	C1	12.0	3.33	3.56	3.56
	C2	21.5	6.00	19.1	6.67
	C3	31.3	8.58	21.8	10.3
Mean		21.6	5.97	14.8	6.83
Fulvic acid	C1	11.9	6.76	10.0	6.27
	C2	20.5	8.13	18.2	11.1
	C3	36.2	10.1	34.3	14.7
Mean		22.9	8.34	20.8	10.7
Citric acid	C1	6.13	1.11	0.89	2.93
	C2	15.9	4.53	10.2	5.11
	C3	25.3	5.11	18.2	8.00
Mean		15.8	5.58	9.78	5.35
Sulfuric acid	C1	13.6	4.98	10.0	9.20
	C2	27.2	9.07	19.6	16.0
	C3	42.4	12.7	36.9	18.9
Mean		27.7	8.92	22.2	14.7
Sulfure	C1	11.7	1.60	7.64	3.56
	C2	24.6	4.67	15.2	7.38
	C3	32.3	15.6	26.2	8.00
Mean		22.9	7.29	16.3	6.31
Compost extract	C1	8.27	1.73	0.44	0.89
	C2	14.8	2.76	6.76	2.67
	C3	20.5	5.38	13.8	4.04
Mean		14.6	3.29	6.99	2.53
Mean of rock p		20.9	6.23	15.2	7.73

Generally, the previous table can be summarized in Fig (2) as follow :

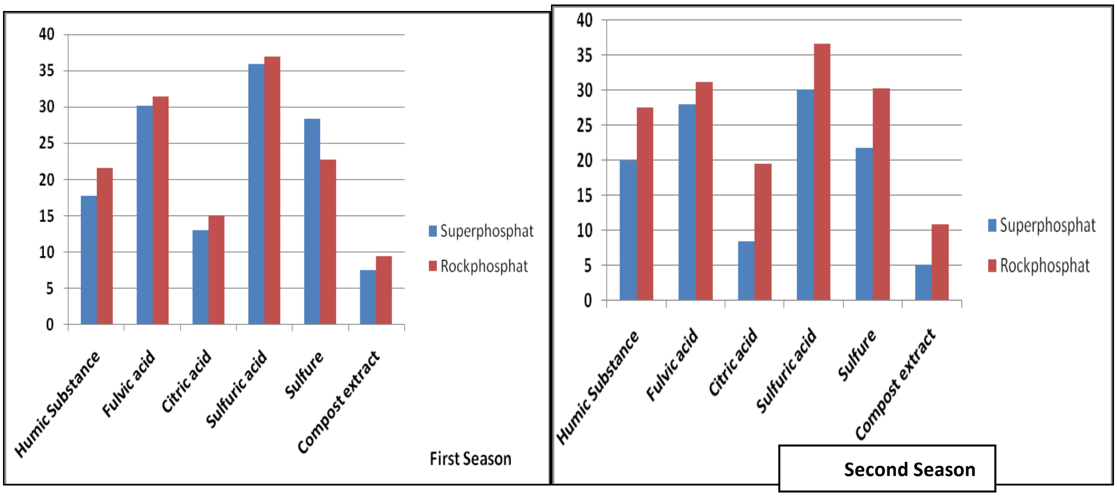

Fig (2): Effect of partially acidulation of different P-sources on P-use efficiency.

Data presented indicated that acidulation of super phosphate and rock phosphate enhance the Phosphorus use efficiency of green pea yield, similar results was observed in both tested seasons especially for rock phosphate. Generally increasing the concentration of acids under investigation cause a significant increase in phosphorus use efficiency due to decrease the pH value and the changes occur in soil pH and convert the rock phosphate to super phosphate and or decreasing the precipitation reaction of phosphorus [15].

The highest phosphorus use efficiency was obtained in presence of sulfuric and fulvic acid for both P-sources super phosphate and rock phosphate as compared to the other treatments, the opposite trend was obtained in presence of citric acid and compost extract in both tested seasons.

Finally, it could be concluded that uses of acidulated rock phosphate became a pronounce alternative phosphate fertilizers because of its effect on increasing the availability of P, P-Use efficiency , nutritional status and yield of green pea on certain Egyptian soil.

References

1. Hagin, J. and S. Katz (1985): Effectiveness of partially acidulated phosphate rock as a source of P to plants in calcareous soils. Fertiliser research 8 : 117 -127.
2. Elgala, A.M. and M.M. Elbordiny (2004) : Studies on the possible use of rock phosphate in alkali soils of Egypt. Egypt. J. Soil Sci. 44:85-95.
3. Mishra, B.; R.D. Sharma and N.P. Mishra (1980 a): Use of Mussoorie RP mixed with superphosphate or low gradepyrites as alternative P source for wheat on neutral soils; Indian J. Agric. Sci. 50:346-351.
4. Mishra, B.; N.P. Mishra and R.D. Sharma (1980 b): Direct and residual effects of Mussoorie RP applied in conjunction with pyrites or superphosphate in mize -wheat rotation on sub mountane soils; Indian J. Agric. Sci. 50:691-697.
5. Gholizadeh, A.; M. Ardalan ;M.M. Tehrani ; H. M . Hosseini and N. Karimian (2009): " Solubility test in some phosphate rocks and their potential for direct application in soil " World applied Sci. J.6: 182-190.
6. Nakamaru , Y.; M. Nanzyo and S. Yamasaki (2000): Utilization of apatite in fresh volcanic ash by pigeonpea and chickpea. Soil Sci. Plant Nut., 46: 591-600.
7. Habib, L.; S.H. Chien; G. Carmona and J. Henao (1999): Rape response to a Syrian phosphate rock and its mixture with triple superphosphate on a limed alkaline soil. Com. Soil Sci. Plant Anal., 30: 449-456.
8. Hamadi , A. S.; S.T. Remedhan and H. A. Ali (2012): Phosphate rock treated with hydrochloric acid for increasing P2O5 content. Eng. and Tech. J. 30: 67-76.
9. Rajan, S.S.S ; J.H. Watkinson and A.G. Sinclair (1996) : Phosphate rocks for direct application to soils. Adv. Agron., 57: 77-159.
10. Chien, S.H. and L.L. Hammond (1989): Agronomic effectiveness of partially acidulated phosphate rock as influenced by soil phosphorus- fixing capacity. Plant and Soil., 120, 159-164.
11. Schnitzer, M. and H. Kodama (1976): The dissolution of Micas by Fulfic acid . Geoderma. 15: 381-391.

12. Song, S.K. and P.M. Huang (1988): Dynamics of potassium release from potassium bearing minerals as influenced by oxalic and citric acids. Soil Sci. Soc. Am. J.52:383-390.
13. Ugolini , F.C and R.S Sletten (1991): The role of proton donors in ped-ogenesis as revealed by soil solution studies. Soil Sci 151:59–75.
14. Chien, S.H.; L.I. Prochnow and R. Mikkelsen (2010) : "Agronomic use of phosphate rock for direct application" Better Crops.94:21-23.
15. Frederick, E.D. and E.N. Roth(1986) : Sulfuric acid - based partially acidulated phosphate rock: Its production, cost and use .Tech. Bull. IFDC-T-31, International fertilizer development center(IFDC), Muscle Shoals, Alabama. , USA .
16. Cottenie, A.; M. Verloo ; L. Kiek ; G. Velghe and R. Camerlynek (1982): " Chemical Analysis of Plants and Soils" Lab. Anal. And Agroch. State Univ., Ghent, Belgium.
17. Snedecor, G.W. and Cochran, W.G. (1980): Statistical Methods. 7th Edition. Iowa State Univ. Press., Ames., IA., U.S.A.
18. Iqbal, Z., A. Latif, S. Ali and M.M. Iqbal (2003): Effect of fertigated phosphorus on P use efficiency and yield of wheat and maize. Songklanakarin J. Sci. Technol .,8:110-119.
19. El-Etr, Wafaa ; Mona, A. Osman and A.A Mahmoud (2011): Improving phosphorus use efficiency and its effect on the productivity of some crops. J.Soil Sci. and Agric.Eng., Mansoura Univ.,2(9):1019-1034
20. Neilsen, D.;I.S. Hoyt; P.B.P. Parchomchuk ;G.H. Neilsen and E.J. Hogue (1995) :Measurement of the sensitivity of orchard soils to acidification. Can. J. Soil Sci.,75:391-395.
21. Fiorentino G.; R. Spaccini and A. T. Piccolo **(**2006): Separation of molecular constituents from a humic acid by solid-phase extraction following a trans esterification reaction. Soil Sci., 68: 1135-1142.
22. Ghosal, P.K. and T. Chakraborty (2012): Comparative solubility study of four phosphatic fertilizers in different solvents and the effect of soil. Resources and Environment 2:175-179.
23. Savini, I.; P. Smithson and N. Karanja (2006): Effects of added biomass, soil pH and calcium on the solubility of Minjingu phosphate rock in a Kenyan Oxisol. Archives of Agronomy and Soil Sci. 52:19-36
24. Ali, M.; A. Ali ; M. Tahir and M.Yaseen.(2012): Growth and yield response of hybrid maize through integrated phosphorus management. Pakistan J. of life and Soc.Sci.10:59-66.
25. Lutz, J.A. (1971): Comparison of partially acidulated Phosphate rock and concentrated superphosphate as sources of phosphorus for corn. Agron.J.63 , 919.
26. Hammond, L. L., S.H. Chien and A.U. Mokwunye (1986): Agronomic value of un acidulated and partially acidulated phosphate rocks indigenous to the tropics. Adv. in Agron.40:89-140.
27. Roy, A.H. and G.H. McClellan (1985): Future prospects for nonconventional phosphate fertilisers in developing countries. Paper presented at the 1985 Autumn meeting of the Raw Materials Committee of the International Fertiliser Industry Association, Kyoto, Japan, October15-16 .IFDC, Muscle Shoals, AL.
28. Govere, E.M.; S.H. Chien and R.H. Fox (2003): Agronomic effectiveness of novel phosphate fertilizers derived from an igneous Zimbabwe phosphate rock. African Crop Sci. J. 11:235-243
29. Bromfield, A.R.(1975): Effect of ground rock phosphate sulphur mixture on yield and nutrient uptake of groundnuts in Northern Nigeria; Expl. Agric. 11:266-272.
30. Sarwar, G.; H.C. Shmeisky ;N. Hussain ; S. Muhammad; M. Ibrahim and E. Safdar (2008): Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. Pak.J.Bot.,40:275-282.
31. Osman, E., J. P. Muir and A. Elgersma (2002): Effect of Rhizobium inoculation and phosphorus application on native texas legumes grown in local soil. J. of Plant Nutr., 25: 75-92.
32. Elsheikh, M.A. ; A.M.A. El-Tilib ; E.A.E. Elsheikh and A.H.A. Elkarim (2007): Effect of phosphate rock and triple superphosphate on growth and leaf N,P and K contents of groundnut (Arachis itypogaea L.)grown on a clay soil. Arab. Univ.J.Agric.Sci.,15 :197-202.
33. Potarzycki, J. (2009): Influence of formulation of phosphorus fertilizer on nitrogen uptake and its efficiency under Maize grain cropping. Acta Sci. Pol., Agric. 8: 3-13.

****