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Impact of Applying Rock Phosphate and Amendments on Soybean Plants Grown under Sandy and Clayey Soil Conditions

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ABSTRACT
The greenhouse experiment aims to apply and study the effect of selected and mixed treatments (oxalic acid, phosphate solubilizing bacteria, farmyard manure, and ammonium thiosulfate) with rock phosphate on the productivity of the fresh and dry weight, as well as the uptake of different elements (nitrogen, phosphorous, and potassium) on the soybean (*Glycine max*) (legume plant) cultivar (Giza 111) crop in both sandy and clay soils, using the Completely Randomized Design (CRD) with three replications. Results were statistically analyzed using the GenStat (11th Edition) statistical software package. The results showed that the highest increase in the fresh-dry weight, shoot and root, plant length, and nutrient uptake when adding and mixing ammonium thiosulfate and oxalic acid with rock phosphate, either separately or in combination, while the soybean plant in the sandy soil similarly, a trend in the clayey soil.

Keywords: rock phosphate, oxalic acid, ammonium thiosulfate, Soybean

1. Introduction

Soybean plays an important role in sustainable agriculture because it is considered the major source of protein and vegetable oil as well as an essential amendment of soil fertility. However, this species is sensitive to P deficiency (Rotaru and Sinclair, 2009). Soybean (*Glycine max* L.), a leguminous crop, is one of the most important and extensively grown crops that accounts for 30% of the world's processed vegetable oil (Graham and Vance, 2003).

Phosphorus is also an essential ingredient for Rhizobium to convert atmospheric nitrogen (N_2) into an ammonium (NH_4^+) form usable by plants. Phosphorus deficiency in soil can severely limit plant growth and productivity, particularly in legumes, where both the plant and their symbiotic bacteria are affected resulting in deleterious effect on nodule formation, development and function (Alikhani *et al.,* 2006).

Phosphorus is widely distributed in nature. Phosphate species are the main forms of P in the environment. A soil has an eminent reserve of total P. More than 43% of the world soils are deficient in phosphorus, but very little amount of P only 0.1% is actually available to the plants to support their growth to fulfill the requirement due to the fixation of phosphorus in the soil as insoluble phosphates (Xiao *et al.,* 2011). Therefore, phosphorus deficiency in agricultural land can drastically affect plant development and metabolism, so is one of the main factors which reduce the crop production (Wu *et al.,* 2005). Addition of extra P to the soil led to consume more resources for the crop production and hence, the costs of production of crop plants per unit area increase (Aziz *et al.,* 2006). Due to the high cost of phosphate fertilizers there is a need for alternative sources and necessitate finding out an economical and eco-friendly way to increase the availability of P and at the same time, reduce the losses of phosphorus. The primary source of P in manufactured phosphate fertilizer was bones; after rapid exhaustion of bone supply, the only source of almost all manufactured phosphate fertilizers became rock

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phosphate. Rock phosphate application as fertilizer is known a long time ago, in recent year's attributes much attention of researcher in this regards to obtain more valuable products and RP enhanced with biological and chemical means can be a good solution.

Rock phosphate is one of the basic raw materials required in the manufacture such as phosphoric acid, cleaners, soaps, detergents and insecticides, food processing applications and water treatment and phosphate fertilizers such as single super phosphate, di-ammonium phosphate and nitro phosphates. Most fertilizers manufacturing processes use sulfuric acid, although some, mostly in Europe, use nitric acid (Samreen and Kausar, 2019).

Several studies have been conducted to improve RP, in order to increase its immediate P availability and enrich its rate of dissolution after application to the soil (Kumari and Phogat, 2008).

Chien *et al.* (2010) mentioned that various organic acids can effectively dissolve minerals and chelate metallic cations. Generally, the great effect of organic acids on dissolution of 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. Taghipour and Jalali, (2013) mention that the ability of organic acids for P release related to the number of carboxylic function group and their ability to release P from Fe-Mn oxide fraction. Also, they provided guidance for the selection of organic acids to enhance P bioavailability in calcareous soils. Furthermore, they proved that the oxalic acid has the largest ability to chelate many metal ions (K^{+}, Mn^{2+}, Zn^{2+} and Cu^{2+}), preventing their precipitation with P.

Ahmad *et al.* (2019) stated that the RP was activated via acidification with HCl, EDTA and oxalic acid using wheat (*Triticum aestivum* L.) plants. They found a significantly ($p< 0.05$) high amounts of soil available P, Fe, Mn and Zn were released from all the RPs treatments after 9 days of seedling transplantation.

Abdel-Kader and Saleh, (2017) suggested that the use of bio-fertilizer with RP or with feldspar is economic and environmental friendly and has potential to improve Roselle yield and quality.

Rotaru and Risnoveanu, (2019) showed that the inoculation treatments showed better plant growth and nutrient uptake when compared to un-inoculated control. The application of the *Burkholderiacepacia* was more efficiently in terms plant growth than *E. radicincitans* especially under insoluble phosphates. Phosphorus concentrations of shoots and roots increased with both bacterial strains. The bacterial inoculation has much better stimulatory effect on nutrient uptake by soybean fertilized with insoluble phosphates.

El-Sayed *et al.* (2018) evaluated the efficiency of RP and potassium feldspar application combined with phosphate and potassium solublizing bacteria on availability of P, K and their uptake on growth, yield and quality of table beet plant grown in sandy soil. Furthermore, they confirmed that, replacing chemical phosphorus and potassium fertilizers by natural one will help in reducing environmental pollution, cheaper in price and produce safe human food.

Rotaru and Risnoveanu, (2019) found the growth of legume plants is usually improved by the rhizobacteria inoculation under low P. Their experimental incubation and pots results revealed that the growth and P contents in shoots and roots of soybean cultivated in P-deficit soil were affected by two strains *Burkholderia cepacia* 36B and *Enterobacter radicincitans* 23D/5 have ability to promote growth and improve P nutrition of soybean plants in presence of soluble or insoluble phosphates in relation to soil moisture level.

Salah, (2018) showed the clear evidence that the elemental S could be highly recommended as a useful and economical material to maintain the efficiency of superphosphate fertilizer in increasing growth and production of soybean plants in high pH clayey soils in Egypt after application of the elemental S with superphosphate.

Mashori *et al.* (2013) recounted that the application of RP along with FYM was effective in increasing the plant height, shoot dry matter yield, P concentration and uptake in maize as SSP. It is concluded that the application of RP along with FYM can be used as an alternate source of SSP. Similarly, the combined application of RP and SSP performed better than the individual application of the two with the recommended percent of RP and SSP as 50+50.

Manzoor *et al.* (2016) evaluated the effect of separate and combined use of indigenous PSB, poultry manure (PM) and compost on solubilization and mineralization of RP and their subsequent effect on growth and P accumulation of maize (*Zea mays* L.). The combined addition of PSB and organic amendments (PM, compost) with RP further increased P mineralization by releasing a maximum of 37.7 µg/g compared with separate application of RP (11.8 µg/g) and organic amendments (21.5 and 16.5 µg/g). The overall effect of PSB (as a group) with RP over RP only on maize growth showing a relative increase in shoot length 21%, shoot fresh weight 42%, shoot dry weight 24%, root length 11%, root fresh weight 59%, root dry weight 35% and chlorophyll content 32%. In the present study to assess the effect of selected and mixed treatments (oxalic acid, farmyard manure, ammonium thiosulfate and phosphate solubilizing bacteria) with rock phosphate was investigated in order to find the best combination of examined factors and examine the efficiency of P bioavailability on growth of soybean in greenhouse experiment.

The current study aims to investigate the effect of the application of different amendments on the availability of phosphorus and the agronomic efficiency of different RPs that have a wide range of reactivity through the application of different amendments, i.e., organic acids, phosphate solubilizing bacteria, farmyard manure, sulphur, and ammonium thiosulfate, to get optimum conditions for the enhancement of the use of RP in agriculture.

2. Materials and Methods

A greenhouse experiment was carried out to evaluate the effect of different amendments on the availability of P from rock phosphate for crop use.

2.1. Materials

2.1.1. Soil samples collection

Soil samples were collected from two different locations; the first location was from the main research station (National Research Center, Giza, Egypt) located at Nubaria region and the second location was from El-Kanater farm. The soil samples were air-dried and ground to pass through a 2mm sieve for laboratory experiments. Some physical and chemical properties of the tested soils are presented in Table (1).

Table 1: Some physical and chemical characterization of the soil samples

Soil Character	El-Kanater soil	Nubaria soil	Soil character	El-Kanater soil	Nubaria soil
Particles size distribution %			**Soluble cations meeq/L**		
Clay	43.5	15.97	Ca^{++}	1.50	0.90
Silt	38.0	3.90	Mg^{++}	0.50	0.30
Sand	18.5	80.13	Na^{+}	1.57	0.92
Texture class	**Clayey**	**Sandy loam**	K^{+}	0.55	0.67
Organic matter%	1.78	0.068	**Soluble anions meeq/L**		
Ec Soil paste (dS/m)	0.39	0.22	Cl^{-}	1.10	0.50
pH (1:2.5) soil: water suspension	7.9	7.5	CO^{2-}_{3} HCO_3^-	0.00 2.50	0.00 2.00
$CaCO_3$ (%)	2.3	5.2	SO_4^{2-}	0.52	0.29
Total P%	0.216	0.195			
Available P (ppm)	15.62	7.26			
Available K (ppm)	260	38.2			

2.1.2. Rock phosphate samples.

A rock phosphate samples were collected from different phosphate mines locations present in the Western Desert between El-Kharga and El-Dakhla Oases (Abu Tartur), the Nile valley near Idfu (El Sebayia) and along the (Red Sea) between Safaga and Quesir. All RP samples were ground to pass through a 100-mesh (150µm) sieve. Some physical, chemical and mineralogical characteristics of RP samples are shown in Table (2).

Table 2: Some of the main physical, chemical and mineralogical characteristics of the RP samples used in the study.

Location	Resource Name	Total P_2O_5 (%)	Available P_2O_5 (mg/kg)	pH (1:2.5)	EC dS/m (1:2.5)	$CaCO_3$ (%)	Active $CaCO_3$ (%)
Western Desert	**Abu Tartur**	24	1.4	7.0	1.4	12.2	1.02
Major minerals	Fluroapatite Apatite-Calcite Francolite Quartiz Low						

The concentrations of some heavy metals found in the RPs samples were determined and given in Table (3).

Table 3: Contents of some heavy metals (mg/kg) of rock phosphate samples collected from different locations.

Sources of RPs	Zn	As	Co	Pb	Cd
Abu-Tartur	681	40	43	11	3

Some chemical properties of (FYM) are shown in Table (4). The soil-available P was determined after each incubation time. Also, the changes in the soil pH values for all treatments were determined using pH meter (soil: water suspension at a ratio, 1: 2.5).

Table 4: Some chemical properties of the farmyard manure used in the current study.

O.C %	O.M. %	C/N ratio	pH (1:10)	EC dSm^{-1} (1:10)	Total nutrients %		
					P	K	N
19.5	33.2	25.2	7.2	5.81	0.35	1.2	1.60

2.1.3. Solubility test of RP samples

Measure of the solubility (reactivity) of direct application rock phosphate (DARP) can be carried out by commonly three solutions, namely neutral ammonium citrate (NAC), 2% citric acid (CA) and 2 % formic acid (FA).

2.1.3. Greenhouse experiment

The experiment was designed to utilize OA, FYM, ATS and PSB mixed with RP to upgrade efficiency of RP used in this study. The previous treatments were applied and thoroughly mixed with the soils and received 9 treatments as follows:

1- Control (no addition phosphorous).
2- Rock phosphate (Abu Tartur P_2O_5 24%) (RP).
3- Single superphosphate (P_2O_5 15.5%) (SSP).
4- Rock phosphate + PSB (RP+PSB).
5- Rock phosphate + Farmyard manure(RP+FYM).
6- Rock phosphate + Farmyard manure + Phosphate Solublizing Bacteria (PSB) (mixture of *Bukholderia cepacia* and *Acintobacte*r sp) PSB (RP+FYM + PSB)
7- Rock phosphate + Oxalic acid (RP+OA)
8- Rock phosphate + Ammonium thiosulfate (RP+ATS)
9- Rock phosphate + Oxalic acid + Ammonium thiosulfate (RP+ OA +ATS).

The experiment was conducted in the greenhouse of Plant Nutrition Dept. NRC, Giza, Egypt using two soil samples to study the effect of P solubility from Abu Tartur rock phosphate with OA (60mmol) equal to 23kg/fed, FYM (20m$^{3/}$fed), ATS (40L/fed) and PSBs (20L/fed) on fresh and dry weight of shoot and root as well as plant height of soybean (*Glycine max* L.) (legume plant) cultivar Giza 111. The experiment was conducted in 40cm diameter plastic pots filled with 10kg sandy loam and clayey soils (3 plants per pot) and allowed for a period of 70 days. The seeds of soybean were inoculated with

Bradyrhizobium japonicum and were applied at a rate of 300g per 60kg seed, using Arabic gum solution (16%) as a sticking agent and were sown on 24 May season 2015. The pots were irrigated up to field capacity. The pots were arranged in a randomized complete block design with three replicates. Fertilizers (NPK) were applied at the recommended rates (Table 5).

Table 5: Description of the applied NPK fertilizers to the soils with soybean

Treatment	Soybean		
	Fertilizer amount (kg/fed)		
	N	P_2O_5	K_2O
	Sandy soil		
Control	20	-	60
RP	20	30	60
SSP	20	30	60
RP+PSB	20	30	60
RP+FYM	20	30	60
RP+FYM+PSB	20	30	60
RP+ATS	20	30	60
RP+OA	20	30	60
RP+OA+ATS	20	30	60
	Clayey soil		
Control	15	-	50
RP	15	25	50
SSP	15	25	50
RP+PSB	15	25	50
RP+FYM	15	25	50
RP+FYM+PSB	15	25	50
RP+ATS	15	25	50
RP+OA	15	25	50
RP+OA+ATS	15	25	50

All pots received a constant rate of ammonium nitrate (0.6 g and potassium sulfate 1.2 g per pot) for soybean while single super phosphate (SSP) was (2 g per pot for soybean and rock phosphate was (1.25 g per pot for soybean)

All fertilizers and amendments mixed well with the top 5 cm top soils. After 70 days, plant samples were taken from each pot and washed with tap and distilled water then dried in oven at 70º C for 24 hrs. The dried plant samples were weighted ground and kept in clean polyethylene bags for analysis. The fresh-dry weight of shoots and roots, plant height (cm) were recorded. Macronutrients (N, P and K) content in all plants were determined and the uptake of N, P and K was calculated.

2.2. Analytical methods for soils and plants

2.2.1. Soil analysis

- Particle size distribution was performed according to the pipette method as described by (Piper, 1950).
- Total organic C was determined using Walkley and Black method (Jackson, 1973).
- Total carbonates were determined gasometrically by using Collins Calcimeter and calculated as $CaCO_3$ (Dewis and Feritas method, 1970).
- Soil pH was measured in (1:2.5) soil: water suspension using a glass electrode (Jackson, 1973).
- The electrical conductivity (EC) was measured in (1:2.5) soil: water extract (Jackson, 1973).
- Available phosphorus was extracted with 0.5 N $NaHCO_3$ solution adjusted at pH 8.5 and determined calorimetrically according to Olsen *et al.* (1973).
- Total nitrogen was determined according to Kjeldahel method, Black, (1965).

- Extractable potassium was extracted by ammonium acetate at pH 7 as described by Dewis and Feritas method, (1970). Potassium was determined using flame photometer.

2.2.2. Rock phosphate analysis

- The geochemical distribution of certain major oxides include SiO_2, Al_2O_3, CaO, MgO, Na_2O, K_2O, MnO and Fe_2O_3 were analyzed by the X-Ray fluorescence, National Research Center and trace elements of rock phosphate samples powdered samples (100-mesh) were determined according to (Shapiro and Brannock, 1962).
- Active carbonates were determined according to Yaalon method, (1980).
- Mineralogical composition of RPs were determined by powder X-ray diffraction (XRD) using a Philips PW1730 diffractometer.
- Reactivity test using three solutions commonly (neutral ammonium citrate (NAC), 2% citric acid (CA) and 2 % formic acid (FA)) to measure the solubility of rock phosphate samples according to Diamond, (1979).
- Some heavy metals assumed to be found in the rock phosphate samples were determined by atomic absorption spectrometry.

2.2.3. Plant analysis

Half gram of plant samples was wet digested using 4 ml of conc. sulfuric acid (overnight) and 2 ml of 30% H_2O_2. The acid digest was analyzed for N, P and K using the following methods:

- The total nitrogen was determined using micro- Kjeldahel apparatus, (Cottenie *et al.,* 1982).
- Phosphorus was assayed using ammonium vanadate method, (Cottenie *et al.,* 1982).
- Potassium being evaluated photometerically using flame photometer.

2.4. Statistical analysis

All data were subjected to the analysis of variance (ANOVA) appropriate to the experimental design to evaluate the effects of treatments on the P solubility. CoStat (Version 6.311, CoHort, USA, 1998-2005) was used to conduct the analysis of variance. Comparison of means was carried out using the least significant difference (LSD) at 5% probability level.

3. Results and Discussion

3.1. Effect of rock phosphate with amendments application on soybean plants in grown sandy and clayey soils.

3.1.1. Biometric parameters

3.1.1.1. Shoot fresh and dry weights

Results in Table (6) represent the effect of RP with amendments, i.e. PSB, FYM, OA and ATS on the shoot fresh and dry weights of soybean grown on the studied sandy and clayey soils. It was noticed that from the results in Table (6) that RP treatment individually or in combination with amendment yielded a significant increase in the yield of the soybean plant (shoots fresh and dry weights) as compared to the control treatment in both sandy and clayey soils. Direct application of RP only or mixed with PSB or FYM showed lower growth (fresh and dry weights of shoots) compared with SSP treatment as the plants showed lower P utilization efficiency. On the other hand, these treatments gave a significant increase in the fresh and dry weights of soybean plants compared to the RP only treatment. The fresh and dry weights of shoots of soybean plants for FYM+RP were 46.2 and 4.16g/plant and 94 and 8.6g/plant in sandy and clayey soils, respectively. It could be concluded that the combination of RP with FYM gave a significant increase in the fresh and dry weights of soybean plants over the RP only treatment by about 31 and 31.2 % and (25.3 and 24.6%) in sandy and clayey soils, respectively.

This result indicated that the organic matter may increase P availability by the release of organic acids which compete with phosphates for binding the sorption sites in the soil and they produce stronger complexes with Ca^{2+} which consequently increase the P content in the soil solution (Mihoub *et al.,* 2016 and Wahba *et al.,* 2018).

Regarding the effect of RP+PSB, there were significant increases in the shoots fresh and dry weights due to inoculation with PSBs (a mixture of *Bukholderia cepacia* and *Acinetobacter sp*) compared to the individual application of RP in both sandy and clayey soils. The fresh and dry weights of shoots of soybean plants for RP+PSB were 43.4 and 3.91g/plant and 88 and 8.1g/plant in sandy and clayey soils, respectively. A combination of RP with PSB gave a significant increase in the fresh and dry weights of the shoots of soybean plants compared to the RP only treatment by 23 and 23.3% and 17.3 and17.4% in sandy and clayey soils, respectively, according to Abdel-Kader and Saleh, (2017) suggested that the use of bio-fertilizer with RP or with feldspar is economic and environmental friendly and has potential to improve Roselle yield and quality.

Table 6: Effect of RP and different stimulant agents on the plant height, shoots- roots fresh and dry weights of soybean crop grown in sandy and clayey soils after 70 days of planting.

Treatments	Plant length (cm/plant)	Shoots		Roots	
		Fresh weight (g/plant)	Dry weight (g/plant)	Fresh weight (g/plant)	Dry weight (g/plant)
			Sandy soil		
Control	21.7	24.7	2.22	2.3	1.13
RP	23.7	35.3	3.17	3.8	1.72
SSP	32.3	128.4	11.56	5.7	2.60
RP+PSB	24.5	43.4	3.91	4.3	1.94
RP+FYM	24.0	46.2	4.16	5	2.25
RP+FYM+PSB	25.3	64.5	5.81	5.3	2.43
RP+OA	34.3	139.7	12.58	6.5	2.96
RP+ATS	36.3	148.6	13.38	7.3	3.28
RP + ATS + OA	38.3	158.3	14.25	7.7	3.50
LSD 5%	**4.77**	**4.94**	**0.44**	**1.15**	**0.4**
			Clayey soil		
Control	25.0	56	5.1	4.4	2.1
RP	27.7	75	6.9	7.5	3.7
SSP	33.3	163	15.0	10.5	5.1
RP+PSB	29.7	88	8.1	8.2	4.0
RP+FYM	29.8	94	8.6	8.8	4.3
RP+FYM+PSB	31.3	119	10.9	10	4.9
RP+OA	35.3	173	15.9	11.4	5.6
RP+ATS	37.0	183	16.9	12.6	6.2
RP + ATS + OA	40.0	193	17.8	13.8	6.9
LSD 5%	**3.67**	**8.24**	**0.73**	**0.8**	**0.28**

It should be noted that the combination of FYM + PSB with RP yielded a significantly efficient effect than FYM or PSB when applied solely with RP. The fresh and dry weight of the shoot of soybean plants significantly enhanced with the application of RP+FYM + PSB, which were 64.5 and 5.81g/plant and 119 and 10.9g/plant in sandy and clayey soils, respectively. Application of RP+FYM+PSB increased of the fresh and dry weights of soybean plants compared to the RP only treatment the increase was by 82.7 and 83.3% and 58.7 and 58% in sandy and clayey soils, respectively.

The growth and yield parameters were significantly improved in chickpea and lentil when treated with RP-enriched with organic fertilizer + PSMs as compared to control and application of RP solely. It might be due to the positive effect of PSM inoculation on the nodules, which increases the supply of N to the crop plants and ultimately growth and yield of both the legumes. It might also be due to the increase in the supply of P by the P-solubilizing activity of PSMs via the production of organic acids and proton extrusion which indirectly increased the nodulation and ultimately more N was fixed (Surange *et al.,* 1997). Furthermore, Sharif *et al.* (2015), they suggested that solubility of P may be enhanced from RP through application with FYM and EM, which has the potential to improve plants N and P uptake and crops yields on sustainable basis.

These results may be due to the combined addition of PSB and organic amendments (PM, compost) with RP further increased P mineralization by releasing a maximum compared with separate application of RP Manzoor *et al.* (2016) It is worthy to mention that the combination of rock phosphate with OA or ATS or OA+ATS when applied together yielded a significantly efficient effect than RP when applied only or SSP treatment in both sandy and clayey soils. On the other hand, RP+OA appreciably increased the fresh and dry weight of shoots to be 139.7 and 12.58g/plant and 173 and 15.9g/plant in sandy and clayey soils, respectively. Application of RP+OA produced higher fresh weight of soybean plants than the RP only or SSP treatment by 296 and 9.0% and 130.7 and 6.1% in sandy and clayey soils, respectively. These results may be due to OA was the most efficient organic acids to solubilize RP compared to SSP. Oxalic acid presents a great potential to solubilize RP and form a great complexity and their mineralogical structure makes solubilization more difficult when compared to SSP. This result indicated that additions of oxalic and citric acids were the most efficient organic acids to solubilize RP; the increase in effectiveness with the addition of organic acids relative to the control was greater for the RP than for mono-calcium phosphate (Klaic *et al.,* 2017).

The effect of ATS with RP on fresh and dry weights of soybean plants was highly significant compared to RP and SSP in both sandy and clayey soils. The fresh and dry weights of the shoots of soybean were 148.6 and 13.38g/plant and 183 and 16.9g/plant in sandy and clayey soils, respectively. Application of RP+ATS increased the fresh weight of soybean plants compared to the RP only or SSP treatment; the increase was by 321 and 16% and 144 and 12.3% in sandy and clayey soils, respectively. A similar trend was observed with dry weights. These results may be due to that the fertilizer ATS has an acidifying effect on soil due to nitrification process in soil and release of H^+ ions and hence, the pH decrease due to the assimilation of NH_4^+ to be the one mechanism promoting RP dissolution, while ATS fertilization may lower soil pH and solubilize of RP (Hinsinger *et al.,* (2003). Furthermore, Gezerman, (2019) observed that when ammonium thiosulfate was used as nitrification inhibitors, leaching of ammonium nitrate from calcium ammonium nitrate in soil is decreased, while the yields and nitrogen intake of the plant are increased.

The highest fresh weights of shoots (158.3 and 193g/plant) were recorded from the RP+OA+ATS treatment as compared to the other treatments of both sandy and clayey soils. A similar trend was observed with dry weight. The relative increase in fresh weight of soybean plants compared to the RP only or SSP treatment was by 348.4 and 23.5% and 157.3 and 18.4% in sandy and clayey soils, respectively. The efficiency of ATS and OA with RP for the best growth parameters may be due to supply P to plants coupled with the additional benefits of ATS or OA on physicochemical characteristics of root proliferation (Table 6). Also, the application of ATS and OA with RP has a positive effect on growth parameters and this may be due to the organic acids contribute to the lowering of solution pH as they dissociation pH depends on equilibrium, these results are accordance with findings of Jamal *et al.* (2018).

3.1.1.2 Roots fresh and dry weights

Roots fresh and dry weights of soybean grown in no P treatment (control) were significantly lower than the root fresh and dry matter recorded in P-treated plants in sandy and clayey soils (Table 6). Single super phosphate application gave roots fresh and dry weights significantly higher than that obtained with the application of RP only in sandy and clayey soils. Rock phosphate when applied individually significantly increased roots fresh weight compared to the control; the increase was by 65.2 and 70.5% in sandy and clayey soils, respectively. Among different treatments, the roots fresh and dry weights were maximum in the treatment under RP+ATS+OA which were (7.7 and 3.5g/plant) and (13.8 and 6.9g/plant) in sandy and clayey soils, respectively. The relative increase in roots fresh weights compared to the RP only or SSP treatment by about (106.2 and 84.0%) and (35.1 and 34.4%) in sandy and clayey soils, respectively. Rock phosphate only had little effect on roots fresh weight. Sequera and Ramiars, (2013) pointed out that partial acidification of RP with ATS and sulfuric acid produces a fertilizer as efficient as the sulfuric acid for growth of the root system in both acid and neutral soil and confirmed its efficiency in the production of dry matter and phosphorus uptake by the plant.

The application of RP with PSB or FYM displayed a significant increase in roots fresh and dry weights compared to that of the solely application of RP. In sandy soil, roots fresh and dry weights of soybean obtained due to the application of RP+PSB and RP+FYM, increased by 13.2 and 12.8% and 31.6 and 30.8%, while in clayey soil increased by 9.3 and 8.6% and 17.3 and 16.5%, respectively. On the other hand, the values of these treatments were lower than those obtained due to the application of SSP. It is worthy to mention that combination of FYM and PSB with RP produced roots yield higher that produced due to the solely application of FYM or PSB with RP. The fresh and dry weights of roots of soybean plants significantly enhanced with the application of RP+FYM+PSB, which were 5.3 and 2.43g/plant and 10.2 and 4.9g/plant in sandy and clayey soils, respectively. Application of RP+FYM+PSB increased the roots fresh and dry weights of soybean plants by 39.5 and 41.3% and 33.3 and 32.4% for the sandy and clayey soils, respectively, compared to the RP solely treatment. These results are accordance with findings of Manzoor *et al.* (2016)

It is worthy to mention that the combined application of RP with OA or ATS or OA+ATS together had a significantly effective effect more than RP when applied solely or SSP treatment in both sandy and clayey soils. In the sandy soil, roots fresh and dry weights of soybean increased by 71.1 and 72.1%, 92.1 and 91.0% and 102.6 and 103.5%, while in the clayey soil were increased by 52.0 and 51.0%, 68.0 and 67.0% and 84.0 and 86.5%, respectively compared to RP only. On the other hand, the values of these treatment in the sandy soil increased by 14 and 13.8%, 28.1 and 26.2% and 35.1 and 34.6%, while in the clayey soil they increased by 8.6 and 9.5%, 20.0 and 21.1% and 31.4 and 35.3% due to the application of RP+OA, RP+ATS and RP+ATS+OA, respectively as compared to SSP. These results confirmed by Gilsanz *et al.* (2016).

3.1.1.3. Plant height (cm)

Results in Table (6) represent the effect of RP combined with amendments, i.e. PSB, FYM, OA and ATS on the height (cm) of soybean plant grown on the sandy and clayey soils. Plant height of soybean grown under no P treatment (control) was lower than plant height recorded in P-treated plants in sandy and clayey soils. SSP application gave plant height significantly higher than that obtained under the application of RP only to both of the studied soils.

The highest plant height for soybean was recorded in RP+ATS+OA, which were (38.3 and 40.0cm/plant) followed by RP+ATS (36.3 and 37cm/plant) and RP+OA (34.3 and 35.3cm/plant) in sandy and clayey soils, respectively, while the lowest plant height was obtained under the control treatment (21.7 and 25cm/plant) in sandy and clayey soils, respectively. Amending the sandy soil with RP+ATS+OA, RP+ATS and RP+OA increased plant height by (61.6, 53.2 and 44.7%), respectively compared to RP. In clayey soil, these values were (44.4, 33.6 and 27.4%), respectively compared to RP. Minimum plant height (21.7 and 25cm) was recorded in control treatment in sandy and clayey soils, respectively. On the other hand, the application of RP with PSB or FYM increased plant height, but not significant when compared with RP only treatment in both of sandy and clayey soils. These results are in accordance with findings of Amanullah *et al., (*2010), Wahba *et al.,* (2018) and Awaad *et al.* (2009).

Jalil *et al.* (2017) They concluded that accurate use of cheaper RP, farm yard manure and effective microbes proved as an alternative of costly fertilizers and sustaining the agricultural productivity. Residual effect of RP with additional use of FYM with effective microorganisms would be a promising strategy for enhancing P use efficiency and productivity of wheat crop in ecofriendly way.

3.2. Effect of application rock phosphate with different amendments on the uptake of nutrients by shoots soybean plants.

3.2.1. Nitrogen

Results in Table (7) show the effect of application of RP without or with amendments, i.e. PSB, FYM, OA and ATS on the uptake of nitrogen by shoots of soybean plants grown on sandy and clayey soils under study. It was noticed that RP treatment individually or in combination with the studied amendment increased nitrogen uptake by shoots soybean plants as compared to the control treatment in both sandy and clayey soils. The values N-uptake ranged between 63.4 and 357.7mg/plant in the sandy soil and between 172.5 and 500.2mg/plant in the clayey soil compared to 44.0 and 126 mg/plant in the control treatment, respectively.

The highest N uptake (357.7 and 500.2mg/plant) by soybean plants occurred in the sandy and clayey soils, respectively was obtained by the use of RP+ATS+OA treatment which increased N uptake by 464.2 and 190%, respectively compared to the application RP only. The lowest plant nitrogen uptake (44.0 and 126.0mg/plant) by soybean plants grown on the sandy and clayey soils was obtained by the control treatment. The effect of PSB applied with RP on N uptake (86.0 and 215 mg/plant) by soybean plants grown on sandy and clayey soils, respectively, was not significant when compared with the individually application of RP.

Table 7: Effect of RP applied individually and in combination with different amendments on N, P and K uptake by shoots soybean plant grown on the studied sandy and clayey soils after 70 days from planting

Treatments	Sandy			Clayey		
	Nutrients uptake (mg/plant)			Nutrients uptake (mg/plant)		
	N	P	K	N	P	K
Control	44.0	6.9	43.1	126.0	15.8	102.0
RP	63.4	10.1	61.8	172.5	22.1	139.4
SSP	268.2	39.3	243.9	384.0	51.0	340.5
RP+PSB	86.0	12.9	83.7	215.0	26.7	190.4
RP+FYM	92.4	13.3	90.7	230.5	27.5	204.7
RP+FYM+PSB	133.6	19.2	130.1	299.8	37.1	266.0
RP+OA	304.4	42.8	298.1	416.6	57.2	394.3
RP+ATS	333.2	50.8	318.4	469.8	65.9	424.2
RP + ATS + OA	357.7	55.6	343.4	500.2	73.0	461.0
LSD 5%	**54.3**	**2.62**	**43.41**	**45.1**	**1.55**	**33.5**

Application of RP+PSB increased N uptake as compared with the application of RP only; the increase was by 35.7 and 24.4% in sandy and clayey soils, respectively. On the other hand, N uptake in this treatment decreased by about 68 and 44% in sandy and clayey soils, respectively, as compared with SSP treatment. These results are in agreement with those of Hellal *et al.* (2013, 2015), Al-Fraihat *et al.,* (2011), Adesemoye and Kloepper, (2009). Nitrogen uptake by shoots soybean plants due to the application of FYM+RP was 92.4 and 230.5mg/plant in sandy and clayey soils, respectively. It could be concluded that combination of RP with FYM gave a significant increase in N uptake by shoots soybean plants compared with the individual application of RP in clayey soil; however, the increase in N uptake in the sandy soil was not significant. These results are conformity with Awaad *et al.* (2009) who observed that RP, when assorted with organic materials can develop nitrogen uptake by the plant. Jan *et al.* (2010) also, support our results that uptake nitrogen by the plant can be increased by the combined use of organic and inorganic sources of N. Our results are also supported by Taalab *et al.* (2008)

It is worthy to mention that a combination of FYM and PSB with RP had a significantly better effect than FYM or PSB when applied individually with RP. Nitrogen uptake by shoots of soybean plants significantly enhanced with the application of RP+FYM+PSB, which were 133.6 and 299.8mg/plant in sandy and clayey soils, respectively. Application of RP+FYM+PSB increased nitrogen uptake by shoots of soybean plants compared to the application of RP; the increase was by 111 and 74% in sandy and clayey soils, respectively. However, N uptake in this treatment decreased by 50.2 and 22% in sandy and clayey soils, respectively, as compared with SSP treatment. These results are in agreement with Stevenson, (1994) who reported that the beneficial effects of the added organic matter may be due to the nutritional status of the investigated manures through their favorable effect on the physicochemical and biological properties of the soil besides that it has a pronounced effect on the nutrient availability to the growing plants particularly nitrogen during the mineralization of the organic manure. Also shairf *et al.* (2015) support our results.

Regarding the effect of RP+OA, there were significant increases in nitrogen uptake by soybean plants in both sandy and clayey soils. Nitrogen uptake by the shoots soybean plants due to the application of RP+OA were 304.4 and 416.6mg/plant in the sandy and clayey soils, respectively. Soil amended with OA with RP significantly increased nitrogen uptake by shoots of soybean plants compared with the application of RP, however, the increase was not significant compared with SSP treatment in sandy and clayey soils, respectively.

The result may be due to the di-carboxylic acids (oxalic acid) which improve the root system of the groundnut and furthermore increasing the yield growth and N-uptake by the plant (Kpomblekou and Tabatabai, 2003). The effect of application of ATS with RP on nitrogen uptake by soybean plants was highly significant as compared to RP and SSP in both sandy and clayey soils. Nitrogen uptake by shoots soybean plants was 333.2 and 470 mg/plant in the sandy and clayey soils, respectively. Application of RP+ATS increased nitrogen uptake by soybean plants as compared with the application of RP only or

SSP; the increase was by 425.5 and 24.2% and 172.4 and 22.3% in the sandy and clayey soils, respectively.

Wahba *et al.* (2018) and Gilsanz *et al.* (2016) reported that the successful treatment with S on the availability of phosphorus is due to the oxidation of S to sulfuric acid and reacts with calcium phosphate and calcium carbonate ending to release of phosphorus. Ammonium thiosulfate inhibitors, together with calcium ammonium nitrate (CAN) fertilizers, have adverse effects on various enzymes, especially when used at the initial stages of growth or in higher amounts as nutrient solutions (Gilsanz *et al.,* 2016). So, ATS is a useful strategy for the efficient management of N fertilizers so, the fertilizer has an acidifying effect on soil due to the nitrification process. According to Gezerman, (2019) observed that when ATS was used as nitrification inhibitors, leaching of ammonium nitrate from calcium ammonium nitrate in soil decreased, whereas the yields and nitrogen uptake by plant increased. Also, Hellal *et al.* (2019) reported that, Legumes are especially suited for the utilization of RPs. They are compelling in dissolving RP and in engrossing its disintegration items in view of their interest for Ca and the acidifying impact of nitrogen (N) fixation in the soil close to the root framework (*rhizosphere*).

3.2.2. Phosphorus

Results in Table (7) show the effect of application of RP without or with amendments, i.e. PSB, FYM, OA and ATS on the uptake of P by shoots soybean plants grown on the studied soils. The application of RP solely or with amendments had a significant effect on the P uptake by shoots soybean plants compared to the control treatment. The values P uptake by soybean plants ranged between 10.1 and 55.6mg/plant in sandy soil and between 22.1and73.0mg/plant in clayey soil. Among different treatments, the highest P uptake was obtained by the application of RP+ATS+OA treatments which was 55.6 and 73mg/plant in sandy and clayey soils, respectively. The relative increase in P uptake compared to the application of RP only or SSP was by 450.2 and 41.4% in sandy soil and by 230.2 and 43.1% in clayey soil, respectively.

The lowest plant P uptake of (6.9 and 15.8mg/plant) was noted in the control treatment in sandy and clayey soils, respectively. Application of RP with PSB or FYM significant increased P uptake compared to that of application of RP solely in both sandy and clayey soils. Phosphorus uptake by shoots of soybean plants increased by 28, 32 and 99% in the sandy soil and 21, 24.5 and 68.0% in the clayey soil due to the application of RP+PSB, RP+FYM and RP+FYM+PSB, respectively. However, the values of p uptake due to these treatments were lower than those occurred due to the application of SSP. Our results was supported by Rotaru and Risnoveanu, (2019) and Egamberdieva *et al.* (2017) who reported that a combination of RP+PSB (*Burkholderia cepacia*) and RP had potential to improve P nutrition and growth of soybean. Also, they suggested that the beneficial effect of *rhizobacteria* on plant growth was attributed to the efficiency of P uptake from soil and fertilizers. Our results are also supported by Taalab *et al.* (2008) who noticed that plant nitrogen and phosphorus uptakes were increased when rock phosphate was mixed with organic fertilizers.

Concerning the effect of RP+OA application on P uptake, results show that there was a significant increase in P uptake by soybean plants in both sandy and clayey soils. Phosphorus uptake by soybean plants due to the application of RP+OA was 43 and 57mg/plant in sandy and clayey soils, respectively. Application of OA with RP increased in P uptake by soybean plants compared to the application of RP or SSP; the increase was by 324 and 9% and 159 and 12% in the sandy and the clayey soils under study, respectively. Our results was supported by Ahmed *et al.,* (2019) and Basak, (2019)

Application of RP acidified with ATS increased phosphorus uptake compared to the application of RP or SSP; the increase was by 403.4 and 29.4% and 198.2 and 29.2% in the sandy and the clayey soils under study, respectively. N, P and K content and uptake due to the application of ATS+RP tended to be higher than those of SSP application. These results attributed to N, P and K uptake increased significantly if compared to SSP treatment. This trend may be due to the release of NH_4^+ from ATS which can affect on pH change as H^+ released from roots during the assimilation of NH_4^+ (Weil, 2000, IPNI, 2016). Thiosulfates readily oxidize to dithionate, then to tetra-thionate and finally to sulfates, in accordance with the following sequence:

$$3(S_2O_3)^{2-} + 2O_2 \Leftrightarrow (S_4O_5)^{2-} + 2(SO_4)^{2-}$$

This transformation makes thiosulfates useful as fertilizers especially in combination with cations such as ammonium, potassium, calcium and magnesium (Sullivan and Havlm, 1992) and Salah, (2018) examined the combined additions of S and P at 238kg/ha and 476kg/ha in the form of elemental S and superphosphate. The fertility of the chosen soil was highly improved through the increase of P availability, which was resulted from the decrease of pH values after application of the elemental S. this study provided clear evidence that the elemental S could be highly recommended as a useful and economical material to maintain the efficiency of superphosphate fertilizer in increasing growth and production of soybean plants in high pH clayey soils in Egypt.

3.2.3. Potassium

Results in Table (7) show the effect of application of RP without or with amendments, i.e. P, FYM, OA and ATS on the uptake of K by shoots of soybean plants grown on the sandy and clayey soils under study. It was noticed that the RP treatment individually or in combination with amendment yielded a significant increase in K uptake by shoots of soybean plants as compared to control in both of the sandy and clayey soils. The values of K uptake ranged between 61.8 to 343.4 mg/plant in the sandy soil and 139.4 to 461mg/plant in the clayey soil, respectively.

The highest K uptake by shoots of soybean plants in sandy and clayey soils obtained under the application of RP+ATS+OA was 343.4 and 461.0mg/plant, respectively, whereas the lowest K uptake (61.8 and 139.4mg/plant) was obtained under the application of RP only to the sandy and the clayey soils, respectively. The effectiveness of the added treatment on increasing K uptake by shoots of soybean plants could be arranged as follows: RP+ATS+OA > RP+ATS >RP+OA > RP. Application of RP+ATS+OA, RP+ATS and RP+OA to the sandy and the clayey soils increased K uptake by shoots of soybean plants grown on the sandy soil by 456, 415.3 and 382.4%, respectively, while in the clayey soil it increased by 230.7, 204.3 and 182.9%, respectively compared to RP only.

On the other hand, application of RP+ATS+OA, RP+ATS and RP+OA to the sandy soil increased K uptake by 40.8, 30.6 and 22.2%, respectively, while in clayey soil it increased by 35.4, 24.6 and 15.8%, respectively compared to SSP. The lowest plant K uptake by 43.1 and 102 mg/plant was obtained in the control treatment of the sandy and the clayey soils, respectively. These results attributed to 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 (Song and Huang, 1988). our results are also supported by Taghipour and Jalali, (2013) mention that the ability of organic acids for P release related to the number of carboxylic function group and their ability to release P from Fe-Mn oxide fraction. Also, they provided guidance for the selection of organic acids to enhance P bioavailability in calcareous soils. Furthermore, they proved that the oxalic acid has the largest ability to chelate many metal ions (K^+, Mn^{2+}, Zn^{2+} and Cu^{2+}), preventing their precipitation with P.

Application of RP with PSB or FYM displayed a significant increase in K uptake compared to the application of RP only to both of sandy and clayey soils except RP+PSB in sandy soil. K uptake by soybean plants increased by 35.4, 47.0 and 111% in the sandy soil and by 36.5, 47.0 and 91% in the clayey soil with the application of RP+PSB, RP+FYM and RP+FYM+PSB, respectively as compared to the application of RP only, while these values decreased by 66.0, 63.0 and 47.0% under the application of RRP+PSB, RP+FYM and RP+FYM+PSB, respectively as compared to SSP, in sandy soil and 44.1, 40.0 and 22.0% in the same order in clayey soil, respectively. These results agreement with those El-Sayed *et al.* (2018) evaluated the efficiency of RP and potassium feldspar application combined with phosphate and potassium solubilizing bacteria on availability of P, K and their uptake on growth, yield and quality of table beet plant grown in sandy soil. Furthermore, they confirmed that, replacing chemical phosphorus and potassium fertilizers by natural one will help in reducing environmental pollution, cheaper in price and produce safe human food.

4. Conclusion

The addition and mixing of ammonium thiosulfate and/or oxalic acid with rock phosphate gave the highest increase in the fresh and dry weight, and the plant length of the soybean plants in the sandy soil were (23.5, 23.3 and 18.6%) and for maize were (19.4, 18.9 and 9.1%) respectively, compared to super single superphosphates), there was a similar trend in clayey soil. While adding treatment (rock phosphate + phosphate-solubilizing bacteria), it recorded the lowest fresh, dry weight and plant length. Through the results obtained, the transactions can be arranged in terms of their efficiency in increasing the fresh and dry weight of the shoot and roots, plant length, nutrient uptake, and recovery of the elements as follows:

Rock phosphate + Oxalic acid+ Ammonium thiosulfate
Rock phosphate + Ammonium thiosulfate
Rock phosphate + Oxalic acid
Rock phosphate + Farmyard manure + PSB)
Rock phosphate + Farmyard manure

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