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# Effect of Application of Rock Phosphate with Amendments on Maize Plants Grown on Sandy and Clayey Soils

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## ABSTRACT

A study was conducted in pots on greenhouse experiment to assess the effect of oxalic acid, phosphate solubilizing bacteria, and farmyard manure and ammonium thiosulfate on the release of available phosphorus from rock phosphate and maize (*Zea mays* L.) hybrid cultivar TWC 324 growth in clay and sandy soil, using the Completely Randomized Design (CRD) with three replications. Available phosphorus and other parameters were assessed using standard methods. Results were statistically analyzed using the GenStat ($11^{th}$ Edition) statistical software package. The amount of available P in the soil positively related to the fresh, dry weight, shoot and root and the plant length of maize. The highest increase in the fresh- dry weight, shoot and root and the plant length when adding and mixing ammonium thiosulfate and oxalic acid with rock phosphate, either separately or in combination, similarly, a trend in clayey soil.

***Keywords:*** rock phosphate, oxalic acid, ammonium thiosulfate, Maize

## 1. Introduction

Phosphorus (P) is the second most common growth-limiting macronutrient responsible for lower crop production. It is associated with many metabolic components and enzymatic reactions within the plant. Unavailability of P to plants during early growth stages results in reduced root growth and seed formation (Ahmad *et al*., 2019). Considering the low recovery of applied and native P and the high cost of chemical phosphatic fertilizers in addition to an increasing concern about environmental degradation (Cordell *et al*., 2011). It is essential to discover feasible alternatives to improve the effectiveness of P fertilizer use. In recent times, interest in using PRs as alternative P sources has increased due to their relatively low cost and potential for utilization (Akande *et al*., 2010). Mashori *et al*. (2013) used maize as a test crop to examine the comparative efficiency of PR in a pot experiment, single superphosphate (SSP) and PR with SSP with and without farmyard manure (FYM). They reported that PR with SSP (25+75 %) with FYM (10t ha-1 / (PR with SSP with FYM) increased maize growth, and P uptake; the next highest increase was seen in the treatment receiving PR with SSP (50+50 %).

Basak, (2019) examined the characteristic and the factors influencing P release from three low-grade RPs by using seven LMWOAs along with two inorganic. These results showed that the amounts of P released by organic acids increased with increasing the concentration of organic acids. The amount of P released by the organic acids from the RPs followed the order, oxalic acid > citric acid > tartaric acid > formic acid > malic acid > succinic acid > acetic acid. Also, he observed a negative correlation between P released and the equilibrium solution pH.

Wahba *et al*. (2018) 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. Also, they confess that sulfur is very beneficial with RP particularly in calcareous soils which cover considerable areas, not only in Egypt, but around the world. The

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concentration of available phosphorus has been significantly increased when 2% of S added and kept to 60-120 days.

Agyarko *et al*. (2016) studied the release of available P from Togo RP, (the experiment was carried out in pots under field condition) using different organic wastes such as poultry manure (PM), cattle manure (CM) and pig manure (PG) on lettuce growth. They found the poultry manure combinations being more significant. The PM at 2.5g RP+5g PM recorded the highest significant ($P<0.05$) values. The growth, yield and percentage P content of lettuce increased relative to the available P in the amended soil.

Husnain *et al*. (2014) studied the effect of application of different sources of RP mixed with manure on maize yield. They found the Morocco RP source appears to be an effective source of P and the significant increase in the maize yield was found when RP was mixed with manure.

Sharif *et al*. (2013) suggested that the use of composts prepared from different organic materials with RP are economic, environmental friendly and have potential to improve crops yield and plants N and P uptakes.

Jalil *et al*. (2017) declared that all yield parameters significantly increased by the treatments consisting of RP (100 kg) with farmyard manure (FYM) (5 t/ha) and effective microbes (EM) at 50 L/ha also enhanced the nutrient uptake of the crop and 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 eco-friendly way.

Ditta *et al.* (2018) studied the release of P from RP using compost of organic wastes with the addition of phosphate solubilizing microorganisms (PSMs), under field conditions. The combined use of PR, soluble P fertilizers and bacterial inoculation is also considered an option that may increase the efficiency of both PR and soluble P fertilizers. Their results showed that reactions involved in the P release process are not only pH-dependent but also related to the structural characteristics of the LMWOAs. Although information is available on alternative ways to increase P availability in PRs using various additives, there is only limited amount of information on the use of LMWOAs to enhance P availability in PRs. In the present study the effect of oxalic acid, citric acid, sulfur, farmyard manure, ammonium thiosulfate and phosphate solubilizing bacteria on available phosphorus of phosphate rock was investigated in order to find the best combination of examined factors. To examine the efficiency of P bioavailability on growth of maize in greenhouse experiment.

## 2. Materials and Methods

The purposes of the current investigation are studying the effect of application of different amendments on the availability of phosphorus and agronomic efficiency of different RPs that have widely ranged of reactivity. As a simulation study for what naturally occurring in the soil taken into account influencing factors including:

Recognition of some factors affecting RP dissolution in soils and availability to crops through application of different amendments, i.e., organic acids, phosphate solubilizing bacteria, farmyard manure, sulfur and ammonium thiosulfate to get optimum conditions for enhancement the use of RP in agriculture.

To achieve the above objectives, the following experiments were applied:

- 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 | **$CO^{2-}_3$** | 0.00 | 0.00 |
| | | | **$HCO_3^-$** | 2.50 | 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 sample was collected from location present in the Western Desert between El-Kharga and El-Dakhla Oases (Abu Tartur, RP sample was ground to pass through a 100-mesh (150µm) sieve. Some physical, chemical and mineralogical characteristics of RP sample is 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 $CaCO_3$ % | Major minerals |
|---|---|---|---|---|---|---|---|---|
| **Western Desert** | **Abu Tartur** | 24 | 1.4 | 7.0 | 1.4 | 12.2 | 1.02 | Fluroapatite Apatite-Calcite Francolite Quartiz Low |

The concentrations of some heavy metals found in the RP sample was determined and given in Table (3).

**Table 3:** Contents of some heavy metals (mg/kg) of rock phosphate sample collected from Western Desert (Abu-Tartur ).

| 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. 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 ($P_2O_5$ 24%) (RP)
3- Single superphosphate ($P_2O_5$ 15.5%)(SSP)

4- Rock phosphate + Phosphate solubilizing bacteria (PSB) (mixture of *Bukholderia cepacia* and *Acintobacter* sp) (RP+PSB)

5- Rock phosphate + Farmyard manure(RP+FYM)

6- Rock phosphate + Farmyard manure + 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 maize (*Zea mays* L.) hybrid cultivar TWC 324 three-way-cross (non-legume plant). 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 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 maize

| Treatment | Maize | | |
|---|---|---|---|
| | Fertilizer amount (kg/fed) | | |
| | N | $P_2O_5$ | $K_2O$ |
| **Control** | 120 | - | 60 |
| **RP** | 120 | 45 | 60 |
| **SSP** | 120 | 45 | 60 |
| **RP+PSB** | 120 | 45 | 60 |
| **RP+FYM** | 120 | 45 | 60 |
| **RP+FYM+PSB** | 120 | 45 | 60 |
| **RP+ATS** | 120 | 45 | 60 |
| **RP+OA** | 120 | 45 | 60 |
| **RP+OA+ATS** | 120 | 45 | 60 |
| **Control** | 120 | - | 50 |
| **RP** | 120 | 31 | 50 |
| **SSP** | 120 | 31 | 50 |
| **RP+PSB** | 120 | 31 | 50 |
| **RP+FYM** | 120 | 31 | 50 |
| **RP+FYM+PSB** | 120 | 31 | 50 |
| **RP+ATS** | 120 | 31 | 50 |
| **RP+OA** | 120 | 31 | 50 |
| **RP+OA+ATS** | 120 | 31 | 50 |

All pots received a constant rate of ammonium nitrate (3.6 g and 1.2 g potassium sulfate per pot) for maize while single super phosphate (SSP) was 3 g per pot for maize) and rock phosphate was (2 g per pot for maize). 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 taps 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). otal 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 photometrical 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

Maize was sown to explore the benefits of the application of RP without or with amendments on the height and biomass of shoots and roots.

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

**3.1.1. Biometric parameters**

**3.1.1.1. Shoots fresh and dry weights**

Results in Table (6) show the effect of application of RP with amendments, i.e. PSB, FYM, OA and ATS on the shoots fresh and dry weights of maize grown on the sandy and clayey soils under study. Application of RP individually or combined with amendments produced significant increase in the yield of maize plant (shoots fresh and dry weights) as compared to control treatment in both of the sandy and clayey soils. In sandy soil, the values of shoots fresh and dry weights ranged between 55 and 185g/plant and between 5.3 and 17.6g/plant, respectively, while in the clayey soil the values of shoots fresh and dry weights were 97 and 217g/plant and 9.2 and 21g/plant, respectively compared to the control.

Inoculation of PSB together with RP significantly increased shoots fresh and dry weights as compared to the control and the application of RP only except fresh weight of the application of RP only in clayey soil. The higher response of plant growth to PSB might be due to the mobilization of available P by the native soil microflora or increased PSB activity in the rhizosphere following PSB application and consequently by enhanced P solubilization which enhanced the growth and yield of plants (Ekin, 2010).

A combination of RP with PSB gave a relative increase in the shoots fresh and dry weights of maize plants compared to the individually application of RP by 18.2 and 17% and 8.9 and 8.7% in sandy and clayey soils, respectively.

These results attributed that the inoculation with microorganisms having phosphate solubilizing ability concurrently improved plant P uptake and crop growth (Hussain *et al.,* (2013).

The addition of RP to soil with FYM significantly increased the shoots fresh and dry weights of maize plants compared with the control plants. The shoots fresh and dry weights increased by 60.5 and 61% and by 58.9 and 59.4% under the application of RP with FYM to the sandy and clayey soils, respectively, compared with control.

The shoots fresh and dry weights of maize plants significantly increased with the application of RP+ FYM + PSB, which were 74 and 7.0g/plant and 128 and 12.0mg/plant in sandy and clayey soils, respectively. The shoots fresh weight increased by 34.5 and 32.1% with the application of RP+FYM+PSB to the sandy and clayey soils, respectively as compared with the individually application RP. However, the shoots fresh and dry weights in this treatment decreased by 52.3% and 31.2% in sandy and clayey soils, respectively, as compared with SSP application. The combined application of PSB and FYM with RP is considered an important management strategy for mobilizing P, where inert P is expected to be converted into plant-available forms because of the acidic environment prevailing during the decomposition of organic manure and the additional beneficial effects of PSB on the processes of acidification, chelation, exchange reactions and the production of organic acids (Ekin, 2010, Nishanth and Biswas, 2008). These combined effects increased the efficiency of the applied materials, and there by increased the growth and yield of the plant as observed in the present study. Our results are in accordance with the previous studies conducted on the use of organic materials and PSB for increasing the efficiency of the applied P fertilizers and their subsequent effect on the growth and yields of plants (Abbasi *et al.,* 2013).

**Table 6:** Effect of application of RP and different stimulant agents on the plant height, shoots and roots fresh and dry weights of maize plant grown on the sandy and clayey soils under study after 70 days from planting

| Treatments | Plant height (cm/plant) | Shoots | | Roots | |
|---|---|---|---|---|---|
| | | Fresh weight (g/plant) | Dry weight (g/plant) | Fresh weight (g/plant) | Dry weight (g/plant) |
| **Sandy soil** | | | | | |
| **Control** | 34.3 | 43 | 4.1 | 2.9 | 1.42 |
| **RP** | 42.2 | 55 | 5.3 | 5.6 | 2.74 |
| **SSP** | 70.3 | 155 | 14.8 | 8.7 | 4.27 |
| **RP+PSB** | 55.3 | 65 | 6.2 | 7.0 | 3.41 |
| **RP+FYM** | 53.0 | 69 | 6.6 | 7.3 | 3.61 |
| **RP+FYM+PSB** | 58.3 | 74 | 7 | 8.0 | 3.94 |
| **RP+OA** | 71.7 | 167 | 15.9 | 10.0 | 4.87 |
| **RP+ATS** | 74.0 | 175 | 16.7 | 11.7 | 5.75 |
| **RP + ATS + OA** | 76.7 | 185 | 17.6 | 12.8 | 6.30 |
| **LSD 5%** | **7.34** | **9.7** | **0.58** | **0.9** | **0.4** |
| **Clayey soil** | | | | | |
| **Control** | 40 | 73 | 6.9 | 4.8 | 2.6 |
| **RP** | 53.1 | 96.7 | 9.2 | 6.6 | 3.2 |
| **SSP** | 73.8 | 185.6 | 17.6 | 8.6 | 4.2 |
| **RP+PSB** | 54.6 | 105.3 | 10 | 7.2 | 3.5 |
| **RP+FYM** | 55.7 | 116 | 11 | 7.51 | 3.63 |
| **RP+FYM+PSB** | 68.3 | 127.7 | 12.1 | 8.73 | 4.25 |
| **RP+OA** | 74.0 | 197 | 18.7 | 10.44 | 5.11 |
| **RP+ATS** | 77.3 | 208.5 | 19.8 | 11.81 | 5.72 |
| **RP + ATS + OA** | 82.7 | 216.9 | 20.6 | 13.32 | 6.44 |
| **LSD 5%** | **7.36** | **12.5** | **0.57** | **1.2** | **0.35** |

It is worthy to mention that the application of the combination of rock phosphate with OA or with ATS or with OA+ATS had a significantly and more efficient effect than the individually application of RP or SSP to both the sandy and the clayey soils except fresh weight of shoots of RP+OA compared to SSP.

Application of RP+OA increased the shoots fresh weight of maize plants compared to the application of RP only or SSP; the increase was by 203.6 and 7.7% and by 103.7 and 6.1% in sandy and clayey soils, respectively. A parallel line was observed in case of shoots dry weight

The treatment which received RP+ATS produced growth comparable to that recorded from the SSP, showing that the relative increase was by 12.9 and 12.3% compared to the application of SSP to sandy and clayey soils, respectively. The highest shoot fresh weight 185 and 217g/plant was recorded from the application of RP+OA+ATS to the sandy and clayey soils, respectively. The relative increase in shoots fresh weight of maize plants compared with the application of RP only or SSP was by 236.4 and19.4% and 124.3 and 16.9% in the sandy and clayey soils, respectively. The treatment which received RP+OA+ATS produced growth comparable to that recorded from RP+OA or RP+ATS treatment. A similar trend was observed with dry weight.

**3.1.1.2. Roots fresh and dry weights**

Results in Table (6) show the effect of application of RP with amendments, i.e. PSB, FYM, OA and ATS on the roots fresh and dry weights of maize plants grown on the studied sandy and clayey soils. The roots fresh and dry weights of maize grown in no P treatment (control) was significantly lower than the roots fresh and dry weights recorded in P-treated plants in sandy and clayey soils.

Single super phosphate application gave significantly higher root fresh and dry weight than rock phosphate only or control treatments in both sandy and clayey soils. The roots fresh weight obtained due to the application of RP, RP+ PSB, RP+FYM and RP+FYM+PSB increased by 141.4, 151.7 and 175.9%, respectively, in sandy soil and by 48.5, 54.8 and 80% in clayey soil as compared with the control. On the other hand, these values decreased by 19.5, 16.1 and 8%, respectively, in sandy soil and by 16.3 and 13.0% in clayey soil compared with the application of SSP. Inoculation together with RP and FYM treatments showed more pronounced effects on the roots fresh and dry weights of maize plants compared to RP+PSB and RP individually treatments. These results are in line with those obtained by Odongo *et al.,* (2007), Zayed and Abdel Motaal, (2005) who reported that phosphorus enriched composting significantly increased phosphorus availability and increased plant growth.

It is worthy to mention that the combination of rock phosphate with OA or ATS or applied together had a significantly more efficient effect on roots fresh weight than the application of RP or SSP treatment in both sandy and clayey soils. Application of RP+OA increased roots fresh weight of maize plants compared with the application of RP only or SSP by about 79 and 15% and by 58 and 21% in the sandy and clayey soils, respectively. A parallel line was observed in case of the root dry weight. Also, application of RP+ATS produced growth comparable to that recorded from the RP or SSP, showing that the relative increase was (109 and 35%) and (79 and 37%) in sandy and clayey soils, respectively. The highest roots fresh and dry weights of maize was observed in the plots received RP+ATS+OA treatment, which was 47 and 55% higher than SSP treatment.

**3.1.1.3. Plant height (cm).**

The effect of SSP or RP with amendments, i.e. PSB, FYM, OA and ATS on the plant height (cm) of maize in sandy and clayey soils are presented in Table (6). Data revealed that in general as the plant growth increased, the plant height also increased. There was a significant increase in plant height of maize due to the application of different amendments with rock phosphate in comparison with the control.

The highest plant height of maize plant was observed in the plots received RP+ ATS+ OA treatment, which was 76.7 and 82.7cm/plant in sandy and clayey soils, respectively followed by RP+ATS (74 and 77.3cm/plant), respectively and RP+OA (71.7 and 74cm/plant), respectively. The plant height under RP+ATS+OA was very close to SSP treatment. However, there was no significant difference among SSP, RP+OA, RP+ATS and RP+ATS+OA treatments for plant height in sandy soil.

The highest plant height return obtained in the plots under RP+ATS+OA and RP+ATS may be due to a higher shoot of maize (Table 6). The smallest plant height was recorded in the control treatment. Interestingly, the highest plant height was not achieved with the application of SSP for maize. It clearly indicated that P acquisition is more important than its amount and availability for higher plant height. The application of RP+FYM increased plant height to 53.0 and 56cm/plant, while application of RP+PSB increased plant height to 55.0 and 55.0 cm/plant in the sandy and clayey soils, respectively, compared with the application of RP only which gave plant height of 42.0 and 53.0cm/plant in the sandy and clayey soils, respectively. Plots under RP+FYM+PSB treatment showed more pronounced effects on maize plant height as compared to the application of RP+PSB, RP+FYM and RP individually application treatments. The obtained results can be due to PSB might have solubilized RP by excreting organic acids, i.e. citric and gluconic acids and chelating materials in the immediate vicinity of the rhizosphere Trabelsi *et al.,* (2017), Wei *et al.,* (2017).

### 3.2. Effect of rock phosphate with amendments application on the uptake of nutrients by the maize plants.

#### 3.2.1. Nitrogen

The results of nitrogen uptake by shoots of maize plants in sandy and clayey soils are presented in Table (7). It was noticed that rock phosphate individually treatment or in combination with different amendments yielded an increase in nitrogen uptake by shoots of maize plants as compared with control treatment in both sandy and clayey soils. The values of N uptake ranged between 91.2 to 436.5 mg/plant in sandy soil, and between 230 to 579mg/plant in clayey soil and (69 and 170mg/plant) in sand and clayey soils compared to control, respectively. 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 of nitrogen by plant can be increased by the combined use of organic and inorganic sources of N.

**Table 7:** Effect of application of RP and different amendments on N, P and K uptake by shoots of maize plants grown on sandy and clayey soils after 70 days from planting

| Treatments | Sandy soil | | | Clayey soil | | |
|---|---|---|---|---|---|---|
| | Nutrients uptake (mg/plant) | | | Nutrients uptake (mg/plant) | | |
| | N | P | K | N | P | K |
| **Control** | 68.9 | 7.8 | 62.7 | 170.4 | 13.8 | 138.0 |
| **RP** | 91.2 | 10.6 | 88.5 | 230.0 | 20.2 | 185.8 |
| **SSP** | 293.0 | 37.0 | 269.4 | 450.6 | 47.5 | 399.5 |
| **RP+PSB** | 105.4 | 13.0 | 106.0 | 265.0 | 23.0 | 235.0 |
| **RP+FYM** | 122.8 | 14.5 | 117.5 | 294.8 | 26.4 | 261.8 |
| **RP+FYM+PSB** | 141.4 | 16.1 | 127.4 | 332.8 | 30.3 | 295.2 |
| **RP+OA** | 346.6 | 38.2 | 302.1 | 489.9 | 48.6 | 463.8 |
| **RP+ATS** | 385.8 | 41.8 | 327.3 | 550.4 | 53.5 | 497.0 |
| **RP + ATS + OA** | 436.5 | 45.8 | 371.4 | 578.9 | 57.7 | 533.5 |
| **LSD 5%** | **73.0** | **8.01** | **59.91** | **39.2** | **5.8** | **55.7** |

Application of RP with PSB increased N uptake by 15.6 and 15.2% compared with the application of RP only to sandy and clayey soils, respectively. Moreover, the application of RP+FYM+PSB increased nitrogen uptake by shoots of maize plants compared with the individually application of RP by 55 and 44.7% to the sandy and clayey soils, respectively. However, N uptake in plot received RP+PSB, RP+FYM and RP+FYM+PSB were lower than SSP treatment in both sandy and clayey soils. Concerning to the effect of RP+OA, there were significant increases in N uptake by maize plants in both sandy and clayey soils compared with RP only. Application of OA with RP resulted in an increase in N uptake by maize plants; the increase was by 280.1 and 18% and by 113 and 9% for sandy and clayey soils, respectively compared with the RP or SSP treatment. Plots under application of RP+ATS increased N uptake by maize plants by 323 and 32% and by 139 and 22% in the sandy and clayey soils, respectively as compared with the application of RP only or SSP treatment.

#### 3.2.2. Phosphorus

The P uptake of maize plant treated with different amendments with RP is presented in Table (7). It was noticed that application of RP only or in combination with amendments yielded a significant increase in P uptake by maize plants as compared with control in both sandy and clayey soils. The values of P uptake ranged from 11 and 46mg/plant in sandy soil and from 20 and 58mg/plant in clay soil compared with 8 and 14mg/plant in the control, respectively.

The total P uptake under RP+PSB was higher than the RP (23 and 14%), but lower than the SSP (65 and 52%) in sandy and clayey soils, respectively. Phosphate uptake measurement is the reflection of P availability in various treatments. The addition of bio-inoculants along with RP fertilization significantly increased P uptake in comparison with RP only. Swarnalakshmi *et al.,* (2013) and Singh and Reddy, (2012) reported that the addition of inoculants along with RP significantly increased P uptake in comparison with chemical fertilizers or PSB inoculation individually in wheat.

The application of RP with FYM increased total P uptake and it was higher than that of the RP by 37 and 31%, but lower than the SSP by 61 and 44% in sandy and clayey soils, respectively. The total P uptake under RP+FYM+PSB was significantly higher than the RP and the increase was by 52 and 50%, but lower than the SSP by 57 and 36% in sandy and clayey soils, respectively.

The highest P uptake was recorded with the treatment of RP+ATS+OA (46 and 58mg/plant) as compared to SSP and other P amendments in sandy and clayey soils (Table 7 and Figure 7). The P uptake under RP+ATS+OA and SSP plots was significant for both soils. The higher P uptake under RP+ATS+OA plots was due to the higher rhizospheric available P and relatively higher value of P concentration under this plot. The application of RP with different P amendments resulted in a significant increase in P uptake compared to SSP, i.e., 3% with OA, 13% with ATS and 24% with ATS+OA in sandy soil. But in clayey soil, these values were 2% OA, 13% with ATS and 21% with ATS+OA. These results indicated that the use of RP+ATS+OA treatment had a dominant effect on increasing plant P uptake compared to the application of other P amendments.

### 3.2.3. Potassium

There was a significant increase in potassium uptake by maize plant at 70 days after sowing due to the application of different amendments sources and RP (Table 7) in comparison with the control plot in sandy and clayey soils. The highest potassium uptake by maize was observed in the plots received RP+ATS+OA treatment, which was higher than SSP treatment by 27 and 34%.

Bacterial inoculation treatments along with RP showed an increase in total K uptake by maize plants in sandy and clayey soils by 16 and 27%, respectively in comparison to the RP treatment. Also, RP+FYM treatment showed significant increases in total K uptake by maize plants in clayey soil, but increase by 40% and 41%, respectively in comparison to the RP treatment. Total K uptake in maize plants was significantly enhanced in RP+FYM+PSB followed by RP+FYM and RP+PSB compared to the control.

The increase in potassium uptake with the application of RP+OA and RP+ATS was by 231 and 259%, respectively compared to RP only treatment, while was 3 and 12% compared to SSP in sandy soil. In clayey soil, these values were 150 and 168%, respectively compared to RP only treatment, while were 24 and 34% compared to SSP.

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