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SOLUBILIZATION OF ROCK PHOSPHATE USING ORGANIC AMENDMENTS AND SUBSTANTIAL IMPACT ON SUNFLOWER GROWTH IN ALKALINE CALCAREOUS SOIL

Sajjad Anwar[1] • Muhammad Ashraf[2]* • Sher Muhammad Shahzad[1] • Muhammad Ali Bhatti[3] • Muhammad Imtiaz[4] • Ahsan Aziz[5] • Muhammad Asif[5]

AUTHOR'S AFFILIATION

[1]Department of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan
[2]Department of Soil Science, Bahauddin Zakariya University, Multan, Pakistan
[3]School of Plant Biology, The University of Western Australia, 35 Stirling Highway, Crawley, Western Australia, 6009, Australia.
[4]Soil and Environmental Biotechnology Division, National Institute for Biotechnology and Genetic Engineering, Faisalabad, Pakistan
[5]Department of Agronomy, College of Agriculture, University of Sargodha, Sargodha, Pakistan
Corresponding author's e-mail: mashraf_1972@yahoo.com

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ABSTRACT

Background Rock phosphate (RP) is a cheap source of phosphorus (P) but cannot be used directly to meet plant P requirements because of its very poor water solubility. However, solubility of RP can be enhanced by amending it with different organic materials. In present study, a pot experiment was planned to assess the effectiveness of various organic manures to solubilize RP, and subsequent impact on growth and yield characteristics of sunflower (*Helianthus annuus* L.).

Methodology Ten treatments consisting of RP, diammonium phosphate (DAP), farm yard manure (FYM), poultry manure (PM), pressmud (PRM), FYM+PM+PRM, RP+FYM, RP+PM, RP+PRM, RP+FYM+PM+PRM were arranged in completely randomized design with five replications.

Results When RP was amended with organic manures, solubilization and bioavailability of P from RP was significantly enhanced which, in turn, improved sunflower growth and yield characteristics. Shoot P concentration improved by 80, 106, 115 and 144% in harvesting-1 while 94, 85, 89 and 109% in harvesting-2 when RP was amended with FYM, PM, PRM and FYM+PM+PRM, respectively compared to RP without any amendment. Shoot P uptake increased from 0.28 to 1.21 mg plant^{-1} when RP was amended with FYM, 1.32 mg plant^{-1} with RP+PM, 1.45 mg plant^{-1} with RP+PRM and 1.80 mg plant^{-1} with RP+FYM+PM+PRM. Subsequently, achene yield increased by 50, 48, 59, and 105% by amending RP with FYM, PM, PRM and FYM+PM+PRM, respectively compared to RP without any amendment.

Conclusion Although, all the three organic manures were effective to solubilize RP, but combined application of these organic manures with RP could be more efficient to enhance P solubility and phytoavailability for improving growth and yield characteristics of sunflower.

INTRODUCTION

Plant growth and development mainly rely on the use of synthetic fertilizers to meet crop nutrients requirements, and to replenish the elements in soil removed as crop harvest (Ashraf et al. 2009; Irfan et al. 2016; Ditta et al. 2018). Among essential plant nutrients, phosphorus (P) is by far the least mobile and available to plants in most soil conditions (Shenoy and Kalagudi 2005). The soils in arid and semiarid regions like in Pakistan are generally low in plant-available P, and often have a high P-fixation capacity because of alkaline and calcareous nature (Gill et al. 2004). Phosphorus deficiency in these soils can, however, be corrected by applying phosphatic fertilizers but according to Dave and Patel (2003), the recovery of applied P is notoriously low due to its rapid conversion to sparingly soluble compounds in such soils. The occurrence of low P availability, low levels of its

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application and a high increase in the price of synthetic P fertilizers motivated the scientist to develop appropriate strategy to use poorly soluble P compounds (Aziz et al. 2006). In this respect, direct application of RP might be an important source of P but its effectiveness to meet plant P requirements depends not only on RP factors such as mineralogy, chemical reactivity and rate of application but also on soil properties including soil pH, calcium content, amount of organic matter, type and amount of clay, soil moisture and soil texture as well as plant factors like root density and exudates (Tisdale et al. 1993; Barber 1995).

Various strategies such as composting with farmyard manure (FYM), poultry manure (PM), pressmud (PRM), green manure (GM), partial acidulation of RP, use of P solubilizing bacteria, use of RP with some chemicals may be employed to facilitate the release of P from RP (Kumari and Ushakumari 2002; Sarfraz et al. 2016; Abbasi and Manzoor 2018). Mishra and Bangar (1986) reported that solubility and availability of P from RP could be enhanced through composting with FYM, GM, partial acidulation, use of P solubilizing organisms, and use of RP with some chemicals. The basic principle underlying the amending of RP with organic manure/farm wastes is the production of organic and mineral acids as a result of their decomposition. Release of these acids lowers the pH in the rhizosphere, and also helps to bind the P fixing agents like calcium (Ca^{2+}), leading to increased release of P in soil. Ivanova et al. (2006) reported that organic acids that are released during the decomposition of organic manures may enhance P solubility from RP due to their influences in lowering the pH of soil and chelation of Ca^{2+} and Mg^{2+} ions within the soil. However, the solubilizing effect of different organic materials on RP may vary depending upon the characteristics and composition of amending material (Abbasi and Manzoor 2018).

Sunflower (*Helianthus annuus* L.) is an important oil seed crop and ranks third next to groundnut and soybean in total oilseed production, worldwide. In the period of past 15 years, the sunflower acreage in Pakistan has been increased from 29, 500 to 107, 700 ha. According to local cropping system in Pakistan, it is grown on an area of 31500 ha with its production 56900 tons and average yield of 1802 kg ha^{-1} which is far below than its potential. Among the different factors, inadequate and imbalanced use of plant nutrients might be considered a major factor responsible for its low yield. It has been reported that P deficiency may decrease flower formation, seed production and delay uniform and earlier crop maturity, and consequently cause a yield reduction of 10-15%. Past studies regarding the RP solubilization with organic amendments were mostly conducted with cereal crops but very little information were found in case of sunflower. The present experiment was planned to evaluate the effect of RP amended with FYM, PM and PRM, either individually or integratedly on the growth and yield characteristics of sunflower under alkaline calcareous conditions.

MATERIALS AND METHODS

A pot experiment was conducted to evaluate the effectiveness of three organic manures to solubilize RP, and its consequential impact on growth and yield attributes of sunflower (*Helianthus annuus* L.) under alkaline calcareous conditions. Soil from 0-15 cm surface layer from a cultivated field under rice-wheat cropping system was collected, air dried, ground and passed through 2 mm sieve. Soil was analyzed for various physico-chemical characteristics using standard procedures as described by Richards (1954). The selected physico-chemical characteristics of soil are presented in Table 1 while, organic amendments in Table 2. Rock phosphate used as P source contained P_2O_5 296 g kg^{-1}, CaO 345 g kg^{-1}, K_2O 3.10 g kg^{-1}, SO_2 5.82 g kg^{-1}, MgO 1.56 g kg^{-1}, Al_2O_3 16.65 g kg^{-1}, Fe_2O_3 17.47 g kg^{-1}, SiO_2 98 g kg^{-1}, MnO 1.34 g kg^{-1}, and moisture content 14.82 g kg^{-1}. Rock phosphate was applied at 2 g kg^{-1} soil while, manures at 25 g kg^{-1} soil. Rock phosphate and manures were thoroughly mixed into soil before filling into pots, and crop was sown after thirty days.

Experimental plan comprised of ten treatments; (i) RP, (ii) diammonium phosphate (DAP), (iii) FYM, (iv) PM, (v) PRM, (vi) FYM+PM+PRM, (vii) RP+FYM, (viii) RP+PM, (ix) RP+PRM, (x) RP+FYM+PM+PRrM which were arranged in completely randomized design with five replications. Seeds of sunflower *Hysun* 33 were used, five seeds were sown in the each earthen pot lined with polythene sheet, and containing 20 kg soil. After germination, three plants were maintained in each pot. The plants were irrigated after every three days with tap water throughout the growing season. Recommended fertilizer doses, 60 mg N kg^{-1} as urea and 40 mg K_2O kg as potassium sulfate were applied. Harvesting was done at three growth stages, one plant from each pot was harvested thirty days after germination, second plant fifty days after germination, while third plant at maturity.

Shoot and root samples of sunflower were washed with distilled water, dried in an oven (EYELA WFO-600ND; Tokyo Rikaikai Co., Ltd., Tokyo, Japan) at 70 ºC for 48 hours. After oven drying, plant samples were ground to 40 mesh using plant grinder (MF 10 IKA-WERKE, GMBH & CO. KG, Germany). Plant samples were digested by wet digestion method

Table 1 Physico-chemical properties of experimental soil

Soil properties	Unit	Value
Sand	%	49.45
Silt	%	22.20
Clay	%	28.35
Textural class		Sandy clay loam
pH		8.06
ECe	dS m^{-1}	1.79
Organic matter	%	0.78
Saturation percentage	%	28.4
Cation exchange capacity	cmol (+) kg^{-1}	18.62
$CaCO_3$	%	17.10
Extractable K	mg kg^{-1}	220
Available P	mg kg^{-1}	6.36
Total P	g kg^{-1}	1.96
Fe	g kg^{-1}	9.60
Al	g kg^{-1}	0.62
Mn	g kg^{-1}	0.23
As	mg kg^{-1}	1.62

Table 2 Chemical characteristics of the organic amendments used in experiment

Characteristics	Farm yard manure	Poultry manure	Press mud
Water content (%)	78.9	70.8	80.7
Organic matter (%)	12.9	28.8	16.7
N (%)	0.27	1.46	1.26
P (%)	0.21	1.17	1.63
K (%)	0.18	0.62	1.22
C: N ratio	25.85	11.47	7.71
C: P ratio	33.24	14.31	5.96
C: K ratio	38.78	27.0	7.96

using di-acid mixture of HNO_3 and $HClO_4$ in 2: 1 ratio (Miller 1998). Phosphorus was measured by spectrophotometer (Shimadzu UV-1600, UK).

At maturity, plant growth and yield characteristics of sunflower in term of fresh biomass, plant height, stem girth, head diameter, head weight, number of achenes $head^{-1}$ and achene yield were recorded. The collected data were statistically analyzed according to completely randomized design. The treatment means were compared by least significant difference test at 5% level of significance (Steel et al. 1997).

RESULTS

Plant growth and yield characteristics

Plant growth and yield characteristics of sunflower in term of fresh biomass, plant height, stem girth, head diameter, head weight, number of achenes $head^{-1}$ and achene yield were significantly ($p \leq 0.05$) affected when RP was amended with different organic manures. In havesting-1, plant fresh biomass increased by 48% when RP was amended with FYM, 45% in RP+PM, 51% in RP+PRM and 68% in RP+FYM+ PM+PRM compared to RP without any amendment. Likewise, in harvesting-2, plant fresh biomass increased from 19.2 g $plant^{-1}$ in RP treatment to 32.4 g $plant^{-1}$ in RP+FYM, 28.4 g $plant^{-1}$ in RP+PM, 36.2 g $plant^{-1}$ in RP+PRM and 46.8 g $plant^{-1}$ in RP+ FYM+PM+PRM (Figure 1). Plant height increased by 25% when RP was used with FYM, 24% with PM, 29% with PRM and 38% with FYM+PM+ PRM compared to RP without any amendment (Figure 2). Stem diameter improved by 31% when RP was used with FYM, 27% with PM, 38% with PRM and 52% with FYM+PM+PRM over RP without amendment (Figure 3). When comparing the effect of different organic amendments on solubilization of P from RP and its impact on head diameter of sunflower, it was found that maximum increase of 50% in head diameter was found when RP was used with all organic amendments (RP+FYM+PM+PRM) compared to alone RP. While, head diameter increased by 21, 19.5 and 23% when RP was applied with FYM, PM and PRM, respectively over alone RP (Figure 4). Lowest number of achenes $head^{-1}$ (232) was produced when

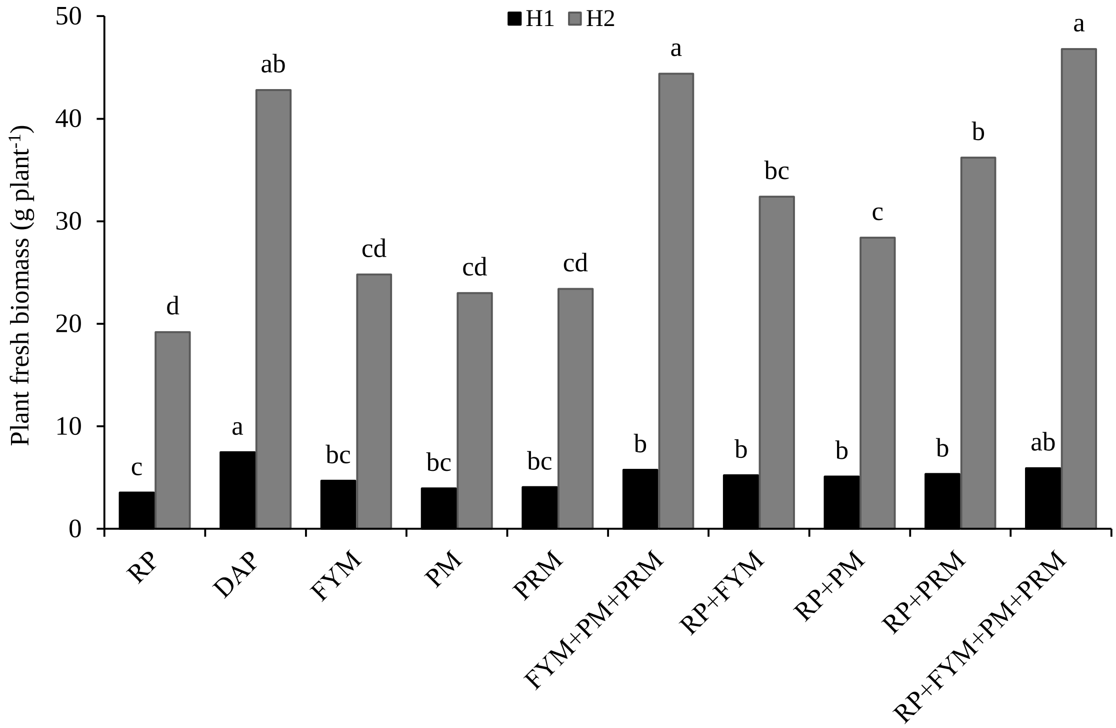

Figure 1 Plant fresh biomass of sunflower grown with RP amended with different organic manures. RP: Rockphosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud)

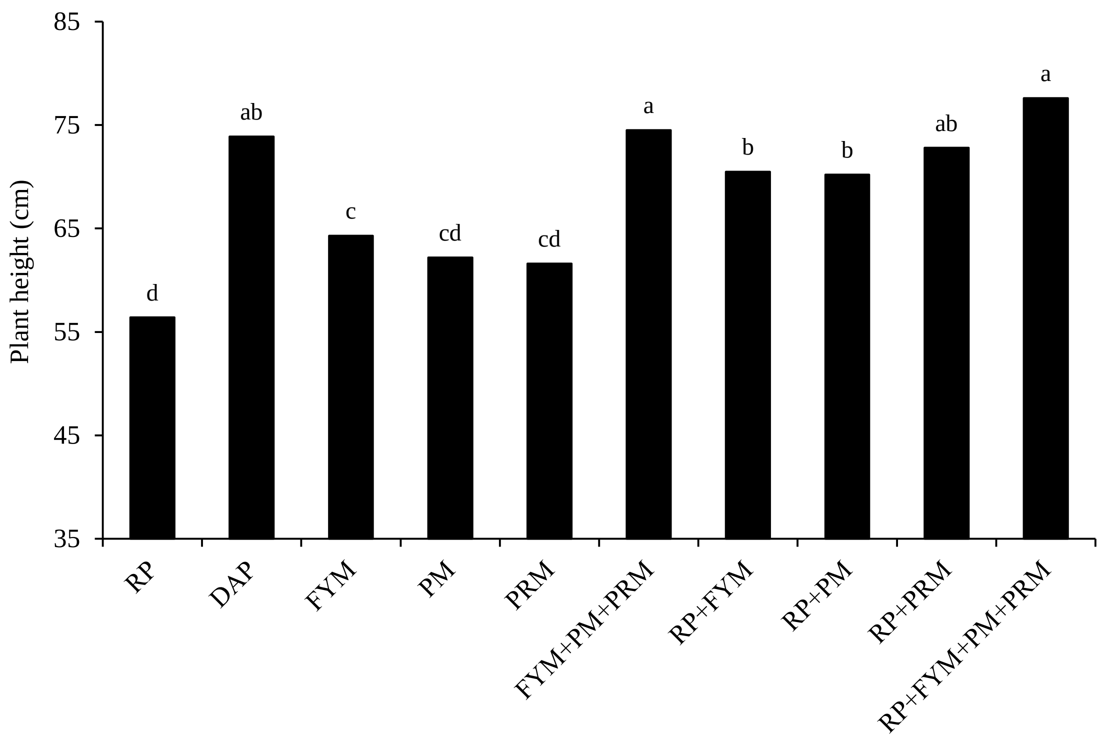

Figure 2 Plant height of sunflower grown with RP amended with different organic manures. RP: Rock phosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud

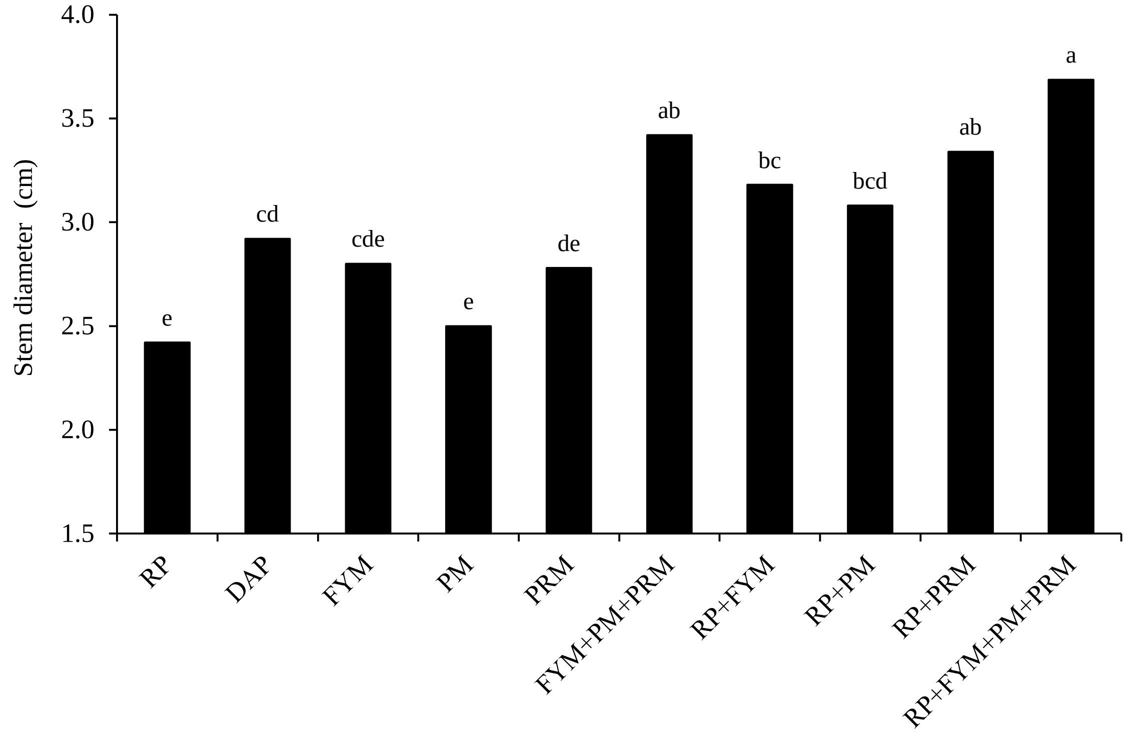

Figure 3 Stem diameter of sunflower grown with RP amended with different organic manures. RP: Rock phosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud.

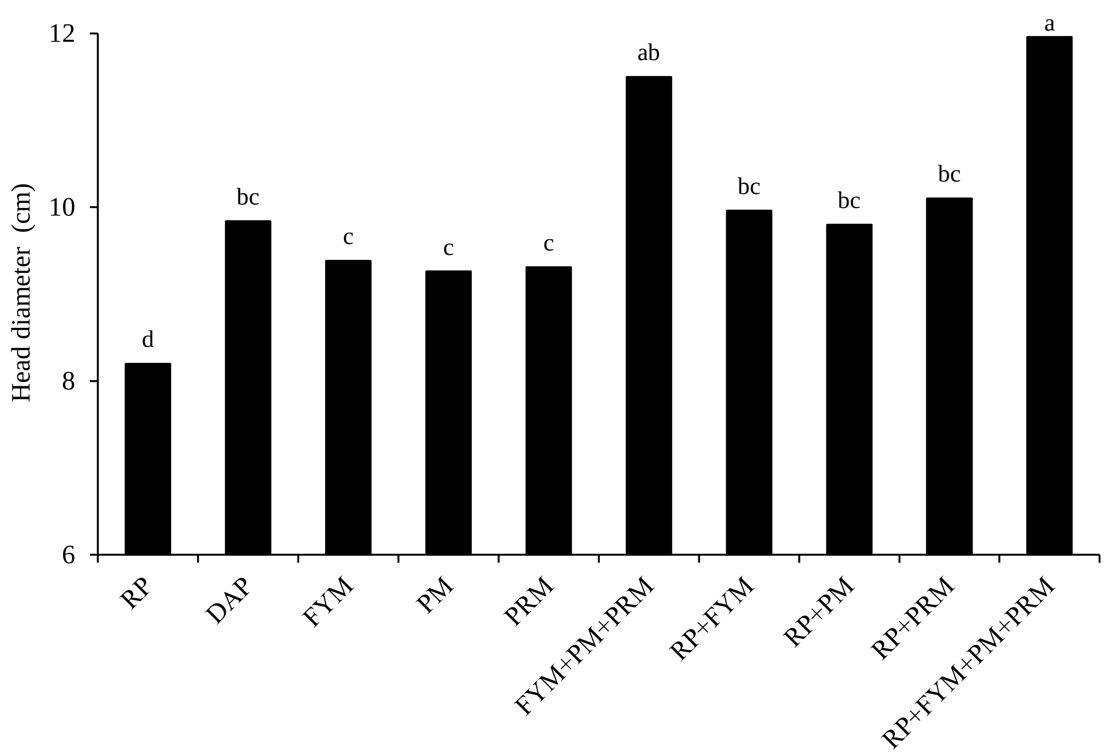

Figure 4 Head diameter of sunflower grown with RP amended with different organic manures. RP: Rock phosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud.

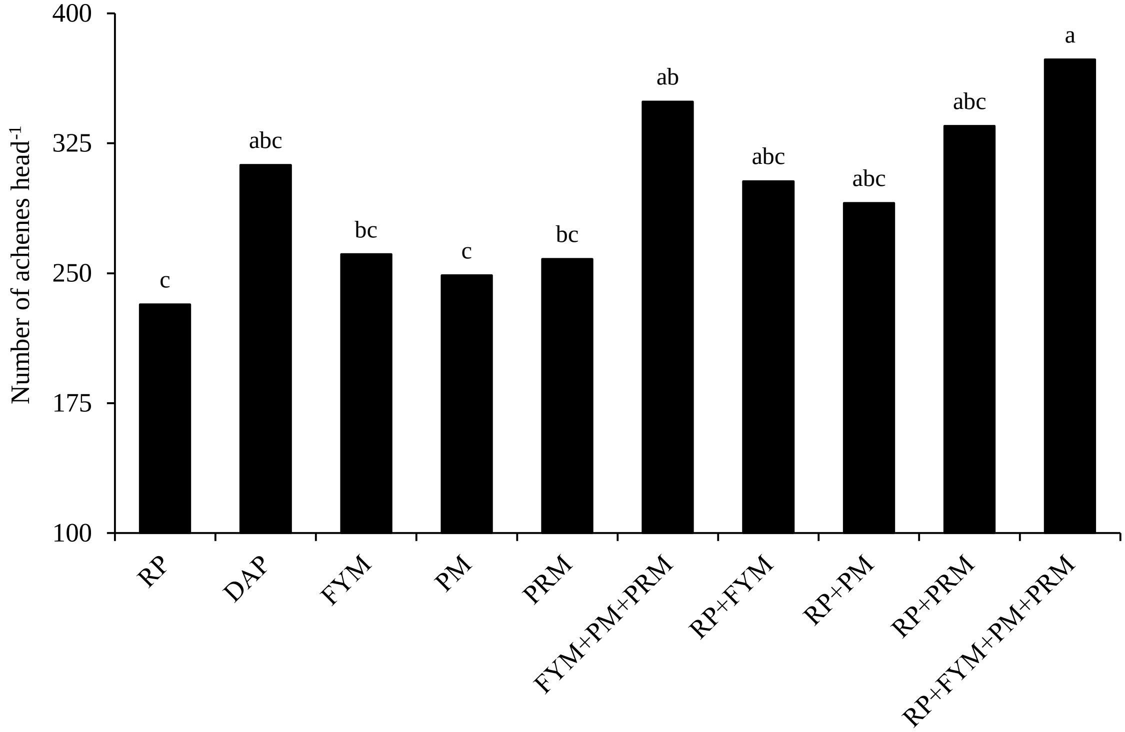

Figure 5 Number of achenes head^{-1} of sunflower grown with RP amended with different organic manures. RP: Rock phosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud.

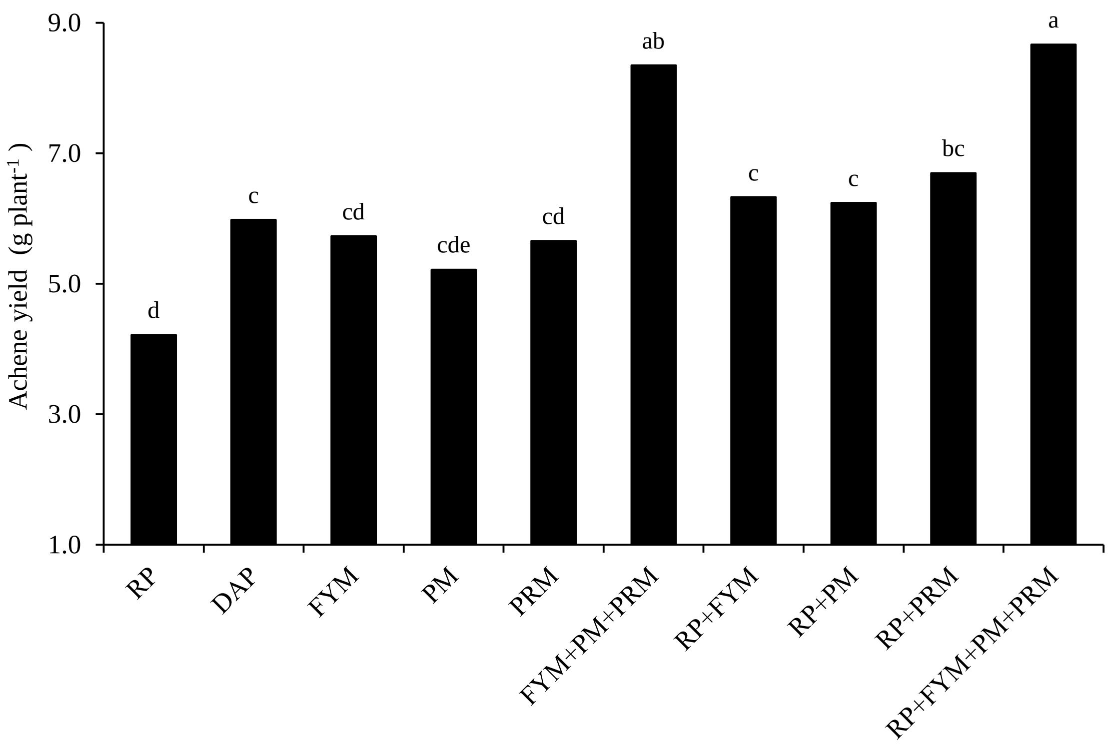

Figure 6 Achene yield plant^{-1} of sunflower grown with RP amended with different organic manures. RP: Rock phosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud

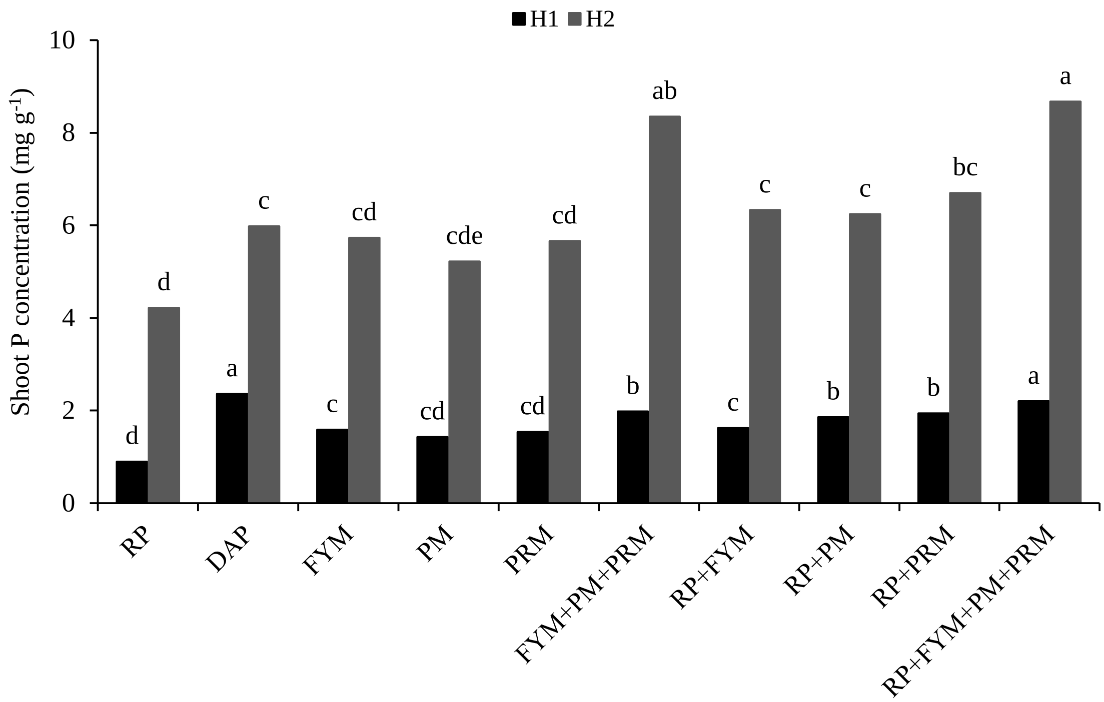

Figure 7 Shoot P concentration of sunflower grown with RP amended with different organic manures. RP: Rock phosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud

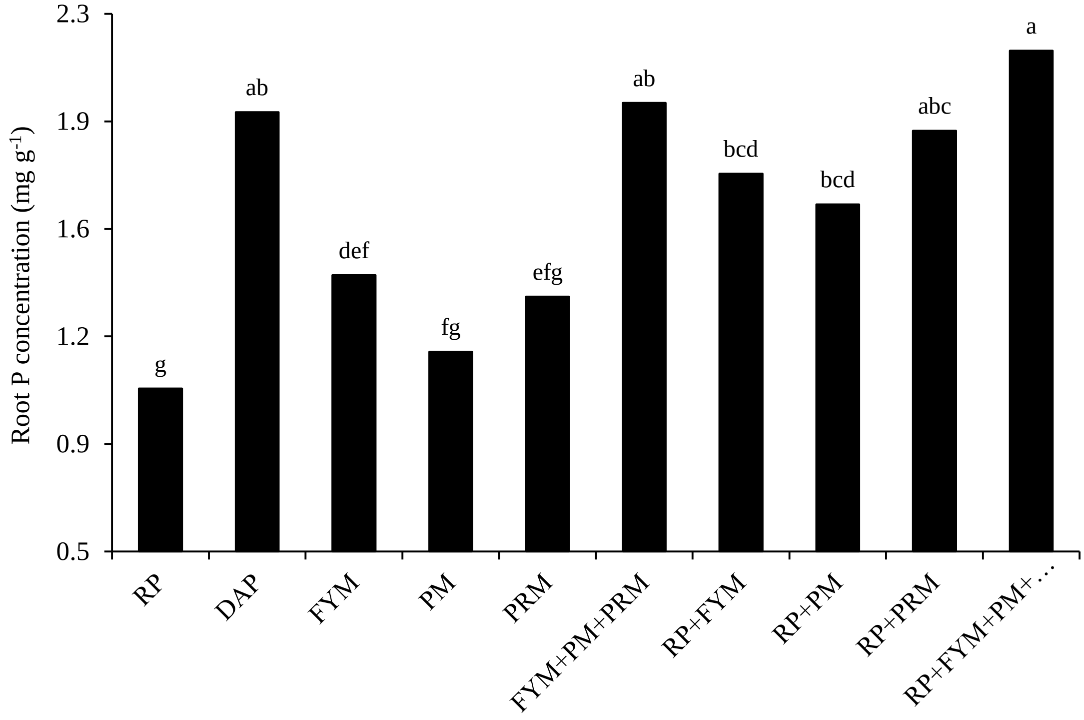

Figure 8 Root P concentration of sunflower grown with RP amended with different organic manures. RP: Rock phosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud

RP was used without any amendment (Figure 5). However, number of achenes head^{-1} increased by 31% when RP was amended with FYM, 25% with RP+PM, 44% with RP+PRM and 61% with RP+FYM+PM +PRM compared to RP without any amendment. Achene yield plant^{-1} increased by 50% when RP was amended with FYM, 48% with RP+PM, 59% by RP+PRM and 105% by RP+FYM+PM+PRM compared to RP alone (Figure 6).

Plant P concentration and uptake

Phosphorus concentration in shoots of sunflower plants was significantly ($p \leq 0.05$) varied when RP was amended with different organic manures (Figure 7). In case of harvesting-1, the lowest shoot P concentration was found in RP treatment (0.9 mg g^{-1}) which was improved by 80%, 106%, 115% and 144% when RP was amended with FYM, PM, PRM and FYM+ PM+PRM compared to RP without any amendment. Similarly, shoot P concentration improved in harvesting-2 by 94% when RP was amended with FYM, 85% with RP+PM, 89% by RP+PRM and 109% by RP+FYM+PM+PRM compared to RP without any amendment. Root P concentration increased by 68% when RP was amended with FYM (RP+FYM), 58% with PM (RP+PM), 81% with PRM (RP+PRM) and 107% with RP+FYM+PM+PRM compared to RP without any amendment (Figure 8). Shoot P uptake increased from 0.28 to 1.21 mg plant^{-1} when RP was amended with FYM, 1.32 mg plant^{-1} with RP+PM, 1.45 mg plant^{-1} with RP+PRM and 1.80 mg plant^{-1} with RP+FYM+PM+PRM (Figure 9). Root P uptake improved from 5.75 to 17.59 mg plant^{-1} when RP was used with FYM, 14.88 mg plant^{-1} with RP+PM, 19.64 mg plant^{-1} with RP+PRM and 28.88 mg plant^{-1} when RP was used with RP+FYM+PM+PRM (Figure 10).

DISCUSSION

The improved plant growth and yield characteristics of sunflower when RP was amended with different organic manures may be attributed to improved solubilization of P from RP (Ditta et al. 2018). Furthermore, organic manures on their decomposition not only released different nutrients but also improved soil health, which subsequently improved plant growth and yield (Zaharah and Bah 1997). Aziz et al. (2006) reported a significant improvement in root and shoot fresh and dry weights of maize by the application of organic manures. Comparing different sources, plant weight was maximum in FYM followed by PM and PRM. Several other studies also reported that the improved shoot and root growth by addition of organic manure might be attributed to improved soil P and K availability (Marschner 1995; Hirzel et al. 2007; Muhammad and Khattak 2009). Akande et al. (2008) reported that complementary application of the Sokoto and Ogun RPs with cowdung increased plant height by 19 and 8%, respectively over RP alone. This might be due to the reason that P is the basic ingredient of energy compounds adenosine triphosphate (ATP), since organic manures improved RP solubilization and release of P from RP, leading to improved plant growth and yield characteristics. Ibrahim et al. (2008) concluded that the application of organic fertilizers increased the grain yield of maize significantly. Akande et al. (2008) studied the efficacy of PM in facilitating the release of P from applied RP and reported that when PM was co-applied with RP, P availability was significantly higher than RP alone. This must have been responsible for the remarkable yield increase observed from the co-application of RP and PM.

Different organic manures solubilized P from RP and transformed into available form which subsequently improved plant growth and yield. It was found that decomposition of organic manures released organic and mineral acids which lowered pH in the immediate vicinity of RP, increasing RP solubilization. Moreover, complexation of Ca^{2+}, main P binding agent in alkaline calcareous soils, with organic manures could also be an important factor for enhanced P availability (Abbasi and Manzoor 2018). The organic acids are actually low molecular weight and characterized by the possession of one or more carboxyl groups. Depending on their dissociation properties and number of carboxylic groups, organic acids carry varying negative charges. These negative charges may allow the complexation of metal cations in solution and displacement of anions from soil matrix. Imran et al. (2011) demonstrated that application of RP with organic wastes yielded an increase of 166 and 257% in P concentration and P-uptake, respectively over RP treatment. Isenmila et al. (2006) used four fresh organic manures namely cow dung, goat manure, palm oil mill and poultry droppings to amend RP for enhancing P dissolution and nutrient availability. The report indicated that addition of the various organic amendments generally increased P by 22 to 579% and enhanced maize plant height and leaf production. Compositing of RPs with manure wastes increased solubility of RPs. The content of P solubility from RP varied with the kind of organic manure, probably due to composition of manure, differential rate of decomposition, and the nature and amount of acids released (Ditta et al. 2018).

Enhanced P uptake from RP amended with organic manures might be due to production of organic acids which lowered the soil pH and also chelated cations which bound P. The increase in P uptake through amendment explained by Mishra and Bangar (1986) as the result of conversion of RP-P to water-

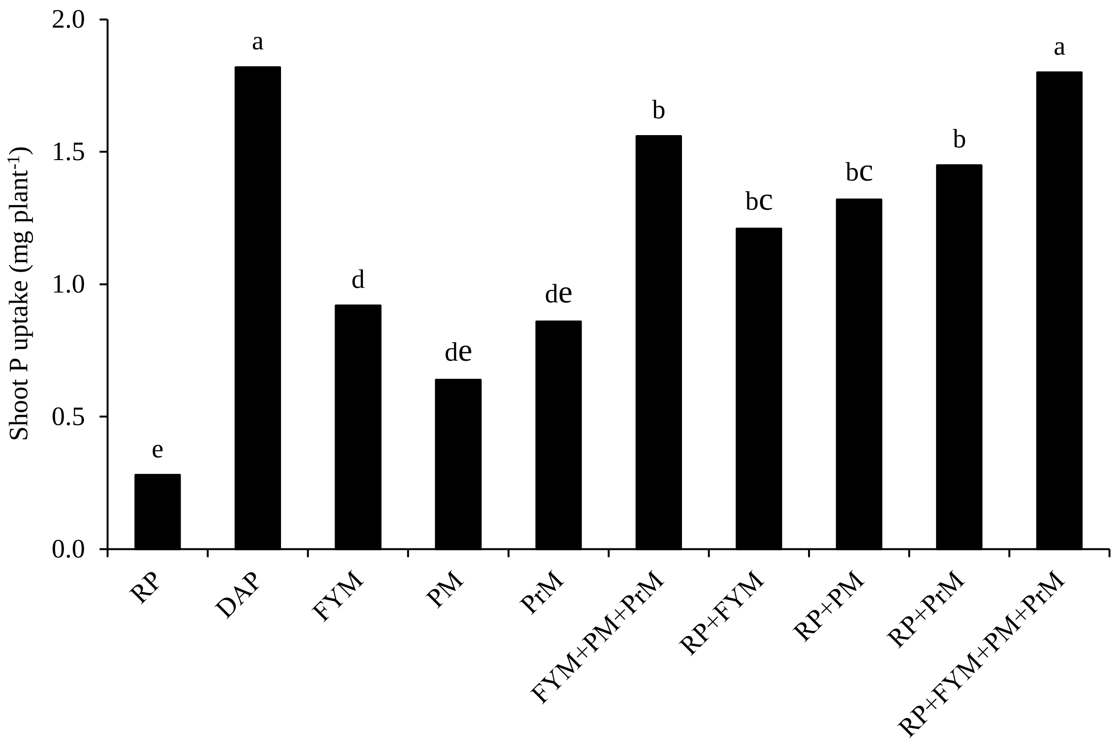

Figure 9 Shoot P uptake of sunflower grown with RP amended with different organic manures. RP: Rock phosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud

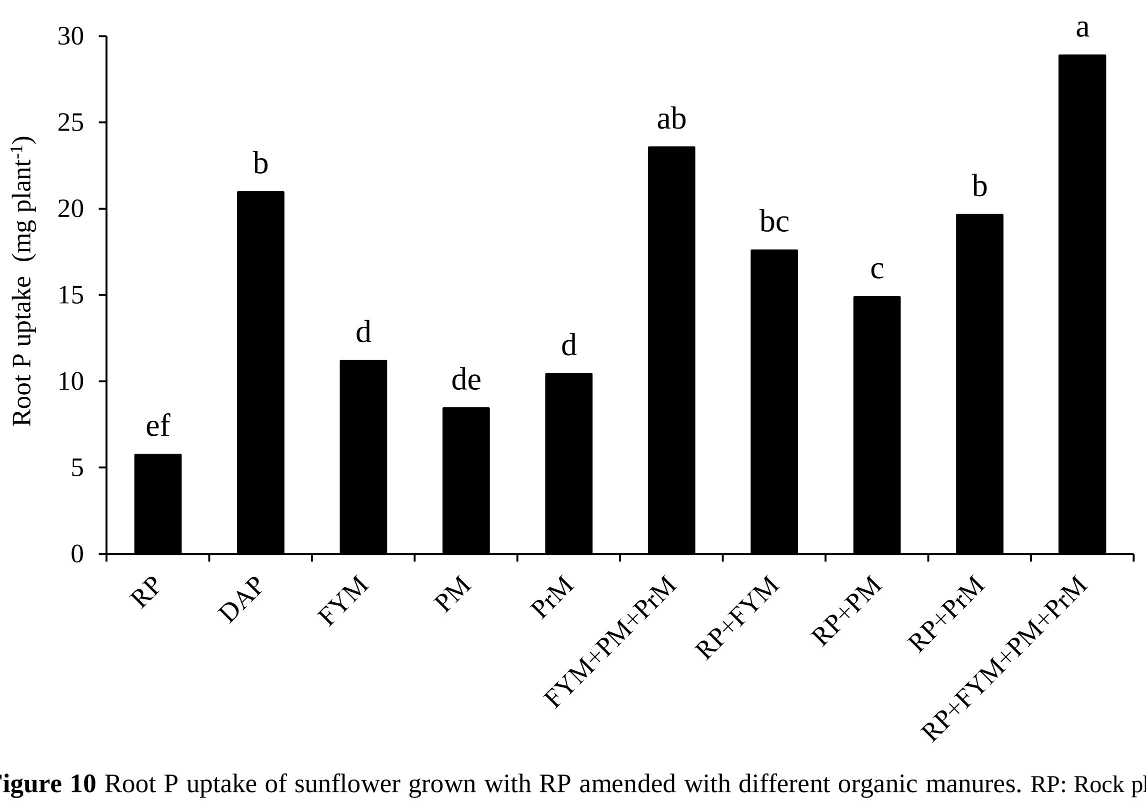

Figure 10 Root P uptake of sunflower grown with RP amended with different organic manures. RP: Rock phosphate, DAP: Diammonium phosphate, FYM: Farm yard manure, PM: Poultry manure, PRM: press mud

soluble, and greater efficiency of the dissolved P in terms of its availability to plant.

CONCLUSIONS

All the three organic materials were significantly ($p \leq 0.05$) effective in solubilizing P from RP and influencing the plant growth and yield of sunflower. While comparing the efficiency of different amendments, FYM proved superior to others. Maximum increase in yield and yield contributing parameters of sunflower were found when RP was amended with the combination of organic materials (RP+FYM+PM+PRM). Integrated use of different manures could be a promising approach to solubilize native soil P compounds of low solubility under alkaline calcareous conditions.

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