Original Article | Open Access

Ahmed et al., 2019. 19: 29-36. J Environ Agric Sci (ISSN: 2313-8629)

Dissolution Kinetics of Phosphorus, Released from Rock Phosphate as Affected by Applied Farm Manure: An Incubation Study

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Received
March 10, 2019

Accepted
May 22, 2019

Published Online
June 28, 2019

Abstract: Phosphorus (P) plays very crucial role n many plant physiological processes including photosynthesis, respiration, energy storage and cell division. In Pakistan about 90% soils are deficient in available P. Application of expensis phosphatic fertilizers forced farmers to search alternate P sources including rock phosphate (RP). Howver, it is crucial to improve the solubility of rock phosphate. In this regard, an incubation experiment was conducted to determine P solubilized from rock phosphate through farm manure (FM) application. The treatments were set in completely randomized design alongwith five replications each. The 10 kg soil per pot was filled. The treatments were: T_1 = Control, T_2 = RP at 5g kg^{-1} soil, T_3 = RP at 10g kg^{-1} soil, T_4 = RP at 5g kg^{-1} soil + 5% FM, T_5 = RP at 5g kg^{-1} soil +10% FM, T_6 = RP at 5g kg^{-1} soil + 20% FM, T_7 = RP at 10 g kg^{-1} soil + 5% FM, T_8 = RP at 10g kg^{-1} soil + 10% FM, T_9 = RP at 10g kg^{-1} soil + 20% FM. Water was applied according to need on day to day basis following field capacity. Soil samples were collected after every 15 days interval. Soil pH, EC_e, organic matter, available P and potassium (K) were determined. Results showed a gradual increase in available P, K and OM with increasing rate of RP and FM, from T_1 (i.e., Control) to T_9 (i.e., RP at 10g kg^{-1} soil + 20% FM). However, soil pH showed non-significant variations. Soil EC was found variable among all the treatments. Overall results indicated that maximum solubilization of P from RP was observed under T_9 where RP at 10g kg^{-1} soil + 20% FM was applied. Present results need further confirmation, especially under field conditions and economic feasibility must be worked out.

Keywords: Phosphorus, rock phosphate, farm manure, solubilization, pH, EC.

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Cite this article as: Ahmed, I., M. Sarfraz, H. Nawaz, A. Ahmad, I. Shehzad, A. Touqeer, M.M. Iqbal, T. Naz, M. Afzal, I.R. Noorka, M.I. Zafar, M. Imtiaz and S. Hussain. 2019. **Dissolution kinetics of phosphorus released from rock phosphate as affected by applied farm manure: An incubation study**. Journal of Environmental & Agricultural Sciences. 19: 29-36.

1. Introduction

Phosphorus is an essential plant nutrient and involved in metabolism. It is vital for transfer of energy from source (photosynthetic sites) and its storage in sink (Jiang et al., 2019; Zhang et al., 2018). Moreover, it is involved in the metabolism of carbohydrates and structural part of the nucleic acids, phosphoproteins, phospholipids and many coenzymes

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(Amin et al., 2017; Bi et al., 2013; Garba et al., 2017; Lambers and Plaxton, 2018).

Plants utilize phosphorous in three different water soluble forms like $H_2PO_4^-$, HPO_4^- and PO_4^- (Mamathashree et al., 2018). Roots of plants secretes different organic acids like malic and citric acid which solubilize phosphates present in soil (Chen and Liao, 2016; Jones, 1998; Sasse et al., 2018; Wang and Lambers, 2019). Phosphate reaction in soil is very slow that leads to decline in the concentration of phosphate in soil solution. Thus, the retrieval of P manure by plants amount to be only to 10-30 % of that added (Ringeval et al., 2017; Tisdale et al., 1985; Tammimi et al., 1986). Phosphorus usually exists in Pakistani soil as insoluble complexes of calcium like di and tri-calcium phosphates. Breakdown of organic matter increase the carbon dioxide level that rise the carbonic acid which help in solubilize intrinsic P mineral and enhance P mobility in soil (Marschner, 1995; Mengel and Kirkby, 2001).

Soil surveys of Pakistani soils reported alkaline and calcareous nature and nationwide phosphorus deficiency with very low phosphorus availability (Ali and Ali 2011; Memon and Rashid 2001). Clay dominated arid soils can fix P and reduces its availability to plants. Consequently, higher rates of phosphorus fertilizers are required to meet plant phosphorus requirement (Dzotsi et al. 2010). Lower phosphorus recovery (15–25% of the amount of fertilizer applied) in irrigated areas further reduces in arid areas, which requires higher amount of fertilizer application (Chattha et al. 2007; Nasim et al., 2017).

High cost of inorganic fertilizer and environmental concerns forcing farmers to consider alternate sources to maintain fertility of their soils (Mafongoya et al., 2000). Rock phosphate (RP) referred to as sedimentary rock contain about 15-20 % P but not completely accessible to plants (Blatt et al., 1996). The RP symbolize cheap preference as a plant fertilizer, mostly in those areas where raw material is not available for production of phosphate fertilizers (Haynes, 1984). Rock phosphate is mainly tri-calcium phosphate with un-available P to plants and RP is basically major raw material for preparation of phosphate fertilizers by reacting with sulfuric acid (Das, 2005).

Variety of organic materials are incorporated into the soil as a source of nutrient and for improving soil quality such as manure, sewage sludge, crop residues, compost and municipal waste are being (Rasmussen and Collins, 1991; Six et al., 2002). Farm waste is a cheap alternative for soil enrichenmt and improvement of nutrient availability (Ahmad et al., 2016; Benbi and Yadav, 2015). After decomposition of manure organically–bound nutrients are released (Mafongoya et al., 2000). In addition to nutrient supply, manures add humus into the soil, which enhances the aggregate stability, aeration and water retention of soil (Aarons et al., 2004).

Using RP with organic manures appeared as worthwhile option due to production of various organic acids throughout the process of decomposition by both microbial and chemical reactions (Rashid et al., 2004). Rock phosphate when used along with manure sustain greater amount of P in soil for longer time period in comparison to using fertilizer alone (Sah et al., 1986). Rock phosphate with combination of organic manure fulfills the nutrient demand of plants in a cropping pattern (Khalil et al., 2002).

When high grade phosphate fertilizer applied with FM or other organic manure it behave like a very active phosphate fertilizer. Soil phosphate solubility enhance the organic matter. Decomposition of organic acids release humic acids that facilitate to change unavailable phosphate into available form (Brady, 1984). Composting of organic manure with RP enhances the availability of P from RP and this is accomplished as effective technology to enhance the fertilizers worth of manures (Mishra and Bangar, 1986; Singh and Amberger, 1991; Mahimairaja et al., 1995). The FM application leads to accumulation of P and also speed up dissolving native P by discharge of weak organic acids (Kiss et al., 1994). Along with FM, green and poultry manure also identified to increases P availability in alkaline soil (Singh and Bahl, 1993; Toor and Bahl, 1997). Mixing phosphate minerals with organic manure or compost increase the soil P availability because acids release from breakdown of organic matter will help in dissolution of phosphate minerals (Moore and Miller, 1984). Thus, an experiment was designed to check the solubilization of P from RP using FM with objectives as (1) to check the effect of FM on P release from RP in an incubation study (2) to investigate the combined effect of RP and FM on pH and EC of the soil.

Table 1: Physico-chemical properties of the soil used for the incubation study

pH	EC ($mScm^{-1}$)	O.M (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})
8.5	1.28	0.62	3.6	96

EC, electrical conductivity; O.M., Organic matter.

2. Materials and Methods

An incubation study was conducted in the Agricultural Research Farm Area, University of Sargodha, Sargodha, Pakistan, to investigate the solubilization of P from RP from applied FM. An incubation study was conducted following completely randomized design (CRD). A 10 kg soil was filled in each pot. Experiment consisted of nine treatments each with five replications using rock phosphate (RP) and farm manure (FM) as: T_1 = Control, T_2 = RP at 5 g kg^{-1} soil, T_3 = RP at 10 g kg^{-1} soil, T_4 = RP at 5 g kg^{-1} soil + 5 % FM, T_5 = RP at 5 g kg^{-1} soil + 10 % FM, T_6 = RP at 5 g kg^{-1} soil + 20 % FM, T_7 = RP at 10 g kg^{-1} soil + 5 % FM, T_8 = RP at 10 g kg^{-1} soil + 10 % FM, T_9 = RP at 10 g kg^{-1} soil + 20 % FM.

Before pot filling the soil was analyzed for different chemical parameters (such as pH, EC, organic matter i.e., OM, available P, available K), following Iqbal et al. (2017), which are presented in Table 1. Then, RP and FM were mixed in the soil according to the treatment plan, leaving one treatment as control pots. Distilled water was applied according to requirement as per field capacity. Soil samples were collected after every 15 days and analyzed for pH, EC, OM, P and K.

Samples were air dried, passed through 2 mm sieve and analyzed for electrical conductivity (EC) by preparing 1:10 soil and water suspension (Soil Salinity Lab Staff 1954), pH (Schofield and Taylor, 1955), organic matter (Walkley and Black, 1934), available phosphorus (Olsen et al., 1954) and extractable potassium (Jackson, 1967).

The present experiment was lasted for 120 days during this period various agronomic practices were accomplished according to the requirement of soil. The collected data was analyzed statistically (Steel et al., 1997) at 5% level of significance by means of "Statistix 8.1" statistical computer-based software package.

3. Results and Discussion

Data regarding EC and pH was presented in Table 2 and 3 respectively. It was observed that addition of RP along with FM improved the P and K concentration in soil as released from RP, resultantly EC of soil also increased. There was no noteworthy consequence of using varying concentrations of RP alone like in first and second treatment but when RP was used in combination with FM, it enhanced the EC and this rise in EC level was maximum when used 20% FM along with 5 and 10 g RP per kg soil. The Table 3 representing the data for pH and no considerable outcome of any treatment on pH; however, the pH had reduced by FM. The pH of present control treatment was 8.5 and this pH level had started to decrease using different treatments but difference between the treatments was not significant.

The present EC and pH results are consistent with the finding of Akram (1978) who investigated that soil pH decreased because of the discharge of H^+ ions through mineralization of organic and inorganic compounds. Addition of organic fertilizers released H^+ ions from the soil during nitrification process which decreased the soil pH. A few studies reported that applied farm manure not changes the soil EC and pH.

Table 2: Variations in electrical conductivities (mS cm^{-1}) as affected by application of different ratios of rock phosphate and farm manure treatments (15-days time interval).

Treatments	EC							
	Days after Treatment application							
	15	30	45	60	75	90	105	120
Control	1.28^{cd}	1.28^{a}	1.28^{ab}	1.28^{a}	1.28^{abc}	1.28^{b}	1.28^{d}	1.28^{b}
RP at 5 g kg^{-1} soil	0.87^{d}	1.50^{a}	1.55^{ab}	1.28^{a}	1.29^{abc}	2.17^{ab}	1.52^{bcd}	1.28^{b}
RP at 10 g kg^{-1} soil	0.96^{d}	0.93^{a}	1.08^{b}	1.06^{a}	0.89^{c}	1.65^{ab}	1.41^{cd}	1.23^{b}
RP at 5g kg^{-1} soil +5% FM	1.31^{cd}	1.13^{a}	1.11^{b}	1.37^{a}	1.09^{bc}	1.99^{ab}	1.56^{bcd}	1.4^{ab}
RP at 5g kg^{-1} soil +10% FM	1.62^{bc}	1.49^{a}	1.55^{ab}	1.79^{a}	1.91^{a}	2.75^{a}	1.91^{abc}	1.85^{a}
RP at 5g kg^{-1} soil +20% FM	2.18^{ab}	1.44^{a}	1.50^{ab}	1.83^{a}	1.43^{abc}	2.56^{ab}	2.36^{a}	1.63^{ab}
RP at 10g kg^{-1} soil +5% FM	1.73^{bc}	1.35^{a}	1.64^{ab}	1.64^{a}	1.65^{ab}	1.95^{ab}	1.53^{bcd}	1.38^{b}
RP at 10g kg^{-1} soil +10% FM	1.43^{cd}	1.29^{a}	1.37^{ab}	1.53^{a}	1.56^{abc}	2.45^{ab}	1.32^{d}	1.43^{ab}
RP at 10g kg^{-1} soil +20% FM	2.47^{a}	1.56^{a}	1.89^{a}	1.49^{a}	1.35^{abc}	2.51^{ab}	2.02^{ab}	1.53^{ab}

Mean with different letter (s) in the same columns are significantly different at P ≤ 0.05, n = 5. RP, Rock Phosphate; FM, Farm manure; EC, Electrical conductivity.

Table 3. Variations in pH as affected by application of different ratios of rock phosphate and farm manure treatments (15-days time interval).

Treatments	**pH**							
	Days after Treatment application							
	15	**30**	**45**	**60**	**75**	**90**	**105**	**120**
Control	8.50^{bcd}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{b}	8.50^{a}
RP at 5 g kg^{-1} soil	8.72^{a}	8.50^{a}	8.04^{b}	8.06^{b}	7.86^{b}	8.08^{b}	8.64^{ab}	8.18^{b}
RP at 10 g kg^{-1} soil	8.54^{abc}	8.54^{a}	8.18^{b}	8.04^{b}	8.00^{b}	8.12^{b}	8.64^{ab}	8.14^{b}
RP at 5g kg^{-1} soil+5%FM	8.50^{ab}	8.50^{a}	8.16^{b}	7.96^{b}	7.84^{b}	8.16^{b}	8.62^{ab}	8.18^{b}
RP at 5g kg^{-1} soil+10%FM	8.40^{bcd}	8.42^{a}	8.14^{b}	7.88^{bc}	7.78^{b}	8.18^{b}	8.66^{ab}	8.02^{b}
RP at 5g kg^{-1} soil +20%FM	8.36^{bcd}	8.40^{a}	8.12^{b}	7.86^{bc}	7.92^{b}	8.08^{b}	8.52^{b}	7.88^{b}
RP at 10g kg^{-1} soil +5%FM	8.34^{cd}	8.50^{a}	8.04^{b}	7.86^{bc}	7.86^{b}	8.16^{b}	8.58^{ab}	7.88^{b}
RP at 10g kg^{-1} soil +10%FM	8.34^{cd}	8.40^{a}	8.04^{b}	7.86^{bc}	7.88^{b}	8.14^{b}	8.60^{ab}	8.00^{b}
RP at 10g kg^{-1} soil +20%FM	8.32^{d}	8.40^{a}	8.12^{b}	7.72^{c}	7.96^{b}	8.14^{b}	8.74^{a}	7.96^{b}

Mean with different letter (s) in the columns are significantly different at $P \leq 0.05$, n = 5. RP, Rock Phosphate; FM, Farm manure; EC, Electrical conductivity.

However, EC under rhizosphere soil was very low than bulk soil (Marschner, 1995). Walker et al. (2004) suggested that application of organic manure changed the soil pH due to oxidation of organic matter and process of releasing carbon dioxide from the soil. Nevertheless, this inconsistency might be due to short small duration of present study. Agbede et al. (2008) suggested non- significant effect of manure on soil pH. Appliance of RP along-with organic materials slightly decline the soil pH because of discharge of H^{+} ions during nitrification of fertilizers (Mbakaya et al., 2006).

Significant variations was observed regarding soil available P and K, which are described in Tables 4 and 5. The present outcome are in consistence with (Laskar et al., 1990) that suggested that addition of RP with or without organic manures appreciably increase the total organic P level in soil. Soil without any treatment have P content 3.6 mg kg^{-1} but when RP was added along with FM soil P level had raised to higher level and maximum soil available P was measured when added 20 % FM .

Similar trend was noted for soil available K. Soil available P reached to maximum level as each sample is taken after every 15 days and all treatment means differ significantly ($p \leq 0.05$). Cavigelli and Thien (2003) also noted the increase in bioavailability of P in soil due to adding of organic manure. There was noteworthy rise in soil available P and K owing to application of organic manure in soil. Sharma and Tripathi (1999) described that efficacy of FM in rising soil available P is linked to its role in chelating phosphate fixing cations and reducing sorption of phosphate with low binding energy and exchange of adsorbed phosphate by organic anions. Use of FM enhances soil water content that are might be possible because of increase in the soil available P or decomposition of organic manures that increases carbonic acid that enhance P bioavailability (Marschner, 1995; Boateng et al., 2006; Mengel and Kirkby, 2001).

Table 4. Variations in available P (mg kg^{-1}) in soil as affected by application of different ratios of rock phosphate and farm manure treatments (15-days time interval)

Treatments	Available P **(mg kg^{-1})**							
	Days after Treatment application							
	15	**30**	**45**	**60**	**75**	**90**	**105**	**120**
Control	3.38^{c}	3.34^{c}	3.56^{c}	3.3^{e}	3.52^{c}	3.54^{d}	3.64^{d}	3.66^{d}
RP at 5 g kg^{-1} soil	2.08^{c}	3.82^{c}	3.34^{c}	3.58^{e}	3.44^{c}	5.24^{cd}	2.96^{d}	4.3^{cd}
RP at 10 g kg^{-1} soil	3.72^{c}	4.08^{c}	3.78^{c}	3.3^{e}	4.5^{c}	6.26^{cd}	3.24^{d}	4.32^{cd}
RP at 5g kg^{-1} soil +5%FM	5.56^{c}	4.08^{c}	4.9^{c}	7.94^{de}	7.12^{bc}	11.26^{b}	7.90^{cd}	10.0^{b}
RP at 5g kg^{-1} soil +10%FM	7.28^{c}	5.76^{bc}	8.5^{b}	14.84^{ab}	9.08^{abc}	16.72^{a}	14.32^{bc}	11.6^{b}
RP at 5g kg^{-1} soil +20%FM	15.82^{bc}	12.86^{a}	12.94^{a}	18.66^{a}	14.18^{a}	20.8^{a}	21.72^{a}	17.38^{a}
RP at 10g kg^{-1} soil +5%FM	10.44^{abc}	4.36^{c}	4.98^{c}	9.64^{cd}	8.56^{abc}	9.04^{bc}	9.2^{cd}	8.38^{bc}
RP at 10g kg^{-1} soil +10%FM	18.88^{a}	8.58^{b}	5.66^{bc}	13.74^{bc}	12.48^{ab}	11.44^{b}	12.94^{c}	11.56^{b}
RP at 10g kg^{-1} soil +20%FM	18.94^{a}	16.06^{a}	14.94^{a}	17.46^{ab}	14.42^{a}	18.5^{a}	20.88^{ab}	19.8^{a}

Mean with different letter (s) in the columns are significantly different at $P \leq 0.05$, n = 5. RP, Rock Phosphate; FM, Farm manure; EC, Electrical conductivity

Table 5. Variations in available K (mg kg^{-1}) in soil as affected by application of different ratios of rock phosphate and farm manure treatments (15-days time interval).

Treatments	Available K (mg kg^{-1})							
	Days after Treatment application							
	15	30	45	60	75	90	105	120
Control	96.6^{f}	98.8^{de}	101.4^{d}	103.2^{d}	107.2^{e}	106.4^{ef}	110.6^{c}	107^{d}
RP at 5 g kg^{-1} soil	90^{f}	98^{e}	131.2^{cd}	112.4^{d}	160.4^{cde}	122^{ef}	157.2^{bc}	124.8^{cd}
RP at 10 g kg^{-1} soil	90^{f}	106^{cde}	136^{cd}	110.8^{d}	136.4^{de}	99.2^{f}	125.6^{bc}	153.2^{c}
RP at 5g kg^{-1} soil +5%FM	153.6^{de}	147.6^{bcde}	197.6^{bc}	166^{cd}	190.4^{bcd}	148de	170.4^{b}	165.6^{bc}
RP at 5g kg^{-1} soil +10%FM	194^{c}	207.6^{ab}	236.8^{b}	247.2^{abc}	236.4^{b}	221.6^{bc}	228.4^{a}	264^{a}
RP at 5g kg^{-1} soil +20%FM	235.6^{b}	254.4^{a}	318.4^{a}	322^{a}	309.2^{a}	250.8^{ab}	277.6^{a}	277.2^{a}
RP at 10g kg^{-1} soil +5%FM	126.4^{ef}	163.6^{bcd}	155.2^{cd}	190.8^{bcd}	226^{bc}	140.8^{def}	137.2^{bc}	162.8^{bc}
RP at 10g kg^{-1} soil +10%FM	176.8^{cd}	168^{bc}	169.2^{bcd}	155^{cd}	184.4^{bcd}	176.8^{cd}	158.4^{bc}	202.4^{b}
RP at 10g kg^{-1} soil +20%FM	306.8^{a}	237.2^{a}	235.6^{b}	269.6^{ab}	204.4^{bcd}	270.4^{a}	256^{a}	265.6^{a}

Mean with different letter (s) in the same column are significantly different at $P \leq 0.05$, n = 5. RP, Rock Phosphate; FM, Farm manure; EC, Electrical conductivity.

Organic matter under different treatment and during variable time period was encountered in Table 6 showing that all treatments varies significantly instead of treatment 5 and 8 during all harvesting period except of 1st and 2nd harvest. Maximum organic matter was observed under higher concentration of FM. Rabindra and Gowda (1986) reported that use of manures in good amalgamation increase the organic matter of soil while Marschner (1995) reported that organic manure increase soil microbial activity which play role to enhance soil organic matter. Furthermore, our results are supported by Tomayo et al. (1997) as they concluded that during the addition of organic manures composted with RP a significant progress was observed in soil organic matter content. However, Iqbal et al. (2016) reported that higher rates of applied FM led to increase OM in different textured both salt-affected Pb-contaminated soils than the initial or lower rates of FM application. Moreover, the decomposition of added FM decreased OM along with ABDTPA extractable Pb, after each incubation time.

4. Conclusion

Rock phosphate is an important locally available source of P but constraint withstand is with its solubility and phyto-availability. However, organic matter applied with rock phosphate can enhance its solubility. The present results proved that applied rock phosphate along with farm manure not only increased the concentration of available phosphorous in the soil but also improved the soil health, as pH of soil was found to be reduced. The combination of rock phosphate and farm manure at its higher applied rate also enhanced the concentration of available potassium, however, the electric conductivity of soil was also increased. Overall the combination was proved beneficial in the present study. However, further study and present results are needed to be checked regarding their effect in a cropped field.

Table 6. Variations in soil organic matter (%) as affected by application of different ratios of rock phosphate and farm manure treatments (15-days time interval).

Treatments	Soil Organic Matter (%)							
	Days after Treatment application							
	15	30	45	60	75	90	105	120
Control	0.62^{cd}	0.63^{de}	0.64^{c}	0.63^{d}	0.64^{e}	0.65e	0.63^{e}	0.62^{f}
RP at 5 g kg^{-1} soil	0.54^{d}	0.49^{e}	0.63 ^{c}	0.62^{d}	0.59^{e}	0.75^{e}	0.66^{e}	0.73^{ef}
RP at 10 g kg^{-1} soil	0.59^{d}	0.61^{de}	0.68^{c}	0.61^{d}	0.68^{de}	0.84^{de}	0.68^{de}	0.68^{f}
RP at 5g kg^{-1} soil +5%FM	0.69^{cd}	0.65^{de}	0.76^{bc}	0.87^{c}	0.83^{cd}	1.04^{bcd}	0.90^{cd}	1.03^{cd}
RP at 5g kg^{-1} soil +10%FM	0.90^{abcd}	0.76^{cd}	0.93^{b}	1.18^{ab}	0.94^{bc}	1.18^{ab}	1.15^{ab}	1.07^{bc}
RP at 5g kg^{-1} soil +20%FM	1.07^{abc}	1.08^{ab}	1.17^{a}	1.36^{a}	1.24^{a}	1.29^{a}	1.33^{a}	1.24^{ab}
RP at 10g kg^{-1} soil +5%FM	0.78^{bcd}	0.55^{e}	0.69^{c}	0.96^{bc}	0.82^{cd}	0.97^{cd}	0.98^{bc}	0.89^{de}
RP at 10g kg^{-1} soil +10%FM	1.25^{a}	0.91^{bc}	0.73^{c}	1.15^{ab}	1.04^{b}	1.08^{bc}	1.17^{ab}	1.07^{bc}
RP at 10g kg^{-1} soil +20%FM	1.24^{ab}	1.22^{a}	1.21^{a}	1.26^{a}	1.32^{a}	1.31^{a}	1.22^{a}	1.28^{a}

Mean with different letter (s) in the columns are significantly different at $P \leq 0.05$, n = 5. RP, Rock Phosphate; FM, Farm manure; EC, Electrical conductivity.

List of Abbreviations: CRD, completely randomized design; EC, electrical conductivity; FM, farm manure; K, potassium; NPK, nitrogen phosphorus potassium; OM, organic matter; P, Phosphorus; RP, rock phosphate.

Competing Interest Statement: All the authors declare that they have no potential competing interest.

Author's Contribution:
I.A. conducted the whole research and do all the belongings of research article. M.A. and M.S. commenced the idea of research, intended and described the treatments. H.N. and I.S. assisted in experimentation and analytical work. A.A. and A.T. statistically analyzed the results. M.M.I. and T.N. provided technical inputs for interpretation of discussion. G.S., M.A. and I.R.N. assessed and supervised throughout the research with useful suggestions. M.I.Z., M.I. and S.H. the evaluated the results and revised manuscript. All other approved final draft of the manuscript.

Acknowledgments: The authors acknowledge the support of technical staff at Soil and Water Testing Laboratory, Chiniot, Pakistan to conduct different analysis.

References

Aarons, S.R., H.M. Hosseini, L. Dorling and C.J.P. Gourley. 2004. Dung decomposition in temperate dairy pastures I. Changes in soil chemical properties. Aust. J. Soil Res. 42: 107–114.

Agbede, T.M., S.O. Ojeniyi and A.J. Adeyemo, 2008. Effect of poultry manure on soil physical and chemical properties, growth and grain yield of sorghum in southwest, Nigeria. American-Eur. J. Sus. Agric. 2: 72–77

Ahmad, N., M. Imran, M.W.R. Marral, M. Mubashir and B. Butt. 2016. Influence of biochar on soil quality and yield related attributes of wheat (*Triticum aestivum* L.). J. Environ. Agric. Sci. 7: 68-72.

Akram, M. 1978. Effect of organic and inorganic fertilizers applied to maize crop. M.Sc (Hons) Thesis. Deptt. Soil. Sci. Univ. Agric. Faisalabad, Pakistan.

Ali L, and M. Ali. 2011. Relationship of yield and yield components of cotton (*Gossypium hirsutum* L.) with P and K fertilization. J Agric. Res 49: 1117.

Amin, A., W. Nasim, M. Mubeen, M. Nadeem, L. Ali, H.M. Hammad, S.R. Sultana, K. Jabran, M.H.U. Rehman, S. Ahmad, M. Awais, A. Rasool, S. Fahad, S. Saud, A.N. Shah, Z. Ihsan, S. Ali, A.A. Bajwa, K.R. Hakeem, A. Ameen, Amanullah, H.U. Rehman, F. Alghabar, G.H. Jatoi, M. Akram, A. Khan, F. Islam, S.T. Ata-Ul-Karim, M.I.A. Rehmani, S. Hussain, M. Razaq, A. Fathi. 2017. Optimizing the phosphorus use in cotton by using CSM-CROPGRO-cotton model for semi-arid climate of Vehari-Punjab, Pakistan. Environ. Sci. Pollut. Res. 24: 5811-5823.

Benbi, D.K. and S.K. Yadav. 2015. Decomposition and carbon sequestration potential of different rice-residue-derived by-products and farmyard manure in a sandy loam soil. Comm. Soil Sci. Plan. 46: 2201-2211.

Bi, J., Z. Liu, Z. Lin, M.A. Alim, M.I.A. Rehmani, G. Li, Q. Wang, S. Wang, Y. Ding. 2013. Phosphorus accumulation in grains of japonica rice as affected by nitrogen fertilizer. Plant Soil. 369: 231-240.

Blatt, H. and J.T. Robert. 1996. Petrology, Freeman. 2nd ed. P. 345-349.

Boateng, S.A., J. Zichermann and M. Kornahrens, 2006. Poultry manure effect on growth and yield of maize. West Africa J. Appl. Ecol. 9: 1–11.

Brady, N.C. 1984. The nature and properties of soils (9th Ed.). Macmillan, New York. P. 750.

Cavigelli, M.A. and S.J. Thien, 2003. Phosphorus bioavailability following incorporation of green manure crops. Soil. Sci. Soc. Am. J. 67: 1186–1194.

Chattha T.H. , M. Yousaf, S. Javeed. 2007. Phosphorus adsorption as described by Freund lich adsorption isotherms under rainfed conditions of Pakistan. Pak. J. Agri. Sci. 4:551–556.

Chen, Z.C. and H. Liao. 2016. Organic acid anions: An effective defensive weapon for plants against aluminum toxicity and phosphorus deficiency in acidic soils. J. Genetics Genomics. 43: 631-638.

Das, K.D. 2005. Introductory Soil Science. 4th ed. Kalyani Publishers, New Dehli, India.

Dzotsi K.A., J.W. Jones, S.G.K. Adiku, J.B. Naab, U. Singh, C.H. Porter, A.J. Gijsman, 2010. Modeling soil and plant phosphorus within DSSAT. Ecol. Model 221: 2839–2849.

Garba, J., A.W. Samsuri, S. Ahmad-Hamdani and R. Othman. 2017. Carbon and phosphorus mineralization from soils amended with cow dung or rice husk ash. J. Environ. Agric. Sci. 10: 84-94.

Haynes, R.J. 1984. Lime and phosphate in the soil-plant system. Adv. Agron. 37: 249-3 15.

Iqbal, M.M., G. Murtaza, S.M. Mehdi, T. Naz, A. Rehman, O. Farooq, M. Ali, M. Sabir, M. Ashraf, G. Sarwar and G. Du Laing. 2017. Evaluation of phosphorus and zinc interaction effects on wheat grown in saline-sodic soil. Pak. J. Agric. Sci. 54: 531-537.

Iqbal, M.M., H. Rehman, G. Murtaza, T. Naz, W. Javed, S.M. Mehdi, S. Javed and A.A. Sheikh. 2016. Transformation and adsorption of lead as affected by organic matter and incubation time in different textured salt-affected soils. J. Environ. Agric. 1: 140-145.

Jackson, M.L. 1967. Soil Chemical Analysis. Prentice Hall of India, New Delhi, p. 205.

Jones, D. L. 1998. Organic acids in the rhizosphere – a critical review. Plant Soil. 205: 25-44.

Khalil, S., M. Sharif Zia and I.A. Mahmood. 2002. Biophos influence on p availability from rockphosphate applied to rice (*Oryza sativa* L.) with various amendments. Int. J. Agric. Biol. 4: 272-274.

Kiss, S., G. Stefanic and M. Dragan-Bularda. 1975. Soil enzymology in Romania (part II). Contributii Botanice Cluj, p.197-207.

Lambers, H. and W.C. Plaxton. 2018. Phosphorus: Back to the Roots. Annual. Plant Reviews 48: Phosphorus Metabolism in Plants. P: 3-22.

Laskar, B.K., N.C. Debnath and R.K. Basak. 1990. Phosphorus availability and transformation from Massoorie RP in acid soils. Environ. Ecol. 8: 612-616.

Mafongoya, P.L., P. Barak, and J.D. Reed. 2000. Carbon, nitrogen and phosphorus mineralization of tree leaves and manure. Biol. Fert. Soils. 30: 298–305.

Mahimairaja, S., N.S. Bolan and M.J. Hedley. 1995. Agronomic effectiveness of poultry manure composts. Commun. Soil Sci. Plant Anal. 26: 1843-1861.

Mamathashree, C.M., G.K. Girijesh, B.S. Vinutha. 2018. Phosphorus dynamics in different soils. J. Pharmacognosy Phytochem. 7: 981-985.

Marschner, H. 1995. Mineral nutrition of higher plants. Academic Press London. 889.

Mbakaya, D.S., J.O. Odenya, C. Njeru and J. Luteya, 2006. Effects of Liming, Organic and inorganic fertilizers on yield of maize in Western Kenya. Proceeding of the 8th KARI Scientific Conference, Nairobi, 12-17 November 2006: 123-129.

Memon, K.S., and A. Rashid. 2001. Soil and fertilizer phosphorus. Book Soil Science: 291–316.

Mengel, K. and E.A. Kirkby. 2001. Principles of Plant Nutrition, 5th edition. Kluwer Academic Publishers, London. 847.

Mishra, A.A. and K.C. Bangar. 1986. Phosphate rock compositing: transformation of phosphorus forms and mechanism of stabilization, Biol. Agric. p. 331-340.

Moore, P.A. and D.M. Miller. 1994. Decreasing phosphorus solubility in poultry manure litter with aluminium, calcium and iron amendments. J. Environ. Qual. 23: 325-330.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L. A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Government Printing Office Washington DC. USDA Circular. 939: 1–19.

Rabindra B. and H. Gowda. 1986. Long range effect of fertilizers, lime and manure on soil fertility and sugarcane yield on red sandy loam soil (Udic Haplustalf). J. Indian Soc. Soil Sci. 34: 200-202.

Rashid M., S. Khalil, N. Ayub, S. Alam and F. Latif. 2004. Organic acids production and phosphate solubilization by phosphate solubilizing microorganisms (PSM) under in vitro condition. Pak. J. Biol. Sci. 7: 187-196.

Rasmussen, P.E. and H.P. Collins. 1991. Long-term impacts of tillage, fertilizer, and crop residue on soil organic matter in temperate semiarid regions. Adv. Agron. 45: 93-134.

Sah, R.N. and D.S. Mikkelsen. 1986. Transformation of inorganic P during the flooding and drainage cycles. Soil Sci. Soc. Am. J. 50: 62-67.

Sasse, J., E. Martinoia and T. Northen. 2018. Feed Your Friends: Do Plant Exudates Shape the Root Microbiome? Trends Plant Sci. 23: 25-41.

Schofield, R.K. and A.W. Taylor. 1955. The measurement of soil pH. Soil Sci. Soc. Am. Proc. 19: 164–167.

Sharma, U.C. and A.K. Tripathi, 1999. Phosphate management in rice mustard cropping sequence on acid soil of Negaland, J. Ind. Soc. Soil Sci. 47: 732-738.

Singh, A. and G.S. Bahl. 1993. Phosphate equilibria in soils in relation to added P, Sesbania aculeata incorporation and cropping-A study of solubility relationships. J. Ind. Soc. Soil Sci. 41: 233-237.

Singh, C.P. and A.A. Amberger. 1991. Solubilization and availability of phosphorus during decomposition of rock phosphate enriched straw and urine. Biol. Agric. Horti. 7: 261-269.

Six, J., R.T. Conant, E.A. Paul and K. Paustian. 2002. Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. Plant Soil. 241: 155-176.

Soil Salinity Lab Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Hand book 60, Washington, DC, USA.

Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. Principles and procedures of statistics. 172-177. A biometrical approach. (3rd ed.), McGraw Hill book Co., Inc. New york, NY, USA.

Tammimi, Y.N., Y. Kanehiro and G.D. Sherman, 1968. Effect of time and concentration on the reaction of ammonium phosphate with humic latosol. Soil Sci. 105: 434-439.

Tisdale, S.L., W.L. Nelson and J.D. Beaton, 1985. Soil and fertilizer phosphorus, In: Soil Fertility and Fertilizers. Macmillan Publishing Co; NY. p: 189-240.

Tomayo, V.A., A.R. Munoz and A.C. Diaz. 1997. Organic fertilizer application to maize (*Zea mays* L.) on alluvial soil in a moderate climate. Actualidades Corpoica. 108: 19-24.

Toor, G.S. and G.S. Bahl. 1997. Effect of solitary and integrated use of poultry manure and fertilizer phosphorus on the dynamics of P availability in different soils. Bioresour. Technol. 62: 25-28.

Walkley, A. and I.A. Black. 1934. An examination of degtjarefe method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37: 28–35.

Walker, D.J., R. Clemente and M.P. Bernal, 2004. Contrasting effects of manure and compost on soil pH, heavy metal availability and growth of *Chenopodium album* L. in a soil contaminated by pyritic mine waste. Chemosphere. 57: 215–224.

Wang, Y. and H. Lambers. 2019. Root-released organic anions in response to low phosphorus availability: recent progress, challenges and future perspectives. Plant Soil. Doi: 10.1007/s11104-019-03972-8.

Jiang, S., H. Hua, H. Sheng, H.P. Jarvie, X. Liu, Y. Zhang, Z. Yuan and L. Zhang. 2019. Phosphorus footprint in China over the 1961-2050 period: Historical perspective and future prospect. Sci Total Environ. 650(Pt 1): 687-695.

Zhang, J., J. Balkovic, L.B. Azevedo, R. Skalsky, A.F. Bouwman, G. Xu, J. Wang, M. Xu and C. Yu. 2018. Analyzing and modelling the effect of long-term fertilizer management on crop yield and soil organic carbon in China. Sci. Total Environ. 627: 361-372.

Ringeval, B., L. Augusto, H. Monod, D. van Apeldoorn, L. Bouwman, X. Yang, D.L. Achat, L.P. Chini, K. Van Oost, B. Guenet, R. Wang, B. Decharme, T. Nesme and S. Pellerin. 2017. Phosphorus in agricultural soils: drivers of its distribution at the global scale. Glob. Chang Biol. 23(8): 3418-3432.