Pak. J. Bot., 50(1): 117-122, 2018.

DEPICTING THE ROLE OF ORGANIC AMENDMENTS FOR BIO AVAILABLE PHOSPHORUS RELEASE FROM DIFFERENT SOURCES OF ROCK PHOSPHATE AND UPTAKE BY MAIZE CROP

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Abstract

A pot study was conducted in the laboratory to evaluate the effect of organic amendments on phosphorus release from imported and indigenous sources of rock phosphate and its impact on growth of maize. Seeds were sown in sand and soil (pH_s pre study = 8.15, pH_s post study = 8.02, EC_e = 1.28 dSm^{-1}, SAR = 4.77 (mmol $L^{-1})^{1/2}$, saturation percentage = 29%, Available P = 7.1 mg kg^{-1}, sandy clay loam texture) culture of 1:1 ratio. In this controlled conditions laboratory experiment, two sources of RP; A;. Alwaha rock phosphate (RPB-rock phosphate brown) and B- Hazara rock phosphate (RPB-rock phosphate brown) with 9 different combinations of organic amendments in a ratio of 1:2 were tested. The experiment comprised of 19 treatment replicated thrice using CRD design: T_1: control(check P), T_2:RPB, T_3: RPB+CM, T_4: RPB+FCP, T_5: RPB+ WS, T_6: RPB+FYM, T_7: RPB+PM, T_8: RPB+PSM, T_9: RPB+CP+PGPR, T_{10}: RPB+ ½ PM+ ½ FCP, T_{11}: RPR, T_{12}: RPR+CM, T_{13}: RPR+FCP, T_{14}: RPR+WS, T_{15}: RPR+FYM, T_{16}: RPR+ PM, T_{17}: RPR+PSM, T_{18}: RPR+CP+PGPR, and T_{19}: RPB+ ½ PM+ ½ FCP. The collected data was subjected to statistical analysis using R-software for windows and least significant difference among the treatments means. Results suggested that use of filter cake press mud (FCP) proved superior in terms of enhancing P release from RP and subsequent uptake by maize crop.

Key words: Rock phosphate, Filter cake press mud, Maize and Organic amendments.

Introduction

Phosphorus is one of the major essential plant nutrients that are required by every living entity. It performs variety of beneficial functions in living organisms including plants. Phosphorus is considered indispensible for agricultural crop production. Since addition of phosphorus is compulsory for crop production as every plant require an optimum supply of P for achieving sustainable growth and yield. Deficiency of phosphorus results in negative trend in plant growth and crop yield (Taiz & Zeigar, 1998; Childers *et al*., 2011).

Plants uptake phosphorus in two major forms i.e., primary and secondary orthophosphates. Despite of its critical roles in plant body, the availability of phosphorus to plants is highly limited (Holford, 1997).The high growth rate and production of large amount of organic content by maize necessitates the use of high amount of phosphorus (Mengel & Kirkby, 2001).

Rock phosphate is one of the cheapest sources of phosphorus but despite of its low cost its low solubility of 10 % offers limitation in its direct application to soil. Thus, bio-solubilization of rock phosphate needs to be increased by using some organic amendments such as farm yard manure, poultry droppings, compost, press mud and green manure etc. (Isherwood, 2000, Sarwar *et al.*, 2009, Saleem *et al*., 2013, Sabah *et al*., 2016). One such mean could be the use of organic materials for rendering insoluble phosphorus in to soluble one mostly the phosphorus contained in rock phosphate ores. In addition to enhancing soil phosphorus content, compost also serve as soil conditioner by improving physical, chemical, biological properties as well as fertility status of soil (Ahmad *et al*., 2006, Sabah *et al*., 2011, Sabah *et al*., 2014).

Rock phosphate is considered to be the major naturally occurring source of phosphorus. Resources of rock phosphate are limited and non-renewable that demands some important measures are needed to be adopted in order to maximize P recovery from rock phosphate. Rock phosphate is considered to be the cheapest source of phosphorus and is a major precursor for almost all phosphatic fertilizers. It is also used as a raw material for livestock feeds. However, agriculture seems to be the major consumer of rock phosphate since it accounts for almost 80-90 % of world total rock phosphate demand (Childers *et al*., 2011).

The term organic manures includes variety of materials like FYM, poultry litter, green manure, crop residues, composts and other animal wastes etc. Organic wastes are enriched source of nutrients. However, the nutritional value of organic waste is highly variable depending upon the source. Bioavailability of phosphorus from rock phosphate can be improved by various means. One such method is the use of organic wastes. Phospho-compost is the name of end product obtained after composting of rock phosphate with organic manures. There are many factors which determine the effectiveness of compost in solubilization of rock phosphate and subsequent release of phosphorus. These factors include the kind and composition of organic waste materials as well as its rate of decomposition. The major mechanism responsible for the solubilization of rock phosphate is the production and release of organic acids and chelating compounds from metabolic activities of various microorganisms during composting. Composting of rock phosphate with poultry manure is not suitable because of the containment of large quantity of impurities and calcium carbonate which offer obstruction in solubilization of rock phosphate (Mahimairaja *et al*., 1995).

It has been reported that incorporation of microorganisms (fungi and bacteria) and energy sources like molasses to the organic wastes material before composting can fasten the rate of decomposition of organic waste (Singh & Amberger, 1991). Composting of rock phosphate with organic manures offers dual benefits. On one hand, it increases the phosphorus release from rock phosphate while on the other hand; it also results in environmental friendly and safe dumping of organic wastes. In addition, phospho-compost can be safely used as an alternative to the expensive chemical fertilizers (Mugwira *et al*., 2002). Keeping in view the above circumstances, the present study was performed in order to investigate the role of organic amendments on the growth of hybrid maize crop and to evaluate P availability from local and imported rock phosphate as well as to check the interaction of organic amendments for bio-solubilization of P from unavailable P sources.

Materials and Methods

Experiment location and treatments: This experiment was performed in the climate growth chamber under specific temperature and humidity conditions in the laboratory of department of Soil & Environmental Sciences, University College of Agriculture, University of Sargodha. The plastic pots with capacity of 250 g were taken and a mixture of soil and sand in the ratio of 1:1were made. This mixture (200 g), containing 100 g soil and 100g sand, were filled in each pot. Two types of rock phosphates namely Rock phosphate Red (Local) from Hazara, KPK, Pakistan (containing 28% P_2O_5, 48% CaO and 3% SiO_2) and Rock phosphate Brown (Imported) containing 32.5% P_2O_5, 49.2% CaO and 4% SiO_2 were used. Various organic materials include compost, pressmud, wheat straw, FYM, poultry manure, P-solubilizing microorganisms, and plant growth promoting rhizobacteria. The rock phosphate and organic materials were incorporated in each pot in a ratio of 1:2. The experiment was consisted of 19 treatments replicated thrice. All the treatments were applied according to the treatment plan in respective pots using CRD. Various treatments of the study include: T_1 = Recommended NPK; T_2 = Rock phosphate brown (RPB); T3 = RPB + compost; T_4 = RPB + press mud; T_5 = RPB + wheat straw; T_6 = RPB + FYM; T_7 = RPB + poultry manure; T_8 = RPB + P-solubilizing microorganisms; T_9 = RPB + compost + PGPR; T10 = RPB + half poultry manure + half press mud; T_{11} = Rock phosphate Red (RPR); T_{12} = RPR + compost; T_{13} = RPR + press mud; T_{14} = RPR + wheat straw; T_{15} = RPR + FYM; T16 = RPB + poultry manure; T_{17} = RPR + P-solubilizing microorganisms; T_{18}= RPR + compost + PGPR; T_{19} = RPR + half poultry manure + half press mud.

Plant growth: After attaining the field capacity, three seeds of hybrid maize were sown on September 10, 2015 in each pot. After germination, thinning of plants was performed. Canal water was used for irrigation purpose. After harvesting the crop on November 09, 2015; various agronomic parameters were noted. P concentration in leaf, available P content of soil was recorded after sample preparation.

Sample preparation: Plants samples were dried in oven at 70°C till constant weight. Grinding of dried plant samples was done by using grinding mill having 2mm sieve. In a conical flask 1 g of dried plant sample was taken. Digestion mixture 10 ml (Per-chloric acid and Nitric acid @ 1:2) was used for digestion of sample. This mixture was then left for overnight. Next day the mixture was then digested at hot plate till colorless solution. The color developing reagent solution was used for estimation of P concentration in leaf and from soil sample by using spectrophotometer (Shimadzu, UV-1201, Kyoto, Japan) at 880 nm wavelength (Olsen *et al*., 1954).

Statistical analysis: Analysis of variance (ANOVA) was done by using CRD (completely randomized design). Least significant difference (LSD) test at $p \leq 0.05$ was used for ranking of treatments (Steel *et al*., 1997) using R-software for windows.

Results and Discussion

Shoot dry weight (g plant^{-1}): Data pertaining to the efficiency of various types of organic amendments and rock phosphate (rock phosphate red and rock phosphate brown) and their combinations on shoot dry weight (g plant^{-1}) of maize was presented in Fig. 1. It was depicted from the data that application of various treatments significantly increased the shoot dry weight of maize. Differences among various treatments for shoot dry weight were found significant in terms of statistics. Data revealed that maximum shoot dry weight was recorded in T_{13} (RPR + press mud) showing the value of 3.85 g plant^{-1} followed by T_{12} (RPR + compost) with the value of 3.8 g plant^{-1}. Whereas, minimum shoot fresh weight was recorded in control i.e. T_1 (2.39 g plant^{-1}) where no imported source of P was applied. It was evident from results that all the organic amendments significantly improved the shoot dry weight of maize. But integrated use of local rock phosphate (RPR) and press mud proved better than all other treatments. Though, the use of press mud with either source of rock phosphate (red rock phosphate and brown rock phosphate) gave improved results than any other organic amendment.

Root dry weight (g plant^{-1}): Root dry weight is good indicator of plant growth since plant contained high amount of water depending upon the amount of water in its growth environment. Therefore, root dry weight tends to be more reliable. Comparative efficiency of various treatments on root dry weight of maize was presented in Fig. 2. It was indicated from the data that differences among various treatments were statistically significant. Maximum root dry weight was recorded in T_1 (check P) with the numerical value of 0.36 g plant^{-1}. Whereas, minimum root dry weight was observed in T_{13} (RPR + press mud) and T_{16} (RPR + poultry manure) each with the value of 0.2 g plant^{-1}.

Root: shoot ratio: Roots are responsible for the uptake of water and nutrients by the plant. Therefore, healthy roots are good indicator of plant health. Data pertaining to the efficiency of various types of organic amendments and rock phosphate (Red rock phosphate and Brown rock phosphate) and their combinations on root: shoot ratio of maize was presented in Fig. 3. It was depicted from the data that application of various treatments significantly increased the root: shoot ratio of maize. Differences among various treatments for root: shoot ratio was found significant in terms of statistics. Data revealed that minimum root: shoot ratio was recorded in T_{13} (RPR + press mud) showing the value of 0.05. That was increased to the maximum value of 0.15 in control i.e. T_1 (check P).

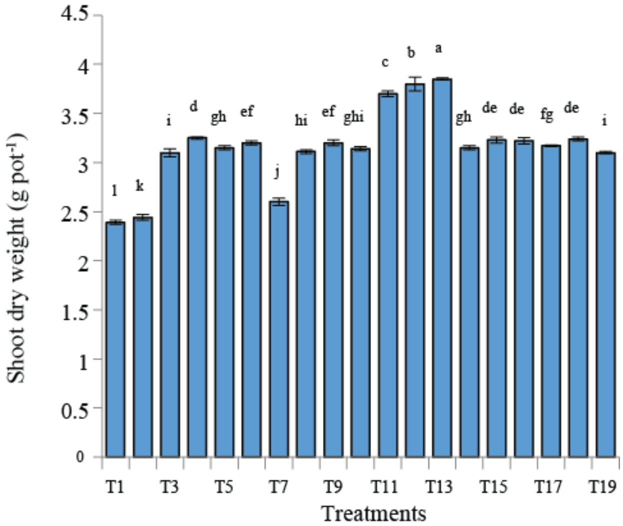

Fig. 1. Role of organic amendments for P release from different sources of RP and shoot dry weight (g plant^{-1}) of maize.

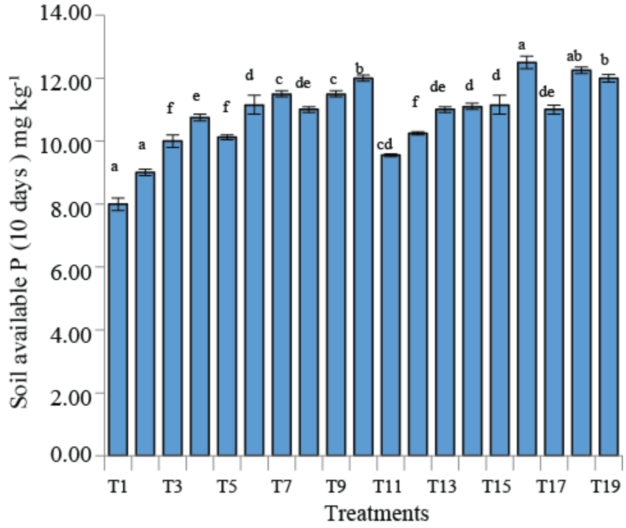

Fig. 4. Role of organic amendments for P release from different sources of RP and soil available P after 10 days (mg kg-1).

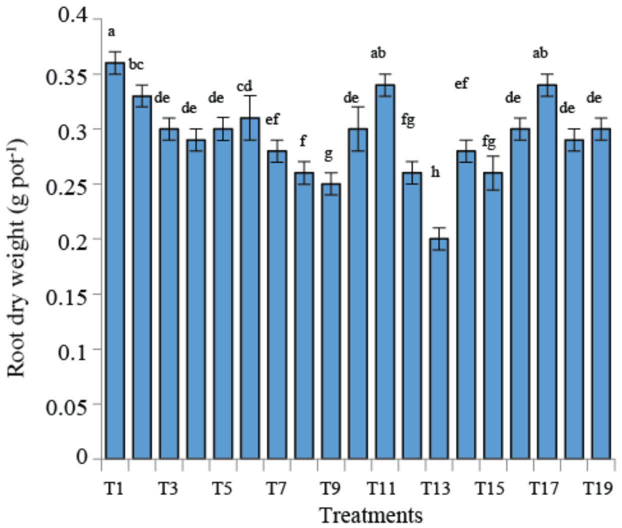

Fig. 2. Role of organic amendments for P release from different sources of RP and root dry weight (g plant-1) of maize.

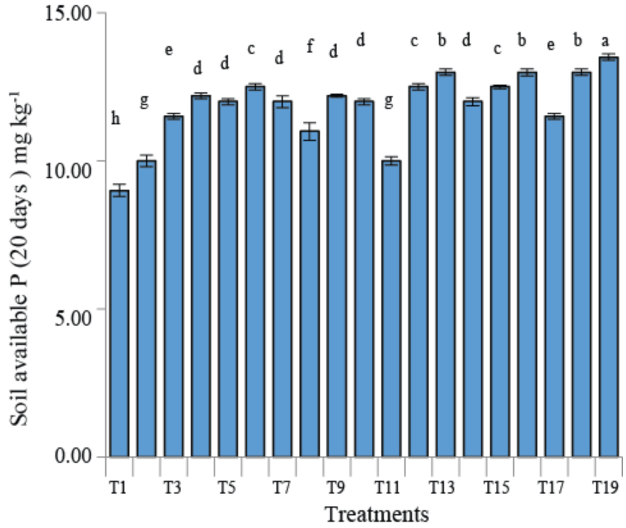

Fig. 5. Role of organic amendments for P release from different sources of RP and soil available P after 20 days (mg kg-1).

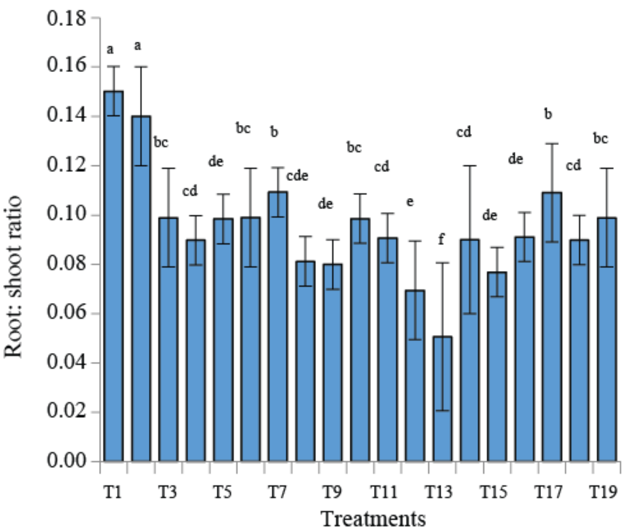

Fig. 3. Role of organic amendments for P release from different sources of RP and root: shoot ratio of maize.

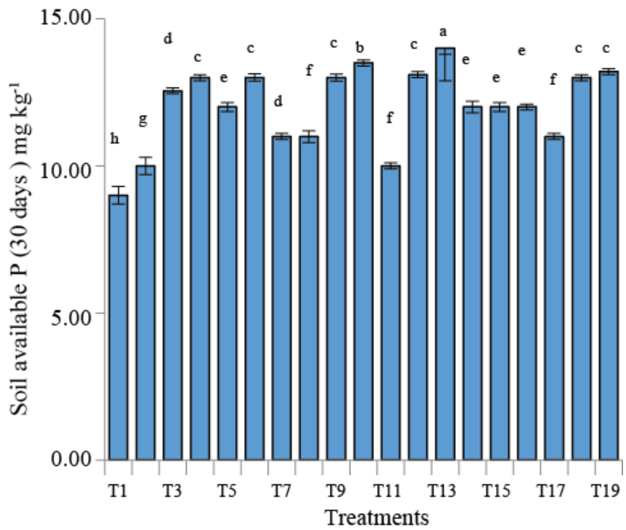

Fig. 6. Role of organic amendments for P release from different sources of RP and soil available P after 30 days (mg kg-1).

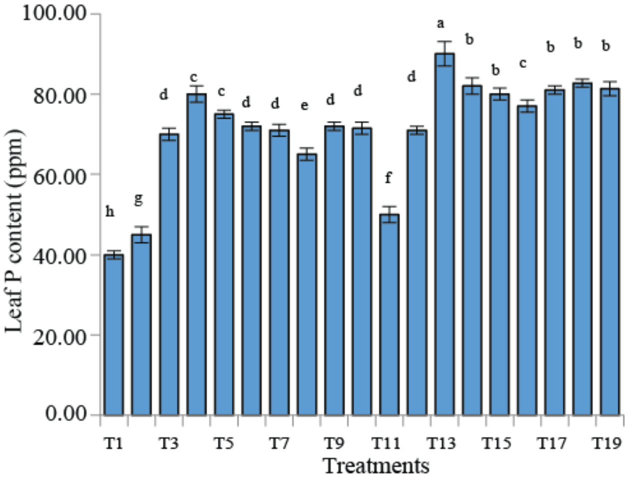

Fig. 7. Role of organic amendments for P release from different sources of RP and leaf P content (mmol kg^{-1}).

Available P after 10 days (mg kg^{-1}): Data pertaining to the efficiency of various types of organic amendments and rock phosphate (Red rock phosphate and Brown rock phosphate) and their combinations on available P content (10 days) of soil was presented in Fig. 4. It was depicted from the data that application of various treatments significantly increased the available P (10 days) content of soil. Differences among various treatments for soil available P content were found significant in terms of statistics. Data revealed that minimum soil available P content was recorded in control i.e. T_1 (check P) showing the value of 8 mg kg^{-1}.That was increased to the maximum value of 12.5 mg kg^{-1} in T_{16} (RPR + poultry manure). It was evident from results that all the organic amendments substantially improved the P release from rock phosphate. However, use of local rock phosphate (RPR) in combination with press mud proved superior to all other treatments. Since, the use of press mud with either source of rock phosphate (red rock phosphate and brown rock phosphate) gave improved results than any other organic amendment in this context.

Available P after 20 days (mg kg^{-1}): Data presented in Fig. 5 indicated the efficiency of various types of organic amendments and rock phosphate (Red rock phosphate and Brown rock phosphate) and their combinations on soil available P content (20 days). It is evident from the data that application of various treatments significantly increased the soil available P content (20 days). Data revealed that maximum soil available P (20 days) was recorded in T_{19} (RPR + half poultry manure + half press mud) showing the value of 13.5mg kg^{-1} followed by T_{13} (RPR + press mud), T_{16} (RPR + poultry manure) and T_{18} (RPR + compost + PGPR) each with the value of 13mg kg^{-1}. Whereas, minimum soil available P was recorded in control i.e.T_1 (9mg kg^{-1}) where no imported source of P was applied. It was found that all the organic amendments performed well in terms of releasing P from rock phosphate. However, incorporation of local rock phosphate (RPR) with press mud proved superior to all other treatments.

Available P after 30 days (mg kg^{-1}): Data pertaining to the efficiency of various types of organic amendments and rock phosphate (Red rock phosphate and Brown rock phosphate) and their combinations on available P content (30 days) of soil was presented in Fig. 6. It was depicted from the data that application of various treatments significantly increased the available P (30 days) content of soil. Differences among various treatments for soil available P content were found significant in terms of statistics. Data revealed that minimum soil available P content was recorded in control i.e. T_1 (check P) showing the value of 9 mg kg^{-1}.That was increased to the maximum value of 13.5 mg kg^{-1} in T_{10} (RPR + half poultry manure + half press mud). It was evident from results that all the organic amendments significantly enhanced the release of P from rock phosphate. Since, application of local red rock phosphate (RPR) along with press mud proved superior to all other treatments.

Leaf P content (mmol kg^{-1}): Data pertaining to effect of various types of organic amendments and rock phosphate (Red rock phosphate and Brown rock phosphate) and their combinations on leaf P content (mmol kg^{-1}) was presented in Fig. 7. It was depicted from the data that application of various treatments significantly increased the leaf P (mmol kg^{-1}) content. Differences among various treatments for P content of leaf (mmol kg^{-1}) were found significant in terms of statistics. Data revealed that minimum leaf P content was recorded in control i.e. T_1 (check P) showing the value of 40 mmol kg^{-1}.This value reached to the maximum level of 90 mmol kg^{-1} in T_{13} (RPR + press mud) followed by T_{18} (RPR + compost + PGPR) with numerical value of 82.7 mmol kg^{-1}. Data indicated that all the organic amendments played their role effectively in terms of releasing P from rock phosphate and subsequent uptake by maize however, application of local rock phosphate (RPR) along with press mud proved superior to all other treatments. Although, the use of press mud with either source of rock phosphate (red rock phosphate and brown rock phosphate) gave better results than any other organic amendment.

Discussion

Rock phosphate is the basic formulating material for all water soluble phosphatic fertilizers. Universal phosphate resources are predicted to be depleted within 50-80 years in an era when more P fertilizers will be needed to produce more food and fiber to sustain a growing global population. An efficient method for the release of plant available P from apatite rock phosphate is the integration of different organic materials with specific size of rock phosphate to provide the P nutrition for growth of field crops Mali *et al*. (2017).

The major mechanism responsible for the solubilization of rock phosphate is the production and release of organic acids and chelating compounds from metabolic activities of various microorganisms during composting. Composting of rock phosphate with poultry manure is not suitable because of the presence of large quantity of impurities and calcium carbonate which offer obstruction in solubilization of rock phosphate (Mahimairaja *et al*., 1995).

Press mud like other organic nutritional sources improves the impaired soil (physical, chemical and biological) properties (Qureshi *et al*., 2014). Such improvement ultimately increased the nutrient availability to the plants. Improvement in shoot fresh weight by the addition of organic manures is contributed to improved soil properties and availability of N, P and K. Each increase in NPK contributed to increase in plant height and growth parameters. Addition of organic material like press mud under alkaline soil conditions resulted in release of various types of acids like carbonic acid which is responsible for dissolution of rock phosphate (Mahimairaja *et al*., 1995). These results are also in line with the findings of Aziz *et al*. (2006); Mujeeb *et al*. (2008); Aziz *et al*. (2010) and Qureshi *et al*. (2014).

The use of organic amendments proved a successful way for the release of available P from water insoluble P sources like rock phosphate. Different organic amendments are considered as more bio active source. In addition to enhance P release from RP, organic amendments also improve soil organic matter status (Aziz *et al*., 2010; Sabah *et al*., 2014; Sabah *et al*., 2015; Sabah *et al*., 2016; Mali *et al*., 2017). Integrated use of organic material along with rock phosphate resulted in significant impact on soil pH of growth medium. The most pronounced impact on change in pH was observed in treatment where red rock phosphate was used along with filter cake press mud. The results are in conformity with the finding of Ali *et al*. (2014) who reported that any change in pH of growth medium release water soluble P from insoluble P sources.

Results of the present study indicated that organic amendments significantly affected the P release from both rock phosphate sources. The response of both rock phosphates to different organic sources was almost similar. However, press mud proved superior in terms of enhancing P dissolution of rock phosphate and subsequent release and uptake of P by maize crop. Use of press mud with either source of rock phosphate improved shoot dry weight, available P content and leaf P content. Several adaptive mechanisms (such as change in root morphology, physiology and biochemistry) developed by plants in response to low availability of phosphorus have been reported by various researchers. Such mechanisms are responsible for modification in the rhizosphere and thus, increase the ability of roots systems to exploit more soil volumes for inorganic P (Vance *et al*., 2003; Lynch & Brown, 2008; Hinsinger *et al*., 2009; Zhang *et al*., 2010; George *et al*., 2011). One such response is the allocation of more proportion of photosynthates to the roots, changes in root morphology etc. in order to utilize more soil volumes (Smith *et al*., 1990, Marschner, 1995; Hinsinger, 2001; Hermans *et al*., 2006; Peret *et al*., 2011). Increase in root and shoot dry weights and root-shoot ratio could be due to these reasons.

Conclusion

Based on results of present study it can be concluded that organic amendments significantly improved the rate of P dissolution and subsequent release bio available P for maize crop. Use of locally available hazara rock phosphate is best comparable with that of imported egyptian rock phosphates in terms of P dissolution. Press mud as organic amendment proved superior to all other organic materials in terms of enhancing P release from either source of rock phosphate and subsequent uptake by maize.

Acknowledgement

The research work reported in this manuscript is part of (Noor-us-Sabah) Ph.D. thesis. We are very grateful to Higher Education Commission, Islamabad for funding the dissertation research (Pin No.112-25009-2AV1-281).

References

Ahmad, R., A. Khalid, M. Arshad, Z.A. Zahir and M. Naveed. 2006. Effect of raw (un-composted) and composted organic waste material on growth and yield of maize (*Zea mays* L.). *Soil Environ*., 25: 135-142.

Ali, A., M. Sharif, F. Wahid, Z. Q. Zhang, S. N. M. Shah, Rafiullah, S. Zaheer, F. Khan and F. Rehman. 2014. Effect of Composted Rock Phosphate with Organic Materials on Yield and Phosphorus Uptake of Berseem and Maize. *Am. J. Plant Sci*., 5: 975-984.

Aziz, T., Rahmatullah, M.A. Maqsood, M.A. Tahir, I. Ahmad and M.A. Cheema. 2006. Phosphorus utilization by six Brassica cultivars (*Brassica juncea* L.) from tri-calcium phosphate; a relatively insoluble P compound. *Pak. J. Bot*., 38(5): 1529-1538.

Aziz, T., S. Ullah, A. Sattar, M. Nasim, M. Farooq and M.M. Khan. 2010. Nutrient availability and maize (*Zea mays* L.) growth in soil amended with organic manures. *Int. J. Agric. Biol*., 12: 621-624.

Childers, D. L., J. Corman, M. Edwards and J.J. Elser. 2011. Sustainability challenges of phosphorus and food: Solutions from closing the human phosphorus cycle. *Biosciences*, 61: 117-124.

George, T.S., A.M. Fransson, J.P. Hammond and P.J. White. 2011. Phosphorus nutrition: rhizosphere processes, plant response and adaptation. In: (Eds.): Bunemann, E., A. Oberson & E. Frossard. Phosphorus in action: Soil biology. *Springer*, 100(2): 245-271.

Hammond, L.L. and D.P. Day. 1992. Phosphate rock standardization and product quality. In: (Eds.): Bachik, A.T. & A. Bidin. *Proceedings of a workshop on phosphate sources for acid soils in the humid tropics of Asia*, pp. 73-89. Kuala Lumpur, Malaysian Society of Soil Science.

Hermans, C., J.P. Hammond, P.J. White and N. Verbruggen. 2006. How do plant response to nutrient storage by biomass allocation? *Trends in Plant Sci.*, 11: 610-617.

Hinsinger, P. 2001. Bio-availability of soil inorganic P in the rhizosphere as affected by root induced chemical changes: a review. *Plant Soil*, 237: 173-95.

Hinsinger, P., A.G. Bengough, D. Vetterlein and I.M. Young. 2009. Rhizosphere: biophysics, biogeochemistry, and ecological relevance. *Plant & Soil*, 321: 117-152.

Holford, I.C.R .1997. Soil phosphorus: its measurement and its uptake. *Aust. J. Soil Res*., 35: 227-239.

Isherwood, K.F. 2000. *Mineral fertilizer use and the environment*. International Fertilizer Industry Association, United Nations Environment Programme, Paris.

Lynch, J.P. and K.M. Brown. 2008. Root strategies for phosphorus acquisition. In: (Eds.): Hammond, J.P. & P.T. White. The ecophysiology of plant-phosphorus interactions. *Springer*, pp: 83-116.

Mahimairaja, S., N.S. Bolan and M.J. Hedley. 1995. Dissolution of phosphate rock during the composting of poultry manure: An incubation experiment. *Fertilizer Res.,* 40: 93-104.

Mali, M.K., R.H. Meena and G. Jat. 2017. Effect of composted rock phosphate with organic materials on yield, nutrient uptake and soil fertility after harvest of maize (*Zea mays* L.). *Intl. J.Current Microbiol. & Appl. Sci*., 6(6): 901-909.

Marschner, H. 1995. *Mineral Nutrition of Higher Plants*. Academic Press International, San Diego, CA, USA.

Mengel, K. and E.A. Kirkby. 2001. *Principles of Plant Nutrition*. (5th Ed) Kluwer Academic Publishers, London.

Mugwira, L., J. Nyamangara and D. Hikwa. 2002. Effects of manure and fertilizer on maize at a research station and in a smallholder (peasant) area of Zimbabwe. *Plant Soil*, 33: 379-402.

Mujeeb, F., Rahmatullah, A. Hannan and M.A. Maqsood. 2008. Response of maize to di-ammonium phosphate and farmyard manure application on three different soils. *Pak. J. Agric. Sci*., 45: 13-18.

Olsen, S.R., C.V. Cole, F. Watanabe and L.A. Dean. 1954. *Estimation of available phosphorus in soils*. US Dept. Agri. Circular No. 939.

Peret, B., M. Clemet, L. Nussaume and T. Desons. 2011. Root developmental adaptation to phosphate starvation: Better safe than sorry. *Trends in Plant Sci.*, 16: 442-450.

Qureshi, S.A., A. Rajput, M. Memon and M.A. Solangi. 2014. Nutrient composition of rock phosphate enriched compost from various organic wastes. *E3 J. Sci. Res.*, 2(3): 47-51.

Sabah, N.U., G. Sarwar, M. Ibrahim, M.A. Tahir, Y. Iftikhar, M.S. Haider, K.H. Han, S.K. Ha and Y.S. Zhang. 2011. Efficiency of various nutritional sources to improve physical properties of saline-sodic soil. *Korean J. Soil Sci. Fert*., 45(1): 93-97.

Sabah, N.U., G. Sarwar and M.A. Tahir. 2014. Role of various nutritional sources for improving the yield of wheat under saline-sodic soil environment. *Pak. J. Agri. Sci.*, 51(4): 963-967.

Sabah, N.U., G. Sarwar and M.A. Tahir. 2015. Comparative evaluation of phosphorous release between local red rock phosphate enriched with organic material and triple super phosphate on maize growth. *Int. J. Agric. Appl. Sci.,* 7(1): 96-99.

Sabah, N.U., G. Sarwar, M.A. Tahir and S. Muhammad. 2016. Comparative efficiency of high (triple super phosphate) and low (rock phosphate) grade p nutrition source enriched with organic amendment in maize crop. *Pak. J. Bot.,* 48(6): 2243-2248.

Saleem, M. M., M Arshad and M. Yaseen. 2013. Effectiveness of various approaches to use rock phosphate as a potential source of plant available P for sustainable wheat production. *Intl. J. Agri. & Bio*., 15(2): 223-230.

Sarwar, G., H. Schmeisky, N. Hussain S. Muhammad, M.A. Tahir and U. Saleem. 2009. Variations in nutrient concentrations of wheat and paddy as affected by different levels of compost and chemical fertilizer in normal soil. *Pak. J. Bot*., 41(5): 2403-2410.

Singh C.P. and A.A. Amberger. 1991. Solubilization and availability of phosphorus during decomposition of phosphate rock enriched Straw and Urine. *Biol. Agri. Hort.*., 7: 261 - 269.

Smith, F.W, W.A. Jackson and P.J. Van den Berg. 1990. Internal phosphorus flows during development of phosphorus stress in *Stylosanthes hamata*. *Aus. J. Plant Physiol*., 17: 451-64.

Steel, R.G.D., J.H. Torrie and D.A. Dichey. 1997. Principles and procedures of statistics: A biometrical approach. 3rd Edition. McGraw Hill co., Inc., New York, USA.

Taiz, L. and E. Zeiger. 1998. Plant Physiology. Second edition. Sinauer Associates, Inc. Publishers. Massachusetts. USA. pp. 792.

Vance, C.P., C. Uhde-Stone and D.L. Allan. 2003. Phosphorus acquisition and use: critical adaptations by plants for securing a non renewable resource. *New phytologist*, 157: 423-427.

Zhang, F. S., J. P. Shen, J.L. Zhang, Y.M. Zuo, L. Li and X.P. Chen. 2010. Rhizosphere processes and management for improving nutrient use efficiency and crop productivity: Implication for China. *Adv. Agron.*, 107: 1-32.

(Received for publication 11 January 2017)