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COMPARATIVE EFFICIENCY OF HIGH (TRIPLE SUPER PHOSPHATE) AND LOW (ROCK PHOSPHATE) GRADE P NUTRITION SOURCE ENRICHED WITH ORGANIC AMENDMENT IN MAIZE CROP

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Abstract

Pakistan falls under arid to semi-arid climate and therefore, Pakistani soils are sufferer of phosphorus deficiency. Costly phosphatic commercial fertilizers and their unavailability at the time of crop demand is the burning issue in Pakistan. Under such circumstances, use of locally available rock phosphate (RP) grasps the interest of researchers now a day. Pakistan has blessed with considerable quantity of cheaper low grade RP in Abbottabad and Hazara districts of KPK province. Due to this scenario, a pot experiment was carried out to evaluate growth efficiency of maize crop by adding organic manure fortified with RP in comparison with TSP in normal soil (pH_s= 8.15, EC_e= 1.28 dSm^{-1}, SAR = 4.77 mmol L^{-1}, saturation percentage = 29% and sandy clay loam texture). The study was comprised of 7 treatments replicated three times including: T1 = Control (0 P); T2 = Recommended NK + organic material; T3 = Recommended NK + RRP; T4 = Recommended NK + RRP + OM; T5 = Recommended NK + TSP; T6 = Recommended NK + TSP + OM and T7 = N + K + TSP + ½ Organic manure. It was concluded that integrated use of organic amendment with RP (Local Hazara Red Rock Phosphate) and TSP proved superior as compared to their sole use on maize crop growth. A significant increase in available P concentration of the growth medium was observed due to addition of organic material along with TSP as a source of P. Addition of organic material also enhanced the soil carbon level as compared to control. It can be concluded that rock phosphate (RP) could be an effective and economic substitution for TSP when it is integrated with suitable organic amendment with specific size.

Key words: Rock phosphate, Triple super phosphate, Maize, Organic amendment.

Introduction

World population is rising at an alarming rate while the agricultural yields are stagnant. There is an increased demand of food for such an increasing population which compels to enhance per capita production. Therefore, there is substantial increase in application of mineral fertilizers in last few decades for the purpose of attaining sustainable crop production and food security as well as enhanced cropping intensities (Anon., 2003).

Resultantly, soils are being depleted of various plant essential macronutrients like phosphorus (P) and potassium (K) as well as micronutrients. Mineral fertilization also resulted in depletion of soil organic matter content (Anon., 2003). Heavy prices of chemical fertilizers, shortage at peak crop requirement time and low use efficiencies has further triggered the situation. Under such situations one attractive package is the use of locally available rock phosphate (RP). Pakistan has naturally gifted with various reserves of cost effective low grade RP in KPK province in Abbottabad and Hazara divisions (Ali *et al*., 2014). But, direct use of RP in high pH soils of Pakistan is not desirable. Therefore, a keen interest has been developed in employing various techniques of rendering insoluble P from RP into soluble one (Alam*et al*., 2005).

Several means can be employed for improving solubilization of rock phosphate such as the use of phosphorus solubilizing microorganisms like Pseudomonas bacillus (Canbolat *et al*., 2006). The use of PGPRs can also aid in enhancing solubility of rock phosphate by penetration into deeper volumes of soil, thus, enhancing availability of phosphorus (Dey *et al*., 2004). Similarly, application of organic amendments could also be used for bio-solubilization of rock phosphate. Organic materials significantly improved the crop production by upgrading soil organic matter pool through betterment of impaired important properties of soil (Ahmad *et al*., 2006; Sarwar *et al*., 2008; Sarwar *et al*., 2009; Sabah *et al*., 2011).

Keeping in view all scenario, present study was designed in pot culture in order to compare local rock phosphate fortified with organic amendment for P solubilization from RP and uptake by maize crop in contrast to mineral fertilizer i.e. triple super phosphate (TSP).

Materials and Methods

Experiment location and treatments: A research experiment was carried out at University College of Agriculture, University of Sargodha, in order to check P bioavailability from local rock phosphate termed as red rock phosphate taken from the region of Hazara, KPK, Pakistan containing 28% P_2O_5, 48% CaO and 3% SiO_2 in comparison with high grade P source (TSP) in maize crops. Upper six inches of normal soil having sandy loam texture, 7.1 mg kg^{-1} available P and 0.62% organic matter was selected from the experimental research area, after primary preparation selected soil were filled in respective pots at the rate of 10 kg pot^{-1}. Pots were arranged using CRD design. Each pot was lined with polyethylene bags to reduce contamination. Recommended dose of N (120 kg ha^{-1}) and K (60 kg ha^{-1}) were applied in the form of urea andK_2SO_4respectively. De-waxed filter cake press mud was used as organic amendment. Following treatments were applied 15 days before sowing; T1 = Control (0 P); T2 = Recommended NK + organic material; T3 = Recommended NK + RRP; T4 = Recommended NK + RRP + OM; T5 = Recommended NK + TSP; T6 = Recommended NK + TSP + OM and T7 = N + K + TSP + ½ Organic manure.

Plant growth: After attaining the field capacity, five seeds of hybrid maize were sown on September 13, 2014 in each pot. After germination, thinning of plants was performed. Canal water was used for irrigation purpose. After harvesting the crop on November 11, 2014; various agronomic parameters were noted. P concentration in leaf, P concentration in root, P concentration and organic carbon fraction of soil was recorded after sample preparation.

Sample preparation: Plants samples were dried in oven at 70^oC 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. 10 ml of digestion mixture (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 to estimate P concentration in shoot and soil sample by using spectrophotometer (Shimadzu, UV-1201, Kyoto, Japan) at 880 nm wavelength (Olsen *et al*., 1954). The organic carbon from soil sample was estimated by L.O.I (loss on ignition) method by using electric muffle furnace (Daihan lab Tech, LEF- 130 S, Seoul, Korea). Leaf area meter was used to determine leaf area of maize plants. Whereas, relative growth rate was calculated as proposed by Beadle (1987) in g $kg^{-1}day^{-1}$.

$$RGR = W_2 - W_1 / T_2 - T_1$$

where W_1 and W_2 are the total dry weights harvested at time interval T_1 and T_2, respectively.

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 length (cm): It was found that application of any source of P resulted in increased shoot length of maize in comparison to control (T_1). Data for shoot length were noted as significant statistically (Fig. 1). Maximum shoot length was recorded in T_6 (N + TSP + K + organic manure) followed by T_5 (N + TSP + K) with numerical values of 90 cm and 86 cm respectively. Whereas, minimum shoot length (55 cm) was observed in control i.e. T_1 (recommended NK) where no P source was applied.

Root length (cm): The data revealed that various treatments played their role in terms of enhancing root length of maize (Fig. 2). Statistical evaluation of data indicated that application of rock phosphate as a source of P along with nitrogen and potash fertilizers (T_3) and T_1 (recommended NK) were proved best treatments in terms of enhancing root length each with numerical value of 34 cm. The minimum root length was recorded in T_7 (N + K + TSP + ½ organic manure) with value of 24 cm. Combined application of organic manure and TSP remained inferior in terms of enhancing root growth of maize.

Shoot dry weight (g plant^{-1}): It was proved that all the treatments remained statistically significant (Fig. 3). Data revealed that T6 (N + TSP + K + organic manure) significantly enhanced the shoot dry weight to the maximum value of 20 g plant^{-1}.This was followed by T_5 (N + TSP + K) with the numerical value of 19 g plant^{-1}. Whereas, minimum shoot dry weight was measured in T_1 (recommended NK) and T_3 (N + RP + K) with numerical value of 13 g plant^{-1}. It was proved that combined application of N, P (as TSP), K and organic manure (T_6) proved superior in terms of enhancing shoot dry weight of maize.

Root dry weight (g plant^{-1}): It was reflected from the data that all the treatments were statistically significant in terms of affecting root dry weight when compared with each other (Fig. 4). Maximum root dry weight was recorded in control i.e. T_1 (recommended NK) followed by T_3 (N+ RP + K) showing the numerical values of 13.2 and 11.2 g plant^{-1} respectively. While, minimum root dry weight was observed in T_6 (8.1 g plant^{-1}) where N, TSP and K were applied along with organic manures. All the treatments proved inferior in terms of enhancing root dry weight compared to control (T_1). Therefore, it was the application of recommended NK which resulted in highest root dry weight of maize.

Root: shoot ratio: It was evident from the data that all the treatments proved significant in terms of statistics when compared with each other (Fig. 5). Maximum value (1.02) of root: shoot ratio was recorded in control i.e., T_1 (recommended NK) followed by T_3 (N +RP +K) with value of 0.86. Whereas, minimum root: shoot ratio was observed in T_6 (N + TSP +K +organic manure).

Relative growth rate (g $kg^{-1}day^{-1}$): Differences among various treatments for relative growth rate of maize were found significant in terms of statistics (Fig. 6). Data showed that highest relative growth rate was recorded in T_3 (N + RP + K) followed by T_1(recommended NK) with numerical values of 0.19 and 0.17 respectively. Whereas, lowest relative growth rate was observed in T_5 (N + TSP + K +organic manure).

Leaf area (cm^2): Differences among various means were found statistically significant (Fig. 7). Maximum leaf area was recorded in T_6 (N + TSP + K + organic manure) followed by T_7 (N + K + TSP + ½ organic manure) with numerical values of 131 cm^2 and 109 cm^2 respectively. However, minimum leaf area (66 cm^2) was recorded in control i.e. T_1 (recommended NK). It was proved from data that use of organic manure either in full or half dose along with N, P (as TSP) and K resulted in significant increase in leaf area of maize plants.

Phosphorus content of leaf (ppm): It was observed that integrated use of organic and mineral source of P performed better in terms of enhancing P content of leaf compared to control (Fig. 8). Thus, use of TSP along with organic manure (T_6) proved superior to all other treatments. Minimum leaf P content was found in control (T_1) where no exotic source of P was applied showing the value of 45 ppm that was increased to maximum level of 93 ppm (T_6) where two sources of P (TSP and organic manure) were used along with N and K.

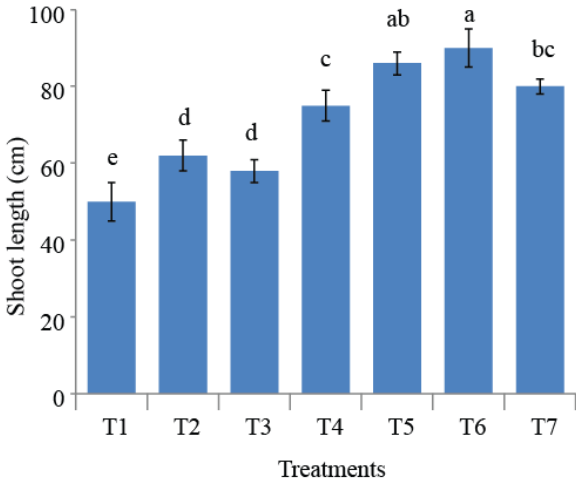

Fig. 1. Comparative efficiency of various sources of P on shoot length (cm) of maize.

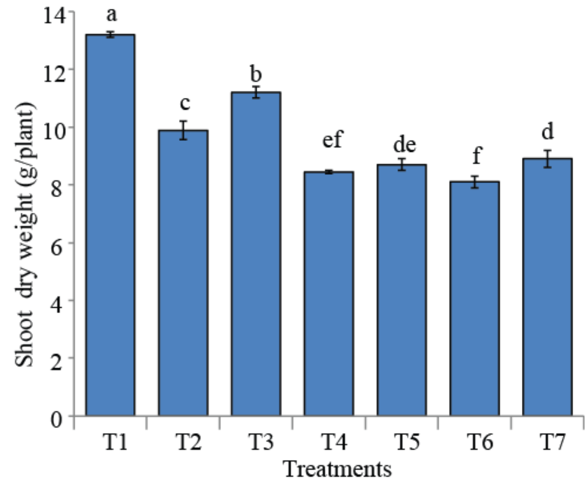

Fig. 4. Comparative efficiency of various sources of P on root dry weight (g $plant^{-1}$) of maize.

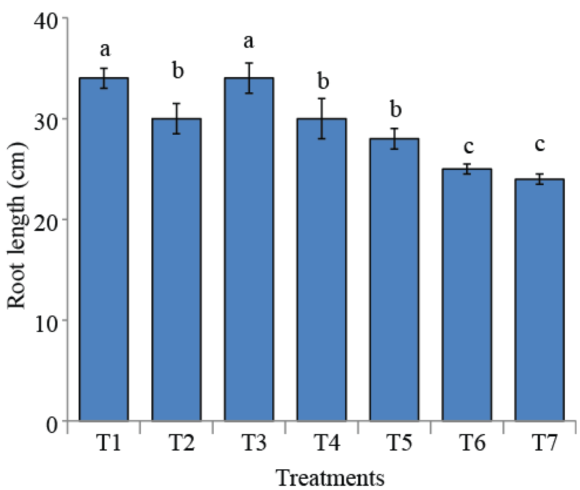

Fig. 2. Comparative efficiency of various sources of P on root length (cm) of maize.

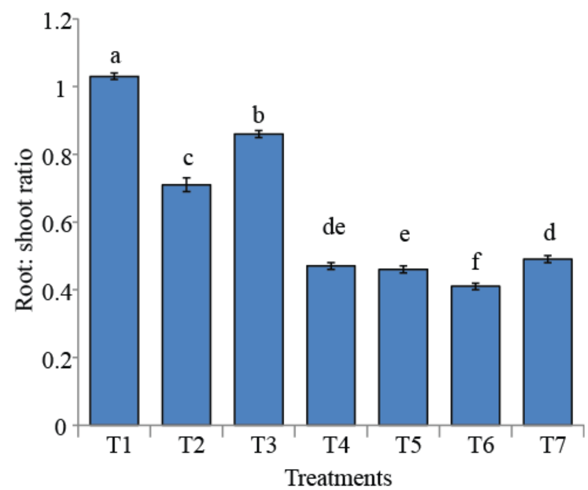

Fig. 5. Comparative efficiency of various sources of P on root: shoot ratio of maize.

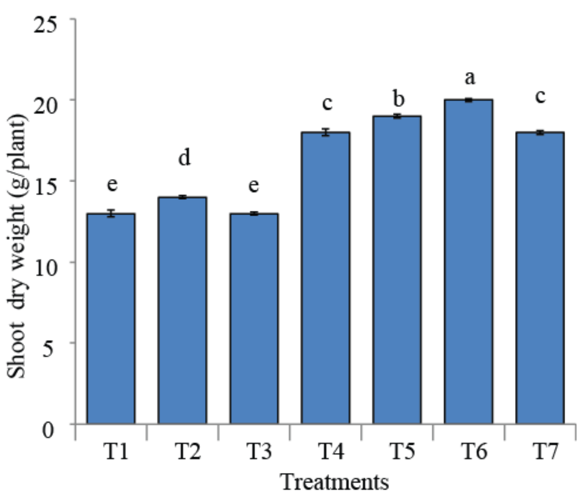

Fig. 3. Comparative efficiency of various sources of P on shoot dry weight (g $plant^{-1}$) of maize.

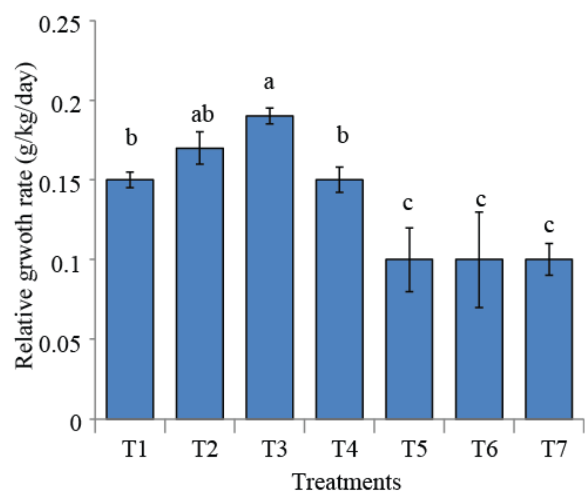

Fig. 6. Comparative efficiency of various sources of P on relative growth rate (g $kg^{-1}day^{-1}$) of maize.

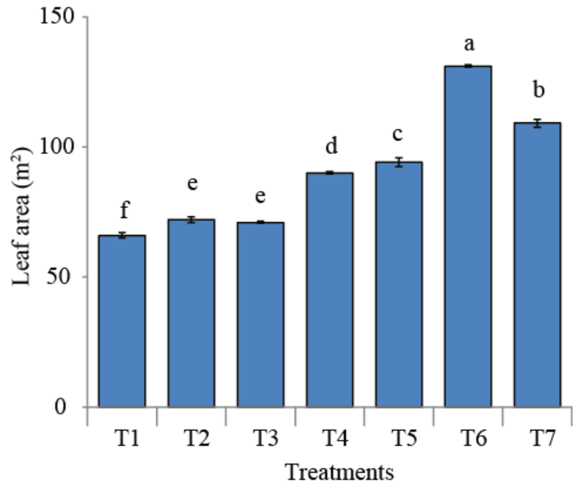

Fig. 7. Comparative efficiency of various sources of P on leaf area (cm^2) of maize.

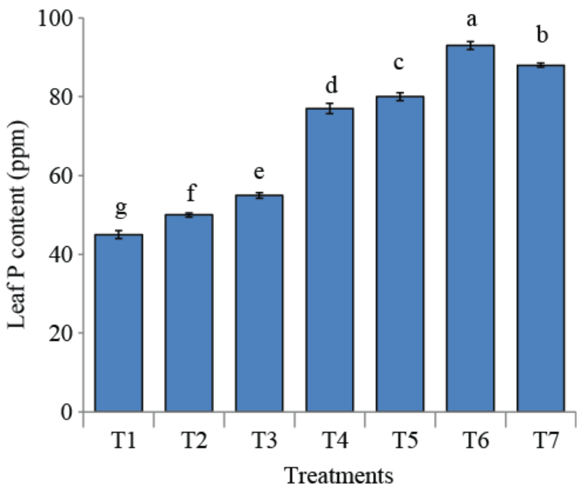

Fig. 8. Comparative efficiency of various sources of P on leaf P content (ppm) of maize.

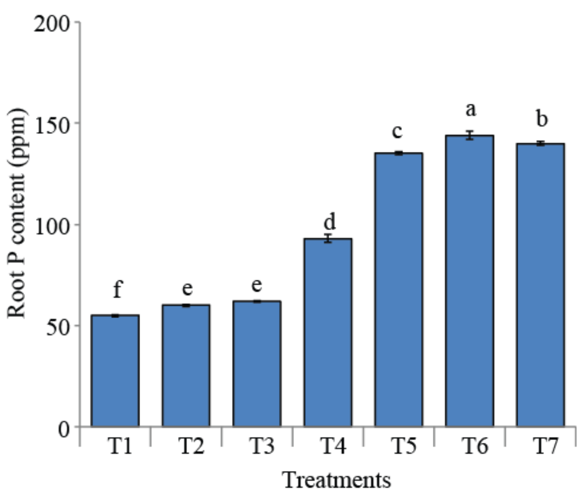

Fig. 9. Comparative efficiency of various sources of P on P content of root (ppm) of maize.

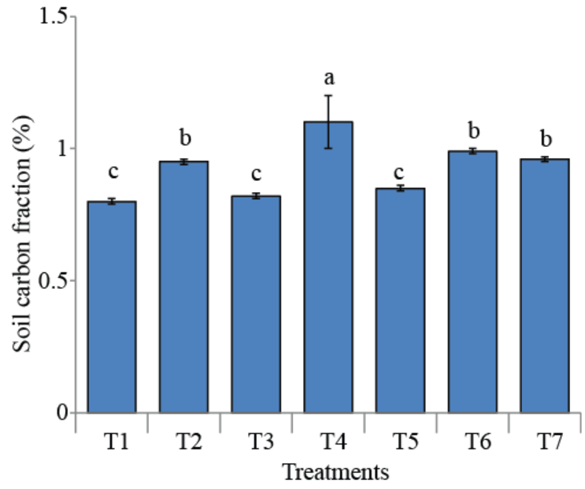

Fig. 10. Comparative efficiency of various sources of P on soil carbon fraction (%) of maize.

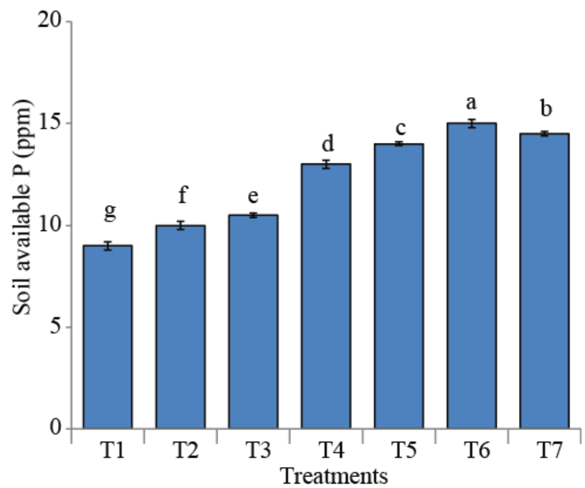

Fig. 11. Comparative efficiency of various sources of P on soil P content (mg kg^{-1}).

Phosphorus content of root (ppm): Differences among various treatments for P content of maize root were found significant statistically (Fig. 9). The data revealed that maximum P content of root (144 ppm) was recorded in treatment where combination of organic (manure) and inorganic (TSP) source of P along with N and K (T_6) were applied. This was followed by T_7 (N + K + TSP + ½ organic manure) with numerical value of 140 ppm. Minimum P content of root was noticed in control i.e. T_1 (recommended NK) with value of 55 ppm. It was found that integrated use P sources performed better in terms of enhancing P content of leaf compared to control. Thus, use of TSP either with full dose of organic manure (T_6) or half dose of organic manure (T_7) proved superior to all other treatments. Differences among various means regarding P content of root were found significant when compared statistically.

Soil carbon fraction (%): It was observed that addition of organic manure in either combination increased soil carbon fraction compared to control (Fig. 10). The differences in determined values of soil carbon fraction for various treatments were statistically significant with respect to control. The lowest analyzed value for T_1 was 0.80 % that reached to 1.11 % in T_4 (N + RP + K + organic manure). This treatment was followed by T_6 (N + TSP + K + organic manure) and T_7 (N + K + TSP + ½ organic manure) with values of 0.99 and 0.96 % respectively. Combined application of rock phosphate and organic manure proved superior over all other treatments in terms of enhancing soil carbon fraction of growth medium.

Soil P content (ppm): The differences in determined values of phosphorus for various treatments were statistically significant with respect to control (Fig. 11). The lowest analyzed value for T_1 was 9.0 mg kg^{-1} that reached to 15 mg kg^{-1} in T_6 (N + TSP + K + organic manure). This treatment was followed by T_7 (N + K + TSP + ½ organic manure) T_5 (N + TSP + K) with values of 14.5 and 14 mg kg^{-1} respectively. Combined application of TSP and organic manure proved superior to all other treatments in terms of enhancing P content of growth medium.

Discussion

Organic manures played vital role in betterment of soil properties. Improved soil properties are responsible for enhanced nutrient assimilation by the plants. Addition of organic manures significantly affected the plant growth and growth contributing parameters e.g. shoot length, root length and plant height (Aziz *et al*., 2006; Aziz *et al*., 2010). The increase in plant growth parameters in treatments receiving organic manures than treatment receiving TSP might be due to improved soil properties and ultimately improvement in nutrient availability and uptake by plants. These results are in line with findings of various researchers like Kashem & Warman, 2009; Zheljazkov & Warman, 2003; Kashem & Singh, 2001.Improvement in shoot length by the addition of organic manures is contributed to improved soil properties and nutrient availability. These results were also favored by Muhammad & Khattak, 2009; Boatend *et al*., 2006; Hirzel *et al*., 2007; Marschner, 1995.

Several adaptive mechanisms (alteration in root morphology, physiology and biochemistry) developed by plants due to deficiency of phosphorus have been reported by various researchers. Such mechanisms are responsible for modification in the rhizosphere and thus, increase the capability of root systems for exploring more soil volumes for inorganic phosphorus (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 percentage of photosynthates to roots, changes in root architecture etc. in order to utilize more soil volumes (Hermans *et al*., 2006; Hammond & White, 2008; Lynch & Brown, 2008; Peret *et al*., 2011; Smith *et al*., 1990, Marschner, 1995; Hinsinger, 2001). Enhancement of root length in response to absence of phosphorus could be possibly due to such reasons. According to Mani (2002) each increase in NPK contributed to increase in plant height and growth parameters.

This increase in P content of growth medium was attributed to betterment of soil characteristics due to addition of pressmud which are responsible for better nutritional status of soil (Aziz *et al*., 2010; Mohanty *et al*., 2006; Hirzel *et al*., 2007; Garg & Bahl, 2008; Nyambati & Opala, 2014). Application of organic materials significantly improved organic carbon fraction of soil due to up gradation of organic matter content in soil. Findings of various researchers also support these results (Ali *et al*., 2014; Aziz *et al*., 2010, Nyambati & Opala, 2014).

Conclusion

It can be concluded that rock phosphate (RP) could be used as an effective and economic substitution for TSP when it is integrated with suitable organic amendment (RP: organic amendment in 1:2 ratio).It could be suggested that the edaphic and environmental conditions of Pakistani soils do not favor the sole use of RP as effective P fertilizers unless it is integrated with suitable quantity of organic amendment for enhancing the dissolution and ultimate release of P from RP.

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