Research Article

# Phosphorus Fractions and Wheat Seedlings Growth in Calcareous Soils Amended with P Enriched Compost

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**Abstract** | Pretreatment of organic materials with phosphatic fertilizers can alter P fractionations in soil and boost up its availability to plant in calcareous soils. For this purpose, a pot experiment was conducted in the green house of the University of Agriculture Peshawar to assess changes in P fractionations and wheat seedlings growth in two diverse calcareous soils. The pretreated composts were prepared by mixing 0, 2 and 4 % P with FYM on dry weight basis either from RP (rock phosphate) or TSP (triple super phosphate fertilizer). The prepared composts were then applied to pots containing 6 kg of soil @ 160 mg $P_2O_5$ $kg^{-1}$ and data were recorded on phosphorus fractionations at 1st, 5th and 10th week of germination and its correlation with wheat seedlings growth and leaf [P]. Results showed that the labile P fraction initially increased and then decreased and as compared to control and untreated FYM composts, all treated pots maintained higher labile P at all the three sampling times. However, the moderately labile and non-labile fractions showed non-significant changes with time. The Plant height, biomass and total P uptake were found significantly higher in the treatment fertilized with 2 % TSP enriched compost followed by 4 % TSP enriched compost as compared to control. The effect of TSP enrichment was better than RP as well as the enrichment with 2 % was better than 4 % for both sources in both soils. Moreover, only labile P determined at $10^{th}$ week of germination and similarly leaf [P] at this stage showed significant correlation with plant growth. These results concluded that enrichment of composting material with P can enhance the bio-available P to plant and cab boost up the plant growth in calcareous soils.

**Received** | August 28, 2021; **Accepted** | September 27, 2021; **Published** | October, 13, 2021
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**Citation** | Waheed, M. and D. Muhammad. 2021. Phosphorus fractions and wheat seedlings growth in calcareous soils amended with p enriched compost. *Sarhad Journal of Agriculture,* 37(4): 1466-1475.
**DOI** | https://dx.doi.org/10.17582/journal.sja/2021/37.4.1466.1475
**Keywords** | Enriched compost, Rock phosphate, Wheat growth, Phosphorus fractionation, Calcareous soils

## Introduction

Phosphorus is finite, non-renewable, non-substitutable and geographically restricted resource (Chodhury *et al.*, 2017). The demand for P fertilizers is continuously growing up to feed ever increasing population. Taking into account the surge in human population and demand for P in agriculture and other industrial uses the world P reserves are expected to deplete in next 70-140 years (Li *et al.*, 2018). Alternate P sources other than applying excavated P along with strategies to improve the P use efficiency will have to be unveiled for sustainable and economically viable crop production. Incorporating mineral P with composting materials can expedite the P cycling and reduce burden on P reserves by improving the P use efficiency.

Phosphorus is placed as second essential nutrient for plant growth. It builds 0.2 % of plant dry matter as constituent of nucleic acids (*e.g* DNA and RNA), phospholipids (in cell wall) and ATPs as energy car-


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rier. It directly or indirectly affects many physiological processes in plant like metabolic respiration, photosynthesis, cell division and control several other enzymatic processes. It also plays a vital role in early flowering, seed and root development. (Plaxton and Tran, 2011). Its deficiency is a common problem all over the world due to high affinity of phosphatic ions by soil solids both in alkaline and acidic soils (Zhu *et al*., 2018). Due to high lime content and adsorption capacity of Pakistani soils, about 90 % are P deficient (Sattar, 2011; Memon, 1996) and one has to apply phosphatic fertilizer for sustainable crop production. But recovery of phosphatic fertilizer is very low where only 10 to 15% of applied P is taken up by plants (Roberts and Johnston, 2015) while the remaining is either precipitated with calcium and magnesium in alkaline and iron and aluminum in acidic condition or adsorb on the clay minerals (Gerard, 2016; Abbasi *et al*., 2013; Zafar *et al*., 2013). The phosphorus concentration in soil solution is ranges < 0.3 mg P $L^{-1}$ and often reaches to 0.001 mg P $L^{-1}$ whereas plant tissues P can have as high as 3000 mg P $kg^{-1}$ (Bieleski, 1977; Manske *et al*., 2000). The phosphorus concentration in soil solution should have to maintain up to 0.2 mg P $L^{-1}$ for proper plant growth and thus it is necessary to apply 22-67 mg P $L^{-1}$ (equivalent to 22-67 kg P $ha^{-1}$) of P to soil in order to maintain it for proper plant growth, depending on soil type and condition (Chaudhry *et al*., 2003; Ahmad *et al*., 2013).

The addition of organic amendments not only supply P but also enhances the P availability by altering the physico-chemical properties of soil which has direct effect on soil P mobility. The organic matter upon decomposition releases $H^+$ ions which lower soil pH and solubilize phosphate compounds with basic cation (Chang *et al*., 1991; Romanyà and Rovira, 2009; Weyers *et al*., 2016). The shift in soil pH not only affects adsorbed P but also P containing minerals (McDowell and Sharpley, 2003; Sharpley *et al*., 2004). The compounds (Like humic acid and fulvic acid) produced during mineralization of organic matter would compete for sorption sites with phosphorus (Khattak *et al*., 2014; Haynes and Mokolobate, 2001), The organic matter could attach with non-specific sorption sites which intensify the –ve charge on soil particle reduces the electrostatic attraction between the soil particle and P ion. Similarly organic matter promotes microbial activity which enhances the P solubility (Brucker *et al*., 2020).

The application of fresh manure and residues to soil may cause some problems regarding to plant growth and environmental pollution (White and Brown, 2010). It can cause pollution in water, air, land and produce green house gases (Eghball and Power, 1994). Plant growth is sometimes retarded when high rates of fresh manure are applied to soil immediately before planting. Similarly, it may contain excess amount of nitrate and salts and also contain pathogen and weed seed. This problem usually doesn't occur if the fresh manure decomposes for few weeks in the soil and can be avoided by using well decomposed solid manure that has been stored for a year or more. The advantages of compost application to soil are further enhanced by enriched composting. It is technique where the composting materials are pre-treated with organic or inorganic amendments to facilitate decomposition and improve the quality of final product. The application of enriched compost has several advantages over non-treated compost.

The major demerits of ordinary composts is low nutritional values especially in term of major nutrients compared to chemical fertilizer, which make composts more costly and less valuable to farmer. This can be compensated by addition of external nutrients like P and minimizing the losses of native nutrient (Biswas, 2011; Moharana *et al*., 2015). Phosphorus Enrichment not only enhances quality of compost which makes it attractive for farmer but also minimize environmental risk associated with ammonia volatilization and eutrophication through runoff. However, the nutrient availability from compost and its quality vary with composting material and enrichment sources while the agronomic effectiveness depends on soil, crop and climatic conditions of the area. The P enriched compost has advantage over ordinary compost and manure in supplying sufficient amount of P in alkaline calcareous conditions and is a cheaper P source as compared to commercial fertilizers. This study aimed to check the performance of locally prepared enriched composts in phosphorus availability, fractionations and uptake by plants in calcareous soil conditions.

## Materials and Methods

This pot experiment was conducted to assess the effect of enriched compost prepared from pretreatment of rock phosphate (RP) and triple superphosphate (TSP) at different levels with the FYM on the wheat seedling growth, P availability, fractionation and uptake by plant in two diverse calcareous soils. These soils *i.e*. Peshawar soil series (16.5% lime) and Guliana soil series (4.5 % lime) were collected from Peshawar and Charsadda, districts. Both the soils had almost similar texture, alkaline in reaction, non-saline and low in organic matter and phosphorus (Table 1). All pots containing 6 kg dry soil of both series received 80 mg $P_2O_5$ $kg^{-1}$ (equivalent to 160 kg $P_2O_5$ $ha^{-1}$) from 2 or 4 % RP or TSP enriched FYM compost. The treatments also included one control and one ordinary compost treatments at rate of 10 t $ha^{-1}$. The pots were arranged in completely randomized design (CRD) with two factors and three replications and were sown with 10 wheat seeds. The pots were then harvested and data were recorded for plant height, biomass, and P uptake. Along with plant data, soil samples at 0, 5th and 10th week of emergence were taken and analyzed for P fractionation and its correlation with plant P uptake and growth.

**Table 1:** *Characteristics of experimental soils used in the study.*

| Parameter | Unit | Guliana SS | Peshawar SS |
|---|---|---|---|
| EC | dS $m^{-1}$ | 0.13 | 0.15 |
| pH | | 7.11 | 7.8 |
| Lime content | % | 4.5 | 16.5 |
| Organic matter | % | 0.89 | 0.79 |
| AB-DTPA Ext. P | mg kg | 2.75 | 2.91 |

*SS= Soil Series.*

*Compost preparation*

Farmyard manure (FYM) was collected from dairy farm of the University of Agriculture Peshawar. The manures were transported to agronomy farm, where it was spread on land for two days in order to evaporate excess amount of water. Pits having size of 1 $m^3$ was dug for different compost. The floor of each pit was covered with polyethylene sheet to reduce seepage of nutrients during composting. FYM were added with 0, 2 and 4 % P from rock phosphate (RP) and triple calcium super phosphate (TSP) on dry weight basis (Wu *et al*., 2019; Luo *et al*., 2013). The P sources were spread over composting materials in difference layers. As such 20-25 kg of FYM was moistened and spread in the pit to make a layer over which a layer of RP or TSP containing 2 to 5 kg P was sprinkled. Then another layer of FYM was made and again 2-5 kg RP or TSP was added. In such a way a pile was made containing 4 layers of FYM with net weight of 100 kg of pile applied with required amount of RP or TSP. The pits were covered with black polyethylene sheet to conserve moisture and heat produced during thermophilic stage of composting process. Composts were mixed at least once in a week for aeration, watering and homogeneity. The triplicate samples were taken from each pit at the end of 150 d of composting for analysis of different fractions of phosphorus and other parameter in the laboratory (Table 2).

**Table 2:** *Characteristics of enriched FYM composts used in the study.*

| Chemical Properties | Ordinary Compost | 2% enriched Compost | | 4% enriched compost | |
|---|---|---|---|---|---|
| | | RP | TSP | RP | TSP |
| Organic carbon (%) | 24.56 | 20.2 | 20 | 20.3 | 19.9 |
| pH | 7.31 | 7.4 | 6.7 | 7.8 | 6.7 |
| Total nitrogen (%) | 0.96 | 1.17 | 1.12 | 1.01 | 1.11 |
| Total P (%) | 0.62 | 2.12 | 1.8 | 3.12 | 3.71 |
| C/N ratio | 25.1 | 17.5 | 17.8 | 18.3 | 18.4 |

*Sequential fractionation scheme*

The soil phosphorus fractionation scheme used to separate P into different fractions described by Hedley *et al*. (1982). In this scheme soil phosphorus is categorized into three fractions, labile (plant available), moderately labile and non labile (unavailable to plant). In the step the 0.5 g of sample was taken with 10 mL deionized water in centrifuge tube having activated anion exchange resin (AER) and shaken for 16 hour on rotary shaker. The resin membrane was transferred in other tubes having 10 ml 0.5 M HCl solution and shaken for 2 h on orbital shaker. AER fraction was determined in this 10 ml 0.5 M HCl. The tubes carrying soil residue in the 10 ml deionized water, was centrifuged for 10 min at 8,000 RPM, and the supernatant was removed and the residual sample was used for determination of other fractions. The soil residue from the AER was followed by treating with 10 mL of 0.5 M $NaHCO_3$ was shaken for 16 hour, centrifuged, and decanted into a 50-mL volumetric cylinder. The soil residue was rinsed twice with 10 mL of 0.5 M NaCl solution. The rinses were combined with the extract in the 30-mL volumetric cylinder and brought to volume of 30 ml with DI water. The Moderately labile fractions were extracted by treating the residue of $NaHCO_3$ with 0.1 M NaOH and HCl (1M). The residual soil from the $NaHCO_3$ was shaken with 0.1 M NaOH for 16 hours, centrifuged and the solution decanted into a 30-mL volumetric cylinder. The soil residue was rinsed twice and added to the cylinder and brought to 30 ml volume with DI water. The soil residue from NaOH-0.1M was shaken with 10 ml HCl (1M) for 16 hour, centrifuged (5 min at 8000 rpm) and the supernatant was decanted into 50 mL volumetric cylinder. The soil residue was washed twice and the washings were added to the volumetric cylinder and brought to 30 ml with DI water.

**Table 3:** *The effect of P-enriched FYM compost on dry biomass, fresh biomass, plant height, and P uptake by wheat seedlings.*

| Source and level of P enriched FYM compost | Dry biomass (g pot$^{-1}$) | Plant height (cm) | P conc. (%) | Total P uptake (g pot$^{-1}$) |
|---|---|---|---|---|
| Control | 7.0 c | 22.5 c | 0.12 c | 0.9 d |
| Untreated FYM | 12.0 b | 47.1 b | 0.14 ab | 1.7 c |
| 2 % RP-FYM | 12.5 b | 52.3 ab | 0.14 ab | 1.7 c |
| 2 % TSP- FYM | 16.3 a | 53.8 a | 0.15 a | 2.5 a |
| 4 % RP-FYM | 12.5 b | 50.9 ab | 0.14 ab | 1.7 c |
| 4 % TSP- FYM | 13.9 b | 53.2 a | 0.15 a | 2.1 b |
| LSD | 3.6 | 11.4 | 0.2 | 0.4 |
| **Averages over similar groups** | | | | |
| RP compost | 12.47 b | 51.6 | 0.14 | 1.7 b |
| TSP compost | 15.10 a | 53.5 | 0.15 | 2.3 a |
| 2 % compost | 14.39 | 53.1 | 0.15 | 2.1 |
| 4 % compost | 13.18 | 52.0 | 0.14 | 1.9 |

*Mean followed by letter in the same group do not significantly different P<0.05*

The non labile fraction has the two fraction extracted with NaOH (0.5M) and concentrated $H_2SO_4$. The soil residue from HCl-1M was shaken with 10 ml NaOH (0.5M) for 16 hour. The solution was centrifuged (5 min at 8000 rpm) and was decanted into 50mL volumetric cylinder. The soil residue was washed twice with 10 mL of 0.5 M NaCl twice. These washings were added to the cylinder and brought upto 30 ml with DI water. The residue remain from these entire step was used for residual phosphorus. A sample of 0.1 g of reside was treated with concentrated $H_2SO_4$ and $MgSO_4$ at 250 °C on a hot plate in 6$^{th}$ step for residual P (Thomas *et al*., 1967) followed by colorimetry (Murphy and Riley, 1962) to measure any residual P that remained.

*Statistical analysis*

All the data were subjected to analysis of various according to completely randomized design with two factors (6 treatments and two soils) by using computer software statistix-8.1 for checking significance, whereas the means were compared through least significant different (LSD) analysis as suggested by (Steel and Toori, 1981).

## Results and Discussion

*Dry biomass and plant height*

Phosphorus enriched compost showed better performance as compared to control or ordinary compost (10 t ha$^{-1}$) regardless of enrichment level or P source. Phosphorus enriched compost significantly enhanced the plant height and dry biomass in both highly as well slightly calcareous soils (Table 3). The 2 % TSP enriched compost showed significantly higher biomass (16 g pot$^{-1}$) and pant height (53.8 cm) of wheat. In case of biomass the 2 % TSP enriched compost was followed by 4 % TSP enriched compost, 2 % RP enriched compost and 4 % RP enriched compost with the same value of 12.5 g pot$^{-1}$while the plant height comparable but still higher or comparable to ordinary compost. It must be noted that enriched compost was applied based on P basis and as such its application rate was about several times less than ordinary compost. In case of enrichment the FYM level was reduced to 2 t ha$^{-1}$ in 2 % and 1 t ha$^{-1}$ in 4 % P enrichment and as such enrichment could save FYM by 3 to 5 time than ordinary compost without compromise on yield. The TSP enriched compost performed better than RP, which may be due to the fact that TSP contains highly available P than RP, and the experiment was only for 110 days from soil preparation to harvesting of plant. In such short duration the RP could not be expected to perform better than TSP. However, the application of compost (treated or untreated) showed comparatively more response in term of increase in biomass and plant height over control in Peshawar than Guliana (Figure 1). When averaged across treatments, the Peshawar soil series gave higher dry biomass (13.1 g pot$^{-1}$) as compared to Guliana soil series (11.6 g pot$^{-1}$), that may be due to high concentration of native P than Guliana soil series. However, the performance of a crop in a given soil depends on many characteristics and availability of all nutrients and as such the difference in only one nutrient (P availability) could not be expected to determine the growth. When averaged across the enrichment level 2 % enriched compost gave higher biomass (14.39 g pot$^{-1}$) and plant height (53.1 cm) than 4% enriched compost that may to due to presence of higher organic material in 2 % than 4 % enriched compost. The Increased in the dry biomass and plant height may be explained by mobilization of P from RP by the action of organic acids produced during composting as a result of organic matter decomposition (Basak, 2018). These organic acids may have augmented the solubilization of P from compost, thereby increasing available P content in the final product of the enriched compost. Immediately after application of enriched compost, available P was then immobilized into the microbial cell as evident by maintaining higher water-soluble, available and microbial P in soil with time. Such increase in plant growth with RP enriched compost was also reported by Moharana and Biswas (2016). Similar, result were also reported Basak and Gajbhiye (2018) who observed increased in the biomass of herbage by the application of RP enriched compost in pot experiment.

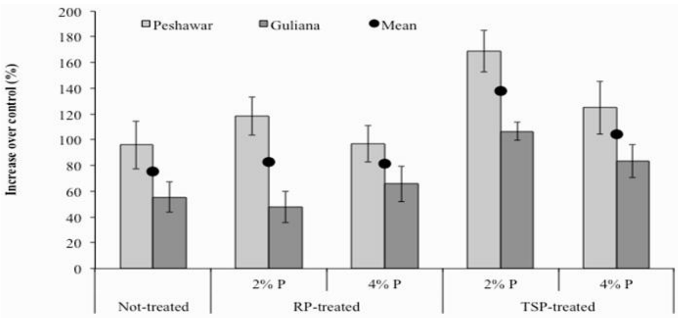


**Figure 1:** *Increase in dry matter of wheat over control with pre-treated compost during pot experiment (untreated FYM was applied @10 t ha-1while treated was applied @ 4 t ha-1 for 2 % and 2 t ha-1 for 4%).*

*Plant phosphorus content and uptake*

Plant phosphorus concentration and uptake was significantly affected by the application of P enriched compost (Table 3). The highest concentration of P was recorded in 2 and 4 % TSP enriched compost with the same values (0.15 %) however the total accumulation was 16 % higher in 2 % TSP enriched compost than 4 % TSP enriched compost. These treatments were followed by 2 % RP enriched compost and 4 % RP enriched compost with the same of P content of 0.14 % and uptake 1.7 g pot$^{-1}$ from both treatments. When averaged across the enrichment sources TSP enriched compost gave higher P concentration (0.15) and uptake (2.3 g pot$^{-1}$) as compared to RP and similarly, when average a cross the level, enrichment with 2 % gave higher plant P content (0.15 %) and uptake (2.1 g pot$^{-1}$) as compared to 4 % enrichment. The available P content and P uptake can significantly affect by P enriched compost as reported by Basak and Gajbhiye (2018). The application of enriched compost in soil increased microbial P and phosphatase enzymes activity that further mobilizes P from RP into an available form (Singh and Amberger, 1998).

Thus, increasing the availability P from enriched compost may attributed higher P uptake in wheat seedling (Meena and Biswas, 2014; Biswas, 2011). The effectiveness of RP-compost ranged from 61.4% (RP-compost) to 94.1% (RP-compost) as that of DAP on dry matter yield and 48.8% (RP-compost) to 83.7% (RP-compost) on total P uptake (Biswas and Narayanasamy, 2006).

**Table 4:** *The effect of P-enriched FYM compost on labile phosphorus fraction in diverse calcareous soil.*

| **Source and level of P enriched FYM compost** | **Peshawar Soil Series** | | | | **Guliana Soil Series** | | | |
|---|---|---|---|---|---|---|---|---|
| | **1st week** | **5th week** | **10th week** | **Mean** | **1st week** | **5th week** | **10th week** | **Mean** |
| **Resin P** | | | | | | | | |
| Untreated FYM | 16 | 47 | 21 | 28c | 26 | 82 | 44 | 51c |
| 2 % RP-FYM | 19 | 80 | 49 | 49b | 40 | 102 | 57 | 66a |
| 4% RP-FYM | 21 | 86 | 53 | 53ab | 29 | 85 | 55 | 56 b |
| 2 % TSP-FYM | 25 | 95 | 46 | 55 a | 32 | 96 | 47 | 58 b |
| 4 % TSP-FYM | 16 | 79 | 58 | 51ab | 32 | 99 | 53 | 61ab |
| Mean | 19 c | 77 a | 45 b | | 32 c | 93 a | 51 b | 59 |
| **$NaHCO_3$ P** | | | | | | | | |
| Control | 7 | 20 | 7 | 12 NS | 17 | 26 | 13 | 19 NS |
| 2 % P RP | 10 | 18 | 10 | 13 | 18 | 21 | 13 | 17 |
| 4% P RP | 8 | 15 | 10 | 11 | 19 | 18 | 19 | 19 |
| 2 % P TSP | 11 | 24 | 12 | 15 | 22 | 28 | 12 | 21 |
| 4 % P TSP | 7 | 25 | 12 | 14 | 18 | 26 | 14 | 19 |
| Mean | 9 c | 20 a | 10 b | 13 | 19 b | 24 a | 14 c | 19 |

*Mean followed by letter in the same group do not significantly different P<0.05*

*Phosphorus fractionation*

Data pertaining to the P available fractions as affected by the application of enriched compost to wheat seedling showed in Table 4, 5 and 6. As the experiment was short of short duration, but still it showed significant differences between the treatments in the case of labile P that consist of resin extractable P (Resin P) and $NaHCO_3$ extractable P. When averaged across treatments, resin P showed increasing with time reaching to 93 mg kg$^{-1}$ in Guliana and 77 mg kg$^{-1}$ in Peshawar soil series at 5th week of germination but then showed decreases with time and as such reached to 51 in Guliana and 45 mg kg$^{-1}$ in Peshawar soil series. Similarly, the $NaHCO_3$ ext. P was also higher at 5th week of germination in both soil series with values of 24 mg $kg^{-1}$ in Guliana and 20 mg $kg^{-1}$ in Peshawar soil series. When averaged across duration, the RP enriched at 4 % or TSP at both level have higher Resin-P than control and as well as than 2 % RP suggesting higher releases and P availability from enriched composts. Similarly, when averaged across the treatment, like the resin ext. P, the $NaHCO_3$ ext. P was also comparatively higher in Guliana soil series than Peshawar and the highest was recorded in the 2 % TSP enriched with values 21 mg $kg^{-1}$, followed by 19 mg $kg^{-1}$ from 4 % RP or 4 % TSP enriched composts.

**Table 5:** *The effect of P-enriched FYM compost on moderately labile phosphorus fraction in diverse calcareous soil under the wheat growth.*

| Extractable P | Peshawar Soil Series | | | | Guliana Soil Series | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st week | 5th week | 10th week | Mean | 1st week | 5th week | 10th week | Mean |
| NaOH-0.1M | | | | | | | | |
| Control | 15 | 28 | 55 | 32 c | 11 | 25 | 45 | 27 c |
| 2 % P RP | 13 | 29 | 44 | 29 b | 11 | 26 | 47 | 28 ab |
| 4% P RP | 14 | 31 | 39 | 28 b | 10 | 28 | 62 | 33 a |
| 2 % P TSP | 15 | 32 | 57 | 35 a | 13 | 26 | 40 | 26 b |
| 4 % P TSP | 12 | 33 | 60 | 35 a | 13 | 29 | 37 | 26 b |
| Mean | 14 c | 30 b | 51 a | 32 | 11 c | 27 b | 46 a | 28 |
| HCl-1M | | | | | | | | |
| Control | 768 | 739 | 710 | 739 NS | 651 | 622 | 627 | 633 NS |
| 2 % P RP | 758 | 724 | 736 | 739 | 654 | 662 | 677 | 664 |
| 4% P RP | 790 | 785 | 751 | 775 | 687 | 686 | 666 | 680 |
| 2 % P TSP | 750 | 752 | 729 | 744 | 658 | 665 | 646 | 657 |
| 4 % P TSP | 776 | 758 | 737 | 757 | 675 | 671 | 711 | 686 |
| Mean | 768 | 752 | 733 | 751 | 665 | 661 | 665 | 664 |

*Mean followed by letter in the same group do not significantly different P<0.05*

The P extracted with NaOH (0.1M) is consisted of moderately labile iron and aluminum bounded P while P extracted with HCl (1M) is moderately labile calcium bonded P. When averaged across the treatments, the NaOH-0.1M ext. P decreased with time in both soil series with comparatively higher values in Peshawar than Guliana soil series at 5th and 10th week. Similarly, the HCl ext. P was also higher in Peshawar than Guliana when averaged across the treatment and showed slightly decreasing trend in Peshawar but remained virtually unchanged in Guliana soil series. In Guliana soil series the RP maintained higher P with the value of 28 and 33 mg $kg^{-1}$ where in Peshawar soil series the high P concentration of 35 and 35 was maintained by TSP enriched compost. The HCl ext. P ranged from 735 to 775 mg kg-1 in Peshawar and 633 to 686 mg kg-1 in Guliana soil series when averaged across the duration. Through treated pots had comparatively higher HCl ext. P than control in both soil series but the differences were statistically non-significant. The higher HCl ext. P in both soil series showed that most of P Ca and Mg bounded P in both series. The comparatively higher NaOH and HCL ext. P in Peshawar could be associated with higher native P.

**Table 6:** *The effect of P-enriched FYM compost on non labile phosphorus fraction in diverse calcareous soil under the wheat growth.*

| Extractable P | Peshawar Soil Series | | | | Guliana Soil Series | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st week | 5th week | 10th week | Mean | 1st week | 5th week | 10th week | Mean |
| NaOH0.M | | | | | | | | |
| Control | 46 | 69 | 52 | 56 c | 46 | 65 | 66 | 59 c |
| 2 % P RP | 55 | 59 | 59 | 58 bc | 63 | 67 | 69 | 67 ab |
| 4% P RP | 61 | 75 | 61 | 66 a | 61 | 71 | 64 | 65 bc |
| 2 % P TSP | 58 | 62 | 63 | 61 ab | 59 | 75 | 67 | 67 ab |
| 4 % P TSP | 54 | 72 | 61 | 62 ab | 63 | 77 | 67 | 69 a |
| Mean | 55 bc | 68 a | 59 b | 61 | 58 c | 71 a | 67 b | 65 |
| **Residual** | | | | | | | | |
| Control | 761 | 738 | 744 | 647 bc | 630 | 620 | 639 | 630 c |
| 2 % P RP | 770 | 783 | 742 | 765 ab | 663 | 679 | 638 | 660 b |
| 4% P RP | 759 | 785 | 781 | 775 a | 654 | 656 | 672 | 661 b |
| 2 % P TSP | 738 | 764 | 725 | 742 c | 648 | 622 | 647 | 639 c |
| 4 % P TSP | 770 | 758 | 777 | 768 ab | 670 | 672 | 673 | 672 a |
| Mean | 759 | 726 | 754 | 746 | 653 | 650 | 654 | 652 |

*Mean followed by letter in the same group do not significantly different P<0.05*

The non labile P consisted of two fractions, one extracted with NaOH (0.5M) that give the aluminum and iron bounded P while second fraction is residual extracted with sulfuric acid that yields basic cation bounded and P fixed in minerals like in apatite. The NaOH (0.5M) ext. P followed increasing trend with time when averaged across the treatments (Table 6). The initial NaOH (0.5M) ext. P was 55 and 58 mg $kg^{-1}$ in Peshawar and Guliana soil series respectively that reached to highest level at 5th week of sampling with value of 68 and 71 mg $kg^{-1}$ in Peshawar and

Guliana soil series respectively. The NaOH (0.5M) ext. P in 10th week sample again reduced to 59 and 67 mg $kg^{-1}$ in Peshawar and Guliana soil series respectively. In both soil series, the residual P was higher in treated pots as compared to control.

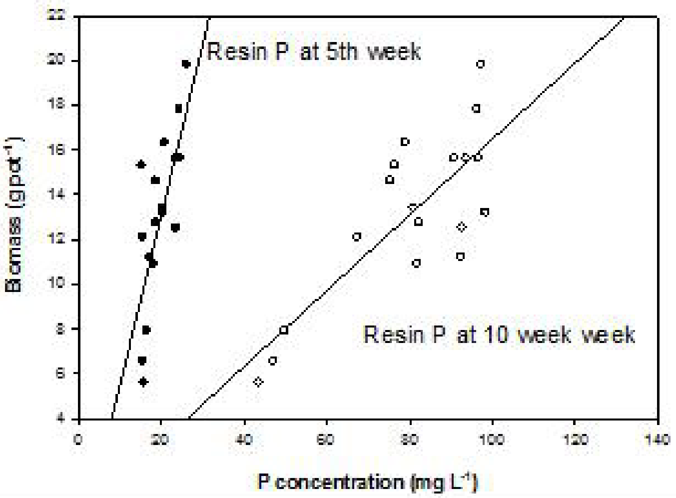


**Figure 2:** *Relationship of Resin P at 5th and 10th week of germination with wheat dry biomass.*

In general, the presence of plants reduces the P concentration in soil as the data shows significant decrease in resin and $NaHCO_3$ ext. P after the 5th week i.e. 10th week of sampling. Such decreasing in resin and $NaHCO_3$ ext. P was also observed by Kar *et al.* (2017). The increase of both fractions at 5th week as compared to sowing time (1st week) could be associated to net conversion of stable P and moderately labile P with time (Kashem *et al.*, 2004), perhaps associated with rhizosphere activity such as phosphatase enzymes and acidification (Armstrong and Helyar, 1992). The gradual decrease of soil resin-P and gradual increase in Ca bound P might reflect a transformation of more readily available P forms to more stable forms with time (Guo *et al.*, 2000) in high pH calcareous soil. RP-compost recorded lower Olsen P at the initial period of incubation study than diammonium phosphate (DAP), but improved significantly with the progress of time. RP compost prepared at 4% resulted in higher Olsen P throughout the incubation period compared to 2% rate (Biswas and Narayanasamy, 2006).

The increase or decrease in HCl ext. P was virtually non significant and it was also reported by Kar *et al.* (2017). Sharply *et al.* (2000) observed decrease in Al and Fe bounded P with manure application to soil but in our case a slight increase was observed with time that might be associated to microbial activity which might have increased the P availability. Overall, results showed that non-labile residual P fraction was not affected by treatments. High pH may favor the transformation of labile P into more stable P forms in high pH calcareous soils (Kar *et al.*, 2017) if not utilized by plants. Residual P did not follow the same trend as the other forms and was relatively unaffected by plant growth. This suggests that the plants had very little access to the residual fraction, which is consistent with the opinion that residual forms are more stable and have little influence upon short-term plant available P.

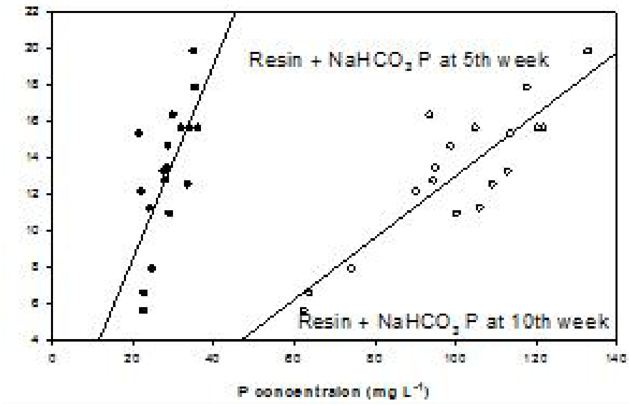


**Figure 3:** *Relationship of Resin + NaHCO3 ext. P (labile P) at 5th and 10th week of germination with wheat dry biomass.*

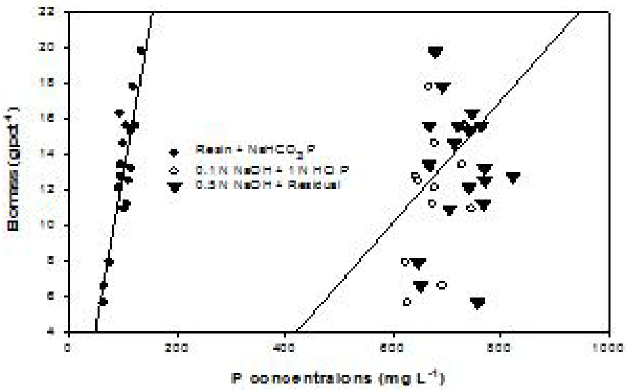


**Figure 4:** *Relationship of P fractions determined at 10th week of germination with wheat dry biomass.*

*Relationship of P fraction with wheat growth*

Regression of various P fractions with wheat biomass (growth) depicted strong correlation only between resin extractable P at 5th and 10th week of emergence (Figure 3 and 4) indicating that resin P is the readily available P and could be used to predict the crop growth. Regression of all other P fraction did not show significant correlation. The combine resin and $NaHCO_3$ ext. P (labile fraction) which is regarded as bio-available fraction showed strong correlation with plant biomass at both 5th and 10th week of emergence

(Figure 4). In Figure 4 the idea of labile P (resin and $NaHCO_3$ ext. P), moderately labile P (NaOH-0.1M and HCl ext. P) and non labile P (NaOH-0.5M and residual P) was regressed with plant biomass and it was revealed that only the available fraction showed significant correlation with crop growth. The data suggested that once the P converted to non-available fraction it is hard to affect the plant growth in normal conditions.

## Conclusions and Recommendations

The TSP treated compost and compost enriched with 2 % P performed better that could be attributed to more P availability and higher organic matter than applied from 4 % P enriched compost. Both labile P fractions increased till $5^{th}$ week of plant growth and then reduced revealing conversion into non labile form and uptake by plant. The HCl (1M) and residual P were the dominant fractions but did not significantly change with treatments and duration in such a short term experiment. The labile P determined at $10^{th}$ week and similarly P in leaf at $10^{th}$ week had significant correlation with plant growth and biomass whereas other P fractions and P determined on other stages had nil or week correlation with plant growth.

## Novelty Statement

Novelty of this research is the pretreatment of mineral P fertilizer with the organic manure enhance the solubility and availability to plant which is clear from the fractionation data of experiment.

## Author's Contribution

**Muhammad Waheed:** Principal author and PhD scholar, designed and conducted research, collected data, analyzed and wrote draft of this manuscript.
**Dost Muhammad:** Major Supervisor, who provided technical guidelines in the whole PhD study and research.

*Conflict of interest*
The authors have declared no conflict of interest.

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