Research Article

Efficacy of P Enriched Organic Manures to Improve Soil Health and Nutrient Acquisition of Wheat

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Abstract | This study was performed to estimate the efficacy of organic substrates to release, solubilize and improve uptake of phosphorous using wheat as test crop. The research was steered through completely randomized design (CRD) with 14 treatments and 06 replications. Pre and post-harvest soil analysis was performed. The results showed maximum increase in nitrogen (N) (0.91 ppm) and potassium (K) contents (2.59 ppm) in wheat crop and maximum increase in all plant parameters were recorded in T_{11} [T_2 + all P from PROM (phosphorus rich organic manure)] followed by T_{13} (T_2 + all P from phosphocompost). In case of soil characteristics, application of recommended NPK from chemical fertilizer (T_2) recorded the highest pH (8.66) of soil, while the maximum EC (2.75 dS m^{-1}) of soil was noted under the application of (T_{13}) (T_2 + all P from compost). Soil organic matter (0.90 %) was found to be maximum under T_5 (T_1 + all P from phosphocompost), while the treatments T_{11} (T_2 + all P from PROM) and T_4 (T_1 + all P from FYM) noted the maximum levels of P (8.0 ppm) and K (3.45%) in soil, respectively. Conclusively, all the treatments significantly improved the soil characteristics and nutrient concentration of wheat plant compared to control (T_1). Use of phosphocompost proved very useful to enhance soil health and consequently nutritional characteristic of wheat crop.

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Introduction

Wheat is an important crop for almost 50% of the world's population and can be grown easily under in rainy and irrigation conditions (Munir *et al.*, 2007). It is considered a key important staple crop and is the most demanded grain around the globe. Within cereals, wheat (*Triticum aestivum* L.) crop is more significant crop in the world in terms of overall growth, production, utilization and growing area around the globe (Ranjana and Kumar, 2013). In Pakistan, wheat is a most adopted cereal crop and it's getting more fame continuously because of its daily consumption and the use of its products in different ways (Laghari *et al*., 2010). Wheat accounts about 72% of total calories and 125kg/year is the per capita consumption of wheat (Khan *et al*., 2015). In Pakistan, wheat accounts for 1.7% of GDP and adds about 9.1% of value addition. In developing countries, the potential of better production of several crops is declined due to insufficient management and restrictions associated with nutrition. The irrational use of fertilizers has increased the NPK ratio instead of reducing it to a balanced proportion, because there are huge differences in N and P uptake. This is the main factor that limits the productivity of many crops around the globe. Balanced use of fertilizers and fertilization is always vital to maximize yield and production (Ghosh *et al*., 2006).

Phosphorus is essential and important nutrient in different crops. Phosphorus application is mandatory to enhance amount of P in the soil to obtain the best crop yield as several yield related factors. P is commonly added to soils in the form of organic and mineral fertilizers (Sawan *et al*., 2006). Its role in increasing efficiency of photosynthesis, area of leaf, weight of dry root and shoot as well is significant and helps in storage of energy, development of root and early ripening and enhance the P contents in desired plant part (Mohanty *et al*., 2006). Phosphorus is not only essential and necessary to increase yield and related traits of field crops but also had an impact to improve the quality of several characteristics and qualities of various products of origin of plant, while their reduction can restrict growth, flowering delay and maturity as well (Chaubey and Kaushik, 2000) that can reduce yields by 10-15% (Shenoy and Kalagudi, 2005). Phosphorus inputs that are provided as inorganic fertilizers usually get fixed in the soil and become unavailable for the crops. Its deficiency becomes more prevalent in calcareous and alkaline soils (Sarwar, 2005; Sabah *et al*., 2014, 2020).

Soils of Pakistan are P inadequate and P fixing and its insufficiency restricts the crop generation and overall production on less than 90% because of high pH and calcareous soil nature (Gill *et al*., 2004). So, its management is the matter of prime significance. One useful strategy to enhance P is to apply mineral fertilizers which are most likely exceptionally troublesome because of their high expenses and simultaneously these are not good for healthy environment. Also, the significant segment of P fertilizer applied is become fixed with soil components, lessening the adequacy of applied P sources (Gahoonia *et al*., 2000). Accessibility of P in soil can be enhanced by the application of natural manures because these organic manures loosely bind nutrient ions and reduces their fixation in mineral soils (Mohanty *et al*., 2006).

Phosphorus acquisition, application, utilization and exploitation of differences among different crop species and even cultivars would be a promising system to build use productivity of applied P and soil available P. Agribusiness profitability could be expanded through proficient usage and P management because of fixation of P in our soils due to having high soil calcium content (Aziz *et al*., 2006). Current trial was done to appraise role of agro based industry wastes on the P bioavailability from rock phosphate used as phosphocompost (phosphate rich organic manure abbreviated as PROM) and P up take by spring wheat plants.

Materials and Methods

Formation of phosphate rich organic manure (PROM)

Phosphate rich organic manure (PROM) was prepared to check the solubilization of rock phosphate. For this purpose, cow dung, press mud and rock phosphate were used in 1:2 mixed thoroughly in a container and left for three weeks. After three weeks, 2% urea solution was sprayed on it and placed it for one week. Later on, mixture was supplied with 2% DAP and again left for one week. After this, the mixture was air dried and sieved for storage and further used. PROM thus prepared contain Total N: 2%, Total P_2O_5: 3.8%, Total K_2O: 2.0, 2% Urea: Total Nitrogen: 0.92%, 2% DAP (N: 0.36%, P_2O_5: 0.92%).

Experimental scheme

Design of research was completely randomized design (CRD) using and 14 treatments and 06 replications. T_1 = No fertilizer addition; T_2 = Recommended NPK from chemical fertilizer N used as urea, P used as TSP and K used as sulfate of potash; T_3 = T_1 + all P from PROM (phosphorus rich organic manure); T_4 = T_1 + all P from FYM; T_5 = T_1 + all P from compost; T_6 = T_1 + all P from press mud; T_7 = T_1 + P half from mineral sources and half from PROM; T_8 = T_1 + P half from mineral sources and half from FYM; T_9 = T_1 + P half from mineral sources and half from compost; T_{10} =

T_1 + P half from mineral sources and half from press mud; T_{11} = T_2 + all P from PROM; T_{12} = T_2 + all P from FYM; T_{13} = T_2 + all P from compost; T_{14} = T_2 + all P from press mud.

Procedure of crop cultivation

Soil was selected by analyzing and added into pots @ 20 kg/pot. To attain a uniform column of soil in pots, irrigation was applied through tap water. In each pot, 05 seeds of wheat cultivar "Punjab-2011" were sown but only 03 plants were maintained after germination. After germination, total phosphorus and potassium were applied but half dose of nitrogen was applied and after 25 days of germination, remaining nitrogen was applied. To provide nitrogen, phosphorus and potassium to wheat plants, urea, DAP (diammonium phosphate), PROM (phosphate rich organic manure) and potassium sulphate were applied as NPK sources respectively. About forty days after treatment completion, leaf samples were collected for the determination of chemical analysis.

Soil and plant analysis

Various properties of soil were studied (Table 1) pre and post crop cultivation. For analysis of soil, analytical methods provided in Hand Book 60 of U.S Salinity Laboratory Staff (1969) were adopted. The procedures other than these methods are also mentioned separately. Method of Moodie *et al.* (1959) was adopted for organic matter determination. Soil available P was determined by using methodology of Watnabe and Olsen (1965).

Table 1: *Soil properties before cultivation.*

Parameters	Unit	Value
Soil pH	-	7.7
Soil EC	dSm^{-1}	0.81
Soil organic matter	%	0.59
Sodium absorption ratio	-	3.82
Total soil N	%	0.29
Available soil P	ppm	7.8
Extractable soil K	ppm	129.7
Soil Textural Class	-	Clay loam

Statistical analysis

The data were collected and analyzed statistically by using Statistix 8.1 software for analysis of variance (ANOVA) technique and LSD test at 5% level of probability (Steel *et al.*, 1997).

Results and Discussion

Soil pH

A significant impact of mineral fertilizer and organic manures was imparted on pH of the soil of experimental area. Figure 1 depicted that application of chemical fertilizer increased soil pH. The application of recommended NPK from chemical fertilizer (T_2) recorded highest pH (8.66) of soil which was followed by T_1 + all P from PROM (T_3). The application of T_1 + half P from mineral fertilizer + half P from FYM (T_8) and T_1 + half P from mineral fertilizer + half P from compost (T_9) produced 8.19 pH of the soil. The minimum value of pH of soil (7.24) was recorded with T_{13} (T_2 + all P from compost). It was disclosed that application of chemical fertilizers significantly augmented the values of pH of the soil as compared to organic manures.

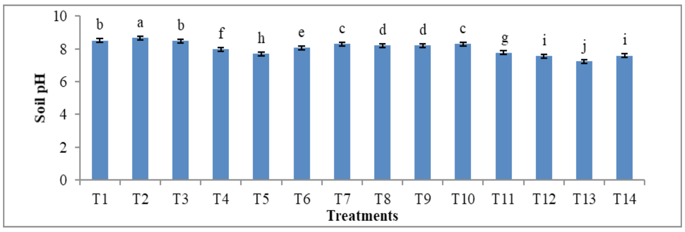

Figure 1: *Effect of various organic and chemical fertilizers alone and in combination on soil pH.*

Soil electrical conductivity (dS m^{-1})

Effect of various organic and mineral fertilizers alone or in mixture on soil EC was checked. Figure 2 exposed that incorporation of various sources of nutrition alone or combined substantially increased soil EC. However, among all tested treatments, the maximum EC (2.75 dS m^{-1}) of soil was noted under T_2 + all P from compost (T_{13}). Treatments T_5 (T_1 + all P from compost) and T_9 (T_1 + ½ P from mineral fertilizer + ½ P from compost) showed same values of soil EC (2.55 dS m^{-1}). The minimum EC (1.25 dS m^{-1}) of soil was observed with T_1 (Recommended N, K and P = 0).

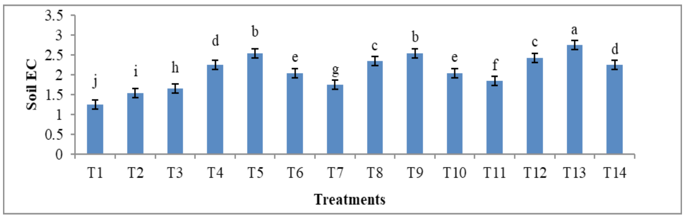

Figure 2: *Effect of various organic and chemical fertilizers alone and in combination on soil EC.*

Soil organic matter (%)

Figure 3 depicted significant impact of various sources of nutrients (organic and mineral) on soil organic matter (%) of experimental area. Highest soil organic matter (0.903%) was observed in treatment grown under T_5 (T_1 + all P from compost) (Figure 3). Soil organic matter of 0.806, 0.798 and 0.826% was recorded in T_7 (T_1 + half P from mineral fertilizer + half P from PROM), T_{12} (T_2 + all P from FYM) and T_{13} (T_2 + all P from compost) respectively. These three treatments (T_7, T_{12} and T_{13}) were statistically similar. However, the lowest organic matter (0.58 %) in soil was measured under T_1 (Recommended N, K and P = 0). Thus, adding organic materials improved percentage of soil organic matter over chemical fertilization.

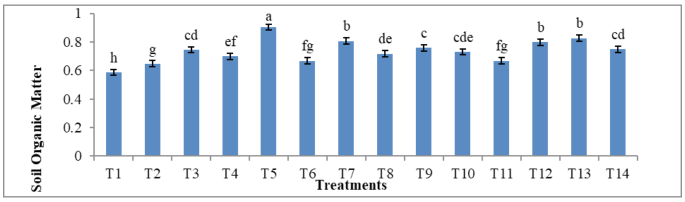

Figure 3: *Effect of various organic and chemical fertilizers alone and in combination on soil organic matter.*

Phosphorus concentration in soil (ppm)

Figure 4 showed that addition of various nutritional sources boosted P in soil. Application of T_2 + all P from PROM (T_{11}) recorded the highest values of P (8.73 ppm) in soil which was followed by T_{12} (T_2 + all P from FYM) and T_{13} (T_2 + all P from compost) that produced 8.10 and 8.15 ppm of P in soil. Minimum values of P (6.11 ppm) in soil were measured with T_1 (Recommended N, K and P = 0). It is concluded from the data, all treatments containing P either chemical or organic enhanced the P in soil as compared to T_1.

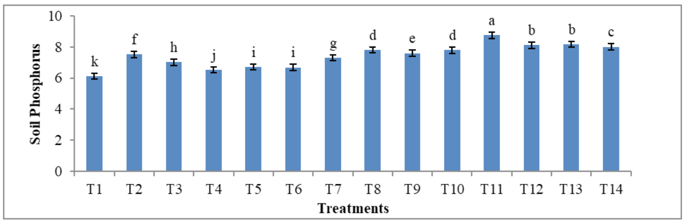

Figure 4: *Effect of various organic and chemical fertilizers alone and in combination on soil phosphorus.*

Water soluble potassium in soil (mmol$_c$ L^{-1})

Figure 5 showed incorporation of nutritional sources in any form (organic or mineral) considerably boosted the K in soil whether used alone or in combined form. However, between all the treatments the maximum K (3.45 mmol$_c$ L^{-1}) in soil was measured under the application of T_4 (T_1 + all P from FYM) which was followed by T_{14} (T_2 + all P from press mud) that produced 3.37 mmol$_c$ L^{-1}of K in soil. The lowest K (2.65 mmol$_c$ L^{-1}) in soil was obtained with T_{11} (T_2 + all P from PROM). It is depicted from results that T_4 treatment was found more effective to produce highest value of K in soil.

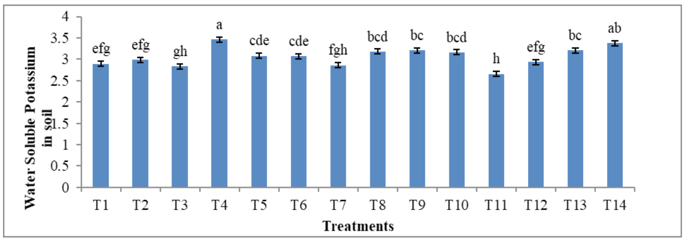

Figure 5: *Effect of various organic and chemical fertilizers alone and in combination on water soil potassium in soil.*

Nitrogen concentration in wheat plants (%)

Maximum N contents (0.911%) in wheat plant was noted in the treatment grown under T_{11} (T_2 + all P from PROM) (Figure 6). Given data displayed in Figure 6 also intimated that N contents in wheat plant of 0.816, 0.820 and 0.821% were recorded under T_4 (T_1 + all P from FYM), T_{13} (T_2 + all P from compost) and T_6 (T_1 + all P from press mud), respectively. These 3 treatments (T_4, T_6 and T_{13}) demonstrated non-significant differences in terms of statistics. The T_1 (Recommended N, K and P = 0) and T_3 (T_1 + all P from PROM) produced lower values of N in wheat plants than all other treatments.

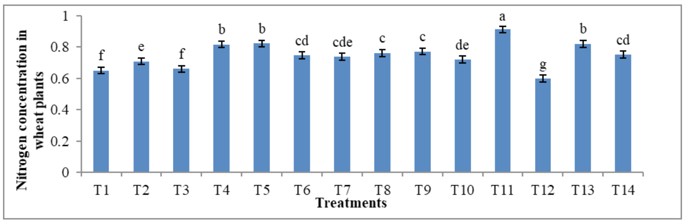

Figure 6: *Effect of various organic and chemical fertilizers alone and in combination on nitrogen content in wheat plants.*

Phosphorus concentration in wheat plants (%)

Data about P contents in wheat plants as exhibited in Figure 7 showed positive impact of applied organic and mineral nutrient sources on P contents in wheat plant. T_{12} (T_2 + all P from FYM) produced highest P contents (0.235%) in wheat plants which were followed by T_{11} (T_2 + all P from PROM) and T_7 (T_1 + half P from mineral fertilizer + half P from PROM) that produced 0.228 and 0.220% P contents in wheat plants, respectively. While the minimum values P contents (0.118%) in wheat plants were measured with T_1 (Recommended N, K and P = 0). According to data, T_{12} performed well than other tested treatments in term of P contents in wheat plants.

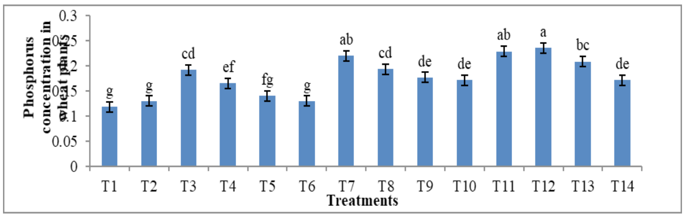

Figure 7: *Effect of various organic and chemical fertilizers alone and in combination on phosphorus content in wheat plants.*

Potassium concentration in wheat plants (%)

Figure 8 showed the positive influence of added nutritional sources on K contents in wheat plants. However, among all treatments, maximum K contents (2.59%) in wheat were noted under the application of T_{11} (T_2 + all P from PROM). Treatments T_{12} (T_2 + all P from FYM) and T_7 (T_1 + half P from mineral fertilizer + half P from PROM) recorded 2.30 and 2.28% K contents in wheat plants. Minimum K contents (1.57%) in wheat plants was obtained with T_1 (Recommended N, K and P = 0). It is intimated from the results that T_{11} was found more efficient to produce optimum value of K contents in wheat plants.

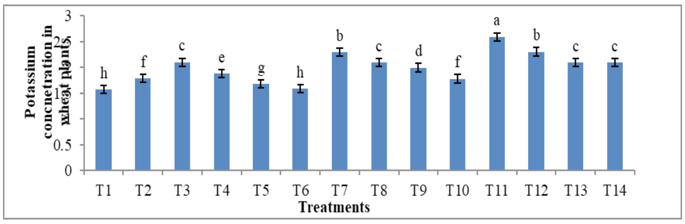

Figure 8: *Effect of various organic and chemical fertilizers alone and in combination on potassium content in wheat plants.*

For plant development, phosphorus is considered as chief supplement and nutrient since it is engaged with cell vitality, movement, transfer, photosynthesis, and respiration (Brady and Weil, 2002). It helps in expanding the area of leaf, P content of shoot and root, weight of shoot dry of plants and crops as well and its inadequacy may lessen crop growth, development, blooming delaying maturity and flower development (Chaubey and Kaushik, 2000). P is essential and necessary in tissues of meristematic cells, where cells are quickly isolated and multiplied. It is basic segment of nucleic acids, phospho-proteins, numerous co-compounds of enzymes and phospho-lipids. Deficiency of P continues biosynthesis of starch. Satisfactory phosphorus contents improve numerous parts of plant physiology, like photosynthesis processes, root elongation, improvement of parallel roots and rootlets of fibrous part (Turk and Tawaha, 2002).

Our findings are in contrast with the findings of Whalen *et al.* (2002) who described that application of FYM can increase the pH in soils. The achievement of greater pH values in manure amended soil over un-amended soil was due to buffering from organic acids as well as bicarbonates in cattle manure. These outcomes are in harmony with the verdicts of Dutta *et al.* (2003) who exposed that when inorganic fertilizers were applied along with organic fertilizers had a higher constructive impact on soil health and improves the soil EC than addition of organic fertilizers alone. Analogous results are also conveyed by Kaur *et al.* (2005) who stated that application of poultry manure and farm yard manure separately or in grouping with chemical fertilizers enhanced the status of organic matter contents of soil, EC, N, and K status. The reduction in soil organic matter contents with inorganic fertilizer may be due to stimulated decay of soil organic matter by the applied fertilizer which led to greater mineralization of nitrogen. Our results are further supported by the work of previous researcher Titilola (2006) who stated that organic matter in the soil increases significantly with organic fertilizer than inorganic fertilizer. A significant reduction of 59% in soil organic matter was observed with inorganic fertilizer. Similarly, Nesgea *et al.* (2012) also showed that application of organic manures enhanced the soil organic matter as compared to chemical fertilization.

The increment in the soil P under combined application of chemical fertilizer and PROM might have been due to promising soil pH. The favorable pH has augmented the P solubility in soil (Sarwar *et al.*, 2009). According to the findings of Singh *et al.* (2002) incorporation of manures including animal dung and press mud boosted the availability of organic matter which resulted in an increase of desorption of phosphate and enhanced the P content in the soil. The enhancement in soil K with organic manures is due to the direct addition of K to the available pool of soil and reduction in soil K absorption.

Similar conclusions were presented by Singh *et al.* (2001), Oo *et al.* (2010), Selvakumari *et al.* (2000), Dixit and Gupta (2000), Sarwar *et al.* (2009) as well as Chaubey and Kaushik (2000) who reported that when inorganic fertilizers were applied along with organic sources such as compost, farm yard manure and green manure caused excessive improvement in plant N contents. Our outcomes are further reinforced by the conclusions of Sabah *et al.* (2014, 2020) showing positive impact of nutrients application on growth and yield of wheat as well as boosted the P contents in crop plant.

Conclusions and Recommendations

Incorporation of any source of nutrients either applied individually or in combination boosted the growth and nutrients contents in wheat as well as properties of the experimental soil. Among all tested treatments, highest N and K contents in wheat plants were recorded withT_{11} (T_2 + all P from PROM). Soil organic matter was observed maximum with T_5 (T_1 + all P from compost). It is concluded that all treatments enhanced nutrient content of wheat significantly than no phosphorus application but T_{11} was found more effective for achieving the optimum results.

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Novelty Statement

Prom proved enriched source of P nutrition and enhanced nutrient content in wheat plants.

Author's Contribution

Rana Amir Shahzad: Conducted the research trial.
Ghulam Sarwar: Supervised the trail.
Sabir Hussain Shah and Sher Muhammad: Technical assistance at every step for write up.
Mukkram Ali Tahir: Co-supervision of the trial.
Noor-us-Sabah: Statistical analysis.
Muhammad Aftab: Proof reading and final editing.
Muhammad Zeeshan Manzoor and Imran Shehzad: Helped in all field and lab. work.

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

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