Research Article

Impact of Integrated Application of Organic and Mineral Fertilizers on Bioavailability of Phosphorus and Potassium in Maize (*Zea mays* L.)

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Abstract | Organic fertilizers incorporation to soil has become an imperative need in order to achieve sustainable agricultural productivity. Since, incorporation of organic fertilizers improve soil properties and subsequently increased availability of nutrient particularly phosphorus (P) and potassium (K). A pot study was performed to identify the effect of organic fertilizers on bioavailability of P and K in maize by applying three types of organic sources as farm yard manure (FYM), poultry manure (PM) and filter cake press mud (FCP). Five treatments were applied with four replications including T1 as control, T2 as inorganic fertilizers in recommended dose NPK (150: 100: 110 kg ha^{-1}), T3 as FYM (10 t ha^{-1}) in addition to chemical NPK application, T4 as poultry manure (10 t ha^{-1}) also named as compost-I in addition to chemical NPK application and T5 as press mud or compost II (10 t ha^{-1}) in addition to recommended chemical NPK application. The results had demonstrated that all the organic and chemical fertilizers increased plant growth and quality attributes (plant height, plant stem diameter, total leaf chlorophyll contents, leaf are index (LAI), shoot and root dry weight, seed germination %, leaf P %, and leaf K %) significantly as compared to control. Similarly, soil chemical properties including organic matter (O.M %) contents, available and extractable concentration of P (ppm) and K (ppm) in soil also increased. Although, all the organic sources had shown positive results but press mud application performed best regarding availability of K and poultry manure performed best in terms of P availability.

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Introduction

Maize ranks third major cereal crop of Pakistan which is cultivated on an area of 1417.8 thousand hectares giving annual production of 8939 thousand tons (Economic Survey of Pakistan, 2021). It belongs to Poacea family and falls in category of C4 plants which is consumed as forages by animals and

as food by human beings. It has also its significance in industry and feed products, alcohol and ethanol industry and in vegetable oil production (Kumar and Jhariya, 2013).

Phosphorus (P) availability is also important for the growth of crop. It is important for plant to store energy in the form of ATPs, root elongation and development. It is key nutrient present in soil and recycled to soil medium as litter, organic manures and plant residues. Phosphorus present in soil is not leached easily but on other end it is lost adversely by water and soil erosion (Aziz *et al*., 2010). Therefore, application of manures to soil could be effective amendment to improve provision of all nutrients which subsequently increase uptake of nutrients to plant to get optimum yield and growth. Application of organic manures particularly poultry manure and press mud (filter cake) in high concentration could improve availability of P to plants in soil for a long period. Chemical application of fertilizers also enhanced P availability to soil but it is hazardous for health and environment as well as sole application of fertilizers in chemical form (NPK) also disrupts soil structure, causes crusting in soil, triggers depletion of other essential elements. Phosphorus is available to all plant in the form of soluble orthophosphate (HPO_4, H_2PO_4) (Aziz *et al*., 2010).

Pakistani soils are naturally organic matter deficient due to its arid to semi-arid climate. In our country level of organic matter is lower than the level of need. Most of the regions in Pakistan have less than 1% organic matter concentration (Azam *et al*., 2001). There could be so many reasons of low organic concentration in Pakistani soils including climatic conditions, intensive tillage and injudicious use of mineral fertilizers. Therefore, it is necessary for these types of soils to apply organic fertilizers in different forms such as poultry manure, farmyard manure, press mud and compost. Because organic matter has ability to improve soil physical, chemical and biological attributes to improve nutrient supply promptly when plant needs as compared to chemical and mineral fertilizers which helps the farmer in increasing yield and productivity of crop. Therefore, application of organic and inorganic manure in integrated formulation could increase crop yield as described by different researchers in various studies (Sabah *et al*., 2014).

Application of organic fertilizers in the form of filter cake press mud obtained from sugar industries in the form of soft, brown and spongy material has ability to increase organic carbon and nutrition in available form in soil. It has high contents of nutrients due to its chemical composition (Cakmak, 2008). Nutrients concentrations of filter cake press mud is about 1.27% P, 2.40% Ca, 1.82% K, 2.60% S and trace amounts of zinc, copper, iron and manganese etc. The problem of food for over population could also be solved by using efficient organic fertilizers instead of inefficient chemical fertilizers (Jones and Healey, 2010).

In last few decades, application of chemical or inorganic fertilizers has increased due to its rapid output and sustainable production of crops. But due to injudicious and maximum use of chemical fertilizer, soil has depleted for plant nutrition especially for phosphorus (P) and potassium (K) and other trace elements because maximum farmers apply only nitrogen nutrient which are considered as among the main reasons of lower concentration of organic matter in soil (NFDC, 2003; Arrieche-Luna and Ruiz-Dager, 2010). Inorganic fertilizers having draw backs such as low use efficiencies and high costs have captured the attention of farmers to convert from inorganic to organic fertilization of crops. Various changes established by applying organic fertilizers like farm yard manure (FYM), Poultry manure (PM), press mud (PrM) in physical, chemical properties and biological attributes of soil. These attributes of soil involved soil aggregation, water holding capacity, cation exchange capacity (CEC), soil pH and microbial activity in soil or in plant root zone. Soil pH (activity of hydrogen ions) is most important chemical character of soil which changes effectively by application of organic matter. By the application of organic matter, pH of soil changes and moves to neutral from acidic or basic scale of pH (Walker *et al*., 2004). In the same way organic matter also acts as a binding agent in soil which is main cause of soil aggregation. Organic matter is also called as nutrient bank which improve provision of all major nutrient and other elements required in trace amount by plant (Marschner, 1995; Clemente and Bernal, 2006; Agbede *et al*., 2008; Muhammad and Khattak, 2009).

Therefore, a pot study was conducted in order to explore effects of organic materials in addition to application of NPK on bioavailability of P and K as well as yield and quality attributes of maize crop.

Materials and Methods

The research was conducted in pots at the research area of Department of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan in order to evaluate the role of various sources of organic fertilizers in addition to recommended application of NPK on P and K bioavailability in maize crop and concentration of P and K in different parts of maize plant. Before conducting a pot experiment soil physico-chemical attributes were determined by taking a random sample of soil from research area which is used to fill the plant pots for maize growth. A composite soil sample was prepared by taking it from different locations of research area with the help of sampling tools from the depth of 0-30 cm. After that soil sample was cleaned with the help of hand to remove debris and stones and then brought to the laboratory to make a final sample by using 2mm sieve under shadow to dry in air for analysis by using standard procedures mentioned in handbook 60 (1954) of US laboratory staff.

Experimental design and layout

Soil (Table 1) was air-dried and passed through a 2 mm sieve, and 8 kg of soil (based on dry weight) was thoroughly mixed with organic materials and applied with recommended doses of N, P and K (150: 100: 110 kg ha^{-1}). Plastic pots were filled with mixture of soil and organic materials for sowing of maize seeds. Following Five treatments were applied to plant pots placed under complete randomized design with four replications. T1, Control (Untreated) without P fertilizer; T2, recommended doses of NPK; T3, FYM (10 t ha^{-1}) in addition to recommended NPK; T4, Compost-1 having poultry manure (10 t ha^{-1}) in addition to recommended NPK; T5, Compost-2 having press mud (10 t ha^{-1}) in addition to recommended NPK. Composition of these organic materials was given in Table 2.

Four seeds were sown in each pot and each treatment. After emergence, maize plants were thinned to maintain only one plant for further determinations up to harvesting. Determination of soil organic carbon was made by loss on ignition (L.O.I) method with the help of electric muffle furnace. Plant samples were wet digested using acid mixture (HNO_3+ $HClO_4$ @1:2). Estimation of K was made using Flame photometer. The amount of available portion of P in soil after harvesting was determined. Phosphorus contents in both soil and maize plants were determined by spectrophotometry (Olsen, 1954). Chlorophyll contents (a, band total) of maize leaves were determined by using spectrophotometer in specific wavelengths as explained by Lichtenthaler *et al*. (1990).

Table 1: *Soil characteristics of experimental area (pre-analysis).*

Sr. No.	Determinations	Unit	Value
1	pH_s	-----	8.2
2	EC_e	dSm^{-1}	1.27
3	Soil Organic matter	%	0.51
4	Available potassium	ppm	110
5	Available Phosphorus	ppm	7.81
6	Ca^{+2}+ Mg^{+2}	$mmol_e L^{-1}$	3.2
7	Soil textural class		Sandy clay loam

Table 2: *Chemical properties of organic materials used in study.*

Determinations	Unit	FYM	Press-mud	Poultry manure
pH		8.0	9.2	8.21
Total Nitrogen	%	1.67	1.65	1.81
Available phosphorus	%	0.67	1.28	0.81
Potassium	%	1.12	0.45	0.90
Organic matter	%	35.57	31.21	36.12
Total organic carbon	%	20.68	18.14	22.60
C: N Ratio		12.38	10.99	12.50

Leaf area index (LAI) was determined using following modal as described by Watson (1956).

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

The collected data was analyzed statistically with the aid of software statistics 8.1 to calculate ANOVA and significant difference of means of treatments were compared by using Tukey's test at the probability level of 5% (Steel *et al*., 1997).

Results and Discussion

Plant height (cm/plant)

Data regarding plant height of maize is indicated that all the treatments are different from each other significantly with respect to control which is untreated (Figure 1). Maximum plant height was observed in T5 (150.73 cm) treatment (compost-II) followed

by T4 (compost-I, poultry manure in addition to recommended NPK), T3 (FYM) and T2 (chemical fertilizer NPK) treatments and minimum plant height was indicated by (T1) control treatment (91.52 cm) which was without phosphorus (P) fertilizer. Overall, all the treatments showed significant increase in plant height. It was also noticed that organic sources of fertilizers performed best to promote plant height as compared chemical sources.

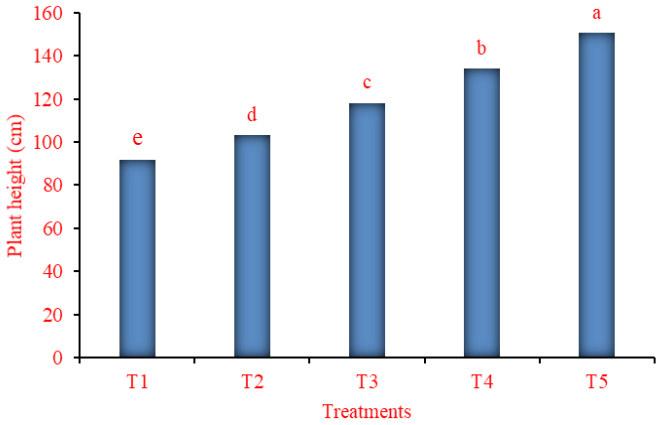

Figure 1: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure and filter cake press mud (FCP) on maize plant height (cm).*

Stem diameter (mm)

It is reflected from the graphical information regarding stem diameter (mm) that maximum stem diameter was observed in case of T5 treatment (21.07 mm) where press mud (compost-II) was applied (10 t ha^{-1}) in addition to recommended NPK to maize crop while minimum stem diameter (10.43 mm) was recorded in case of control (T1) treatment where zero P was applied (Figure 2). Readings of T4 (poultry manure in addition to NPK), T3 and T2 (NPK) were also at par as compared to untreated control treatment. A significant behavior was observed between T5 and T4 treatment. All the treatments were different significantly from each other relative to control.

Shoot dry weight (g $plant^{-1}$)

Shoot dry weight of maize plant was also maximum (16.43 g $plant^{-1}$) in case of T5 treatment (compost-II as filter cake press mud) followed by T4 (compost-I as poultry manure), T3 (FYM) and T2 (chemical fertilizer) treatments (Figure 3). Minimum shoot dry weight (9.4 g $plant^{-1}$) of maize was recorded in T1 (untreated) control treatment where no chemical and organic fertilizer of P was applied. It was also observed from the graphical data that all organic fertilizers showed best results than application of chemical fertilizers. All the chemical and organic treatments were different significantly from each other relative to control.

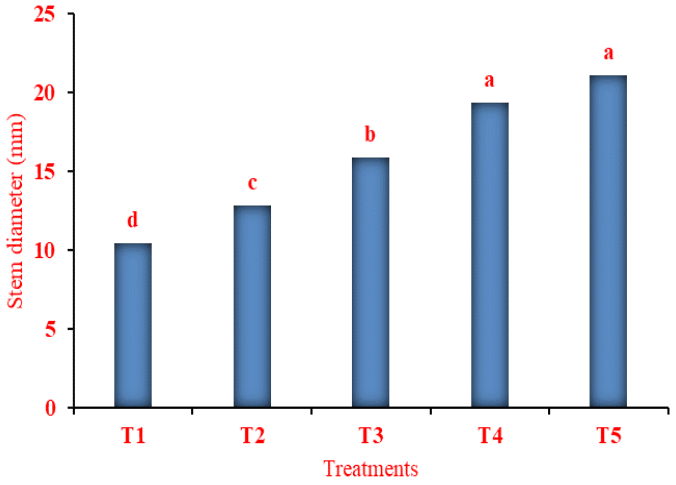

Figure 2: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure and filter cake press mud (FCP) on maize stem diameter (mm).*

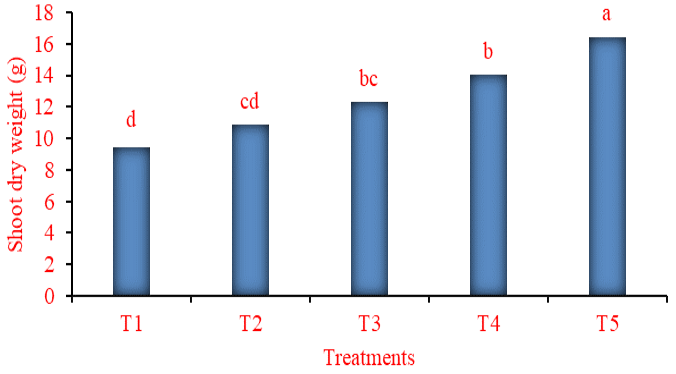

Figure 3: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure and filter cake press mud (FCP) on maize shoot dry weight (g).*

Root dry weight (g pot^{-1})

Graphical data related to root dry weight of maize plants elucidated (Figure 4) that highest root dry weight (10.33 g) was recorded in T5 treatment where organic fertilizer in the form of filter cake press mud (compost-II) was applied followed by T4 as compost-I organic fertilizers (poultry manure), T3 as farmyard manure in addition to recommended NPK and T2 as chemical application of N: P: K showed increased root dry weight gradually as compared to control treatment. While minimum reading of root dry weight (5.1 g) was indicated by control treatment (T1) which is untreated. All treatments had shown significant increase in dry root weight relative to control.

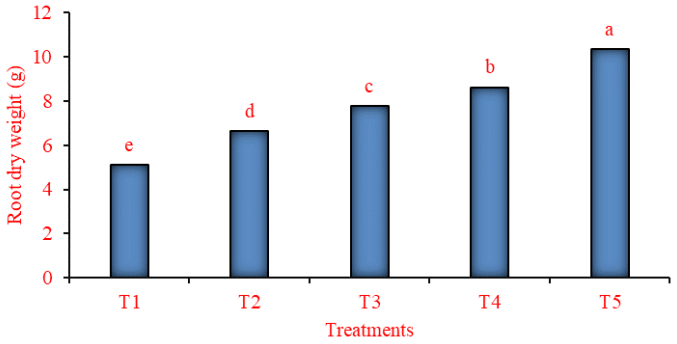

Figure 4: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure (compost-I) and filter cake press mud (compost-II) on maize root dry weight (g).*

Leaf area index (LAI)

A non-significant effect of organic manure and chemical fertilizers was recorded in all the treatments relative to control which is untreated and without any fertilizer (Figure 5). The maximum value of leaf area index was noted in treatment (T5) where press mud was applied as compost-II showing the value of (5.83) and followed by T4 (poultry manure as compost I) 4.95, T3 (farm yard manure) 4.54 and T2 (chemical application of NPK) 4.27 and minimum leaf area (3.31) was noted in control treatment which was untreated with P fertilizer.

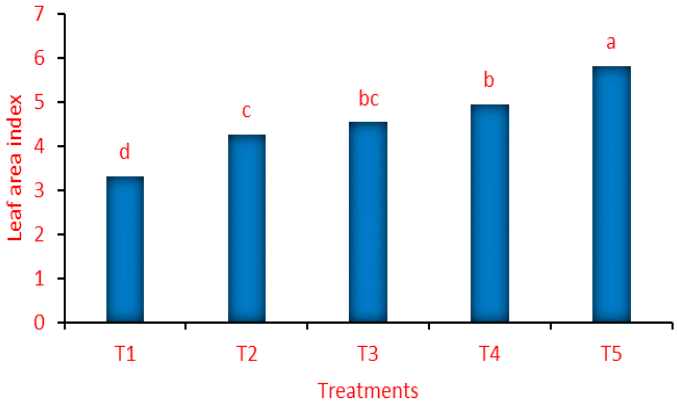

Figure 5: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure (compost-I) and filter cake press mud (compost-II) on maize leaf area index (LAI).*

Total Chlorophyll contents (µg g^{-1})

The maximum value of total chlorophyll contents (5133 µg g^{-1}) in maize leaves were recorded in case of T5 treatment (Figure 6) which was applied in the form of press mud and minimum chlorophyll contents were found in control treatment showing the value of 2470 µg g^{-1}. All the treatments had shown a significant difference among each other and relative to control treatment. A significant behavior was observed among all the treatments over untreated control.

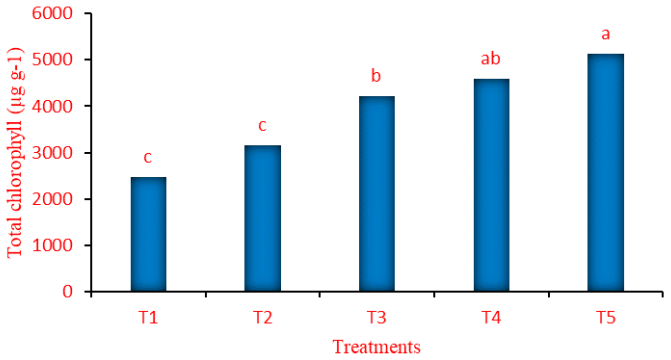

Figure 6: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure (compost-I) and filter cake press mud (compost-II) on maize total chlorophyll contents (µg g^{-1}).*

Leaf P contents (%)

Results regarding phosphorus concentration (P) of maize leaf in graphical form indicated that maximum P concentration (0.86 %) in maize leaf were obtained in T4 treatment where organic manure was applied as poultry manure and minimum concentration (0.35 %) of leaf P was indicated by T1 which was untreated and unfertilized with any organic or inorganic P form of fertilizer (Figure 7). After T4 treatment T5 and T3 showed maximum values (0.74 % and 0.72 %) of P concentration which was non-significant difference. While T2 where chemical fertilizer was applied in the form of N, P and K showed 0.54 % P value.

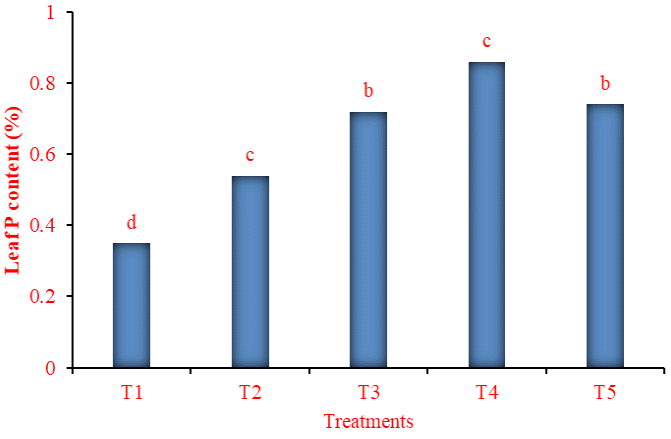

Figure 7: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure (compost-I) and filter cake press mud (compost-II) on maize leaf P contents (%).*

Leaf K contents (%)

Graphical data of potassium concentration in maize leaf had demonstrated that all the chemical and organic sources of fertilizers had increased potassium concentrations in maize leaves relative to control treatment which remained untreated (Figure 8). Maximum value of potassium percentage (1.56%) in maize leaf was obtained by T5 treatment which was fertilized with press mud. Minimum potassium

percentage of potassium (1.08) was recorded in control (T1) treatment. All the treatments were significantly different from each other relative to control (untreated).

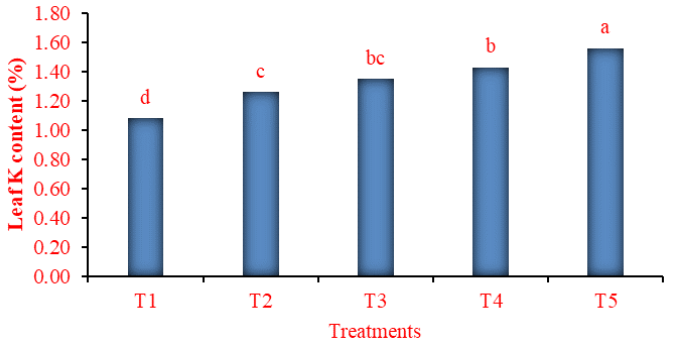

Figure 8: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure (compost-I) and filter cake press mud (compost-II) on maize leaf K contents (%).*

Soil organic matter (%)

Concentration of soil organic matter after harvesting of maize crop was also increased where organic sources of fertilizers were applies in the form of farmyard manure, poultry manure and press mud as compared to control treatment which was untreated (Figure 9). A non-significant behavior was determined between control (T1) and T2 treatment (chemical NPK application) which was free from organic fertilization. Maximum concentration of organic matter (1.10 %) was determined in T5 (press mud compost II). Minimum (0.70 %) organic matter was recorded in T1 (control) treatment.

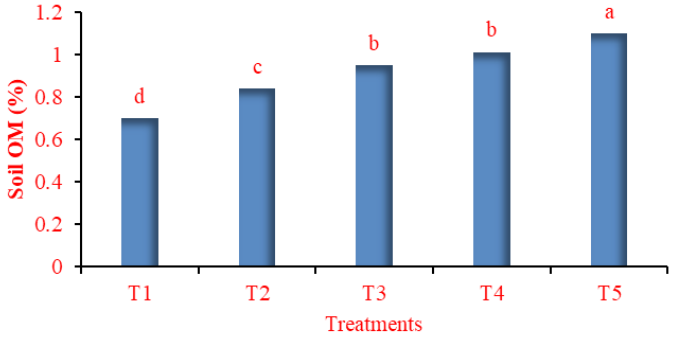

Figure 9: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure (compost-I) and filter cake press mud (compost-II) on soil O.M contents (%).*

Soil P contents (ppm)

Data regarding phosphorus concentration (P) in soil after harvesting of maize had indicated that maximum P concentration (13.0 ppm) in soil was obtained in T4 treatment where organic manure was applied as poultry manure (compost I) in addition to NPK and minimum concentration of P in soil after harvesting was indicated by T1 (9.21 ppm) which was untreated and unfertilized with any organic or inorganic form (Figure 10). After T4 treatment T5 (compost-II as FCP) and T3 showed maximum values (11.9 ppm and 11.10 ppm) of P concentration, respectively. While T2 where chemical fertilizer was applied in the form of N, P and K showed 10.5 ppm P value.

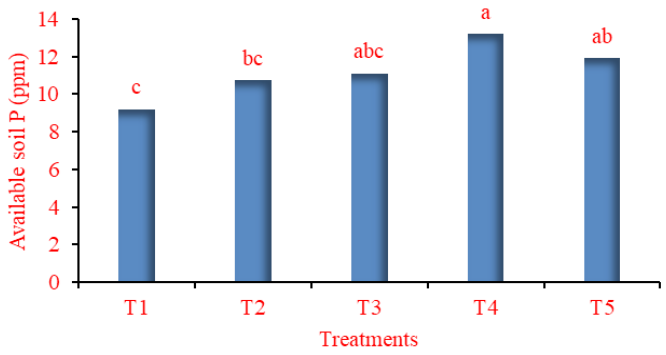

Figure 10: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure (compost-I) and filter cake press mud (compost-II) on available soil P (ppm).*

Soil K contents (ppm)

Graphical data of potassium concentration in soil after harvesting of maize crop demonstrated that all the chemical and organic sources of fertilizers had increased potassium concentrations in soil relative to control treatment which remained untreated (Figure 11). Maximum value (240 ppm) of potassium in soil was obtained by T5 treatment (Compost-II) which was fertilized with press mud (FCP) and followed by T4 (210 ppm), T3 (200 ppm), T2 (190 ppm) and T1, respectively. Minimum potassium value (167.30) was recorded in control (T1) treatment.

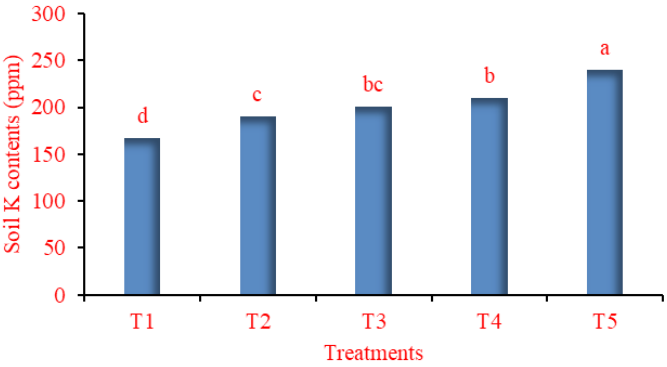

Figure 11: *Effect of organic fertilizers (Control P, NPK, FYM, Poultry Manure (compost-I) and filter cake press mud (compost-II) on extractable soil K (ppm).*

Effect of organic materials on growth attributes of maize

The results reflected that organic manure increased plant growth attributes. Plant height (cm), stem diameter (mm) and leaf area were increased in

maximum ratio in T5 treatment where press mud was applied as compost-II to maize plant as an organic source as than poultry manure (compost-I), farm yard manure (FYM) and chemical application of NPK fertilizers. Subsequently leaf area index (LAI) was also increased with same trend. The same results were noted by Boateng *et al.* (2006), Muhammad and Khattak (2009). Similarly shoot and root dry weights of maize plant were also recognized in press mud application as organic fertilizer than other organic and in organic sources of fertilizers. All these improvements in plant growth attributes may be due to increased mineral nutrition to plant especially P and K due to poultry manure and press mud application. The improvement in plant growth parameters were also determined by (Muhammad and Khattak, 2009; Boateng *et al.*, 2006; Hirzel *et al.*, 2007). They also suggested that this improvement in plant growth attributes might be due to increased availability of P and K nutrition due to organic sources of fertilizers which take part in increasing fertility status of soil particularly nitrogen and phosphorus and potassium nutrients (Marschner, 1995) which play significant function in enlargement of plant cell, chlorophyll formation and root growth. The similar results were also found by Soro *et al.* (2014) who reported that maize seeds germinate well when germination percentage is more than 70 %.

Effect of organic materials on leaf P and K and total chlorophyll contents in maize

Increase in P concentration in plant leaf was also maximum in treatments where organic sources of fertilizers were applied as compared to in organic sources fertilizers or without any fertilizers. Maximum P concentration in maize leaves were noticed where poultry manure filter cake press mud and farmyard manure (10 t ha^{-1}) in addition to chemical fertilizer were applied. This increased concentration of P and K values in plant vegetative parts could be attributed to high uptake of nutrients from soil due increased root mass and growth. More roots or roots proliferation increased uptake of nutrients in plants. Our findings are in the same line of results of Aziz *et al.* (2010). Higher concentration of P is also due to high availability of nutrients because of organic matter application which promote availability of nutrients present in soil natively (Mohanty *et al.*, 2006; Hirzel *et al.*, 2007; Ewulo *et al.*, 2008; Garg and Bahl, 2008). Total chlorophyll contents were also increased by application of organic sources of fertilizers than chemical fertilizers and control pots which were remained untreated. Maximum chlorophyll contents were increased where press mud was applied as organic source followed by poultry manure and farm yard manure relative to control. This may be due to the fact that most of the nutrients could be available at the site of activity of photosynthesis process which is ultimately responsible of crop yield. The same results were obtained by Amujoyegbe et al. (2007) who also suggested that organic manure is source of nutrients which increase the availability of other nutrients in soil and make available to plant to regulate plant metabolism and other reactions in plant like photosynthesis to increase total chlorophyll contents and plant production.

Effect of organic materials on soil attributes

It was also revealed from the results that addition of different sources of organic manure increased organic matter concentration in soil after harvesting of maize crop. All the organic sources increased organic matter concentration in soil but maximum organic percentage was found in T5 treatment where filter cake press mud was applied as organic sources of fertilizers in addition to inorganic fertilizers. This may be due to the effect of increased activity of microbes in plant roots as compared to T1 control which is untreated with P fertilizers. Increased organic matter concentration in soil could also be due to microbial activity and releasing of organic substances by plants into soil (Marschner, 1995). Other reason of increased concentration of organic matter could also be itself addition of organic sources of organic matter into soil (Agbede *et al.*, 2008). Addition of organic fertilizers improved organic matter concentration in soil which is ultimately a bank of nutrients that increased availability of nutrient in increased concentration in soil to uptake by plant. Therefore, concentration of P and K in soil also increased due to addition of organic sources of fertilizers than chemical application of N, P and K or without any fertilizer. This may be due to availability of respective nutrients in organic sources. The similar results were obtained from the study of Cavigelli and Thien (2003). Addition of organic matter increase water concentration in soil which helps in availability of P to plant from soil through diffusion (Marschner, 1995; Boateng *et al.*, 2006).

Conclusions and Recommendations

Incorporation of organic and chemical fertilizers improved the plant growth, yield and quality. All

sources of organic and mineral nutrients increased the plant growth and quality attributes (plant height, plant stem diameter, total leaf chlorophyll contents, leaf are index (LAI), shoot and root dry weight, seed germination %, leaf P %, and leaf K %) significantly as compared to control. Similarly, soil chemical properties including organic matter (O.M %) contents, available and extractable concentration of P (ppm) and K (ppm) in soil also improved. Although, all the organic sources had shown positive results but press mud application performed best regarding availability of K and poultry manure performed best in terms of P availability. However, verification of this pot trial needs to be testified under field conditions.

Novelty Statement

Combined use of organic and mineral sources of fertilizers improved maize yield and soil attributes.

Author's Contribution

Noor-us-Sabah: Designed and supervised
Mukkram Ali Tahir: Co-supervised the research
Tayyab Boota: Conducted the research
Muhammad Luqman: Statistical analysis
Ghulam Sarwar: Technically assisted at every step
Ameer Hamza and Amir Aziz: Laboratory analysis

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

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