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Comparative analysis of organic and inorganic amendments on maize yield and soil health in clay loam soil

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Abstract

Maize (*Zea mays* L.) is widely regarded as a valuable food and fodder crop. Organic and inorganic nutrients are required for crop growth and soil health improvement. This study was conducted at experimental site of Gomal University Dera Ismail Khan, KP, Pakistan, and aimed to evaluate the performance of maize fertilized with organic and inorganic fertilizers in clay loam soil. The organic amendments were farmyard manure (FYM), poultry manure (PTM), and pressmud (PM), whereas the inorganic fertilizers were N, P_2O_5, and K_2O. As a control, no ameliorants were added to the soil. The experiment was done in a randomized complete block design with three replications. The results show that when NPK @ 150+100+60 kg/ha^{-1} was given to maize crop, there was a higher increase rate in terms of plant height, number of plants per plant, cob weight, grain weight, thousands grain weight, grain yield, biomass yield in NPK treated soil in comparison to FYM, PTM, PM, and control (2019 and 2020). Similarly, economic study revealed that soil treated with inorganic fertilizer had the highest benefit-cost ratio (BCR) compared to other treatments. Furthermore, the findings indicate that organic additions boosted the NPK concentration of the soil. Conclusively, NPK application appears to be more successful than organic nutrition sources for maize productivity.

Keywords: Manure, Maize growth, NPK, Pressmud, Soil properties

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Introduction

Maize is consumed as a food, feed, and industrial raw material in the manufacturing of edible value-added goods (Batool et al., 2019; Noor et al., 2021). It is the third most main cereal crop in Pakistan and is termed as the "Queen of cereals" because of its usage for multipurpose (Anjum et al., 2014; Aslam et al., 2021; Iqbal et al., 2022; Raza et al., 2023). Maize crop yields can be boosted by using various fertilizers and insecticides. Because fertilizer is expensive, Pakistani farmers are unable to apply the ideal amount; as a result, many of them use little amounts of inferior fertilizer, which lowers output. This chemical fertilizer is of poor grade and does not provide the crop with enough nutrients (Gruhn et al., 2000). Organic amendments such as FYM and PTM are not only containing abundant nitrogen (N), phosphorus (P), and potassium (K) but also micronutrients. Deksissa et al. (2008) reported that these amendments when combined with inorganic N, cause improvement in soil physical characteristics including soil moisture, aeration, nutrient retention, water holding capacity and water infiltration rate. Another source of organic nitrogen is PM, which is made from sugarcane. Its quality is determined by the technique of formation, sugar cane variety, soil type, and nutritional content (Rangaraj et al., 2007).

Organic amendments (farmyard and poultry manure) have a high concentration of macronutrients (N, P, and K) and micronutrients (Noor et al., 2021; Shehzad et al., 2022; Shehzad et al., 2023). Deksissa et al. (2008) found that applying organic fertilizer (OF) in addition to inorganic N improved soil attributes such as soil structure, water holding capacity, aeration, nutrient retention, and water infiltration rate. The PM prepared from sugar cane, is another source of organic N. The quality of PM is determined by the manner of formation, the kind of sugar cane, the region of sowing, the type of soil, and the nutritional content. According to the findings of Sarwar et al. (2008), the addition organic manure into the soil improved chemical and physical characteristics of

soil and also increased yield of the wheat and rice crop. The application of OM (15 Mg per hectare) increased organic carbon (0.143%) and crop yield. The FYM addition not only improves hydraulic conductivity and total porosity of soil but also and decrease soil bulk density **(**Appavu & Saravanan, 2000). The PM, PTM, and FYM are used in agriculture farming to meet the organic form of nitrogen (N) and energy components requirements. In the compost, OM is present in high concentrations. By utilizing compost and inorganic N, the physicochemical characteristics of the soil can be enhanced, increasing crop output. According to reports, adding FYM 10 t ha^{-1} to sodic soil improved its physical and chemical properties, including as water permeability, porosity, bulk density, and hydraulic conductivity, and this enhanced crop yield (Hussain et al., 2001).

About 15 million tons of FYM are utilized as organic manure in Pakistan (Azam et al., 2012). PTM was estimated to have been 290 million tonnes as of the latest recent estimations. Poultry droppings add around 101000 tonnes of organic nitrogen (ON), 58000 t of phosphorus (P_2O_5), and 26000 t of potassium (K_2O) to the PTM. PTM is disliked by Pakistani farmers due to its unpleasant odor, however there is no information on how it affects wheat and maize yields. According to Anonymous (2017), in order to meet the demands for hidden hunger, the production of wheat and maize products should be increased in many countries, including Asia. Ali et al. (2012) witnessed that OF promote seed germination and root growth, while tillage practices help to conserve the soil moisture, ensuring better aeration, hence aid to increased crop yield. Sarwar et al. (2009) reported two reasons for less fertile soils of Pakistan. One of them was the presence of less quantity of soil macronutrient, while other was low content of organic matter. Researchers have tested different composts for the improvement soil fertility. They observed that the use of compost resulted in significant change in soil properties like soil pH, electrical conductivity (EC), and sodium adsorption ratio (SAR). Mahdy et al. (2011) experimented with different compost @ 12 and 24 ton ha^{-1}, with and without fertilizer for the purpose to improve soil fertility as well as crop yield. They noticed that SAR and pH of soil were become low due to leaching of sodium and release of calcium in acidic soil. The current study was designed to evaluate the performance of maize fertilized with organic and inorganic fertilizers in clay loam soil.

Materials and Methods

Experimental site

The present study was intended to examine the effect of various organic and inorganic amendments on soil properties under maize crop. This study was conducted at research area of Gomal University, D. I. Khan (31.696^o N and 70.5491^o E).

Experimental layout & measurements

This experiment was conducted using RCB Design with three replicates (Table 1). The sowing of maize (S-7720) was done manually in February 2020 and 2021 on ridges. The different treatments i.e., T1: control, T2: FYM@ 15 tons ha^{-1}, T3: PM @ 15 tons ha^{-1}, T4: pressmud @ 15 tons ha^{-1}, T5: NPK @ 150:100: 60 kg ha^{-1} were applied. The characteristics of organic amendments are given in Table 2. Maize ears were harvested when they had fully turned brown and dry at physiological maturity, as evidenced by the establishment of block layers. Harvested ears were air dried till 12% moisture content. The plant heights (PHs) were measured using a measuring tape, and the average plant height was calculated. In the case of the number of leaves per plant, five plants were picked at random from each plot and the average was computed by counting. Cob weight (g), thousand-grain weight (g) and grain weight per plant were measured by digital balance. Biomass yield (BY) was measured from biological yield (BY) = biomass m^{-2} (kg) x 10000. The soil sampling was done at the depth of 15 cm with help of auger and composite samples were made for the determination of physical and chemical characteristics of soil. The physical and chemical properties of experimented soil were done according to the standard procedures Table 3.

Economic analysis

For the comparison of the cost and revenue of maize, benefit cost ratio (BCR) was calculated by using Eq. 1.

BCR = TR/TC

Where BCR= Benefit cost ratio, TR= Total revenue, TC= Total cost.

Statistical analysis

The data was analysed statistically at the harvest of crop using software Statistix 8.1. The analysis of variance (ANOVA) technique was applied (Steel et al., 1997) and the comparison of means was done using Tukey's HSD Test (Gomez and Gomez, 1984).

Results

Effect of organic and inorganic amendments on maize growth attributes

The results obtained show that various sources of nutrients had noteworthy effect on PH of maize during both the years (Fig. 1). The application of recommended NPK (T5) produced the maximum number of plant height (224.33 cm and 222.11 cm during 2019 and 2020, respectively), which was 11.99% and 14.22% more in comparison to unfertilized control for the period of two years. Application of different sources of OMs

also significantly influenced the PH (Fig.1a). Amongst the OMs, the maximum pH (219.20 cm and 220 cm during 2019 and 2020, respectively) was recorded in the treatment where PM (T4) was applied. This treatment was followed by treatments T3 and T2, respectively. The control treatment (T1) where nutrient was not applied, showed minimum PH (198.33 cm and 196.40 cm during 2019 and 2020, respectively). Results showed no. of leaves per plant were greatly influenced by various sources of fertilizer (Fig.1b). The top no. of leaves per plant (14.45 and 14.33) was obtained from the treatment receiving NPK (T5) in both the years, which was 5.58% and 19.41% more than control during both the years. Different source OMs also showed significant effect on the no. of leaves per plant. Amongst the OMs, the treatment T4 showed maximum no. of leaves per plant (13.68 and 14.0). This was followed by T3 and T2, which showed almost identical no. of leaves per plant. The least no. of leaves per plant (12.0 and 12.0 during 2019 and 2020, respectively) were obtained from the control treatment (T1) where nutrient was not applied. Similarly, maximum leaf area index was noticed for NPK (T5) and minimum was recorded for control (Fig.1c).

Table 1 Blocking of area

Block 1	Block 2	Block 3
T_1: Control	T_4: Pressmud @ 15 tons ha^{-1}	T_5: NPK 150:100: 60 kg ha^{-1}
T_2: FYM @ 15 tons ha^{-1}	T_5: NPK 150:100: 60 kg ha^{-1}	T_4: Pressmud @ 15 tons ha^{-1}
T_3: PM @ 15 tons ha^{-1}	T_1: Control	T_2: FYM @ 15 tons ha^{-1}
T_4: Pressmud @ 15 tons ha^{-1}	T_2: FYM @ 15 tons ha^{-1}	T_3: PM @ 15 tons ha^{-1}
T_5: NPK 150:100: 60 kg ha^{-1}	T_3: PM @ 15 tons ha^{-1}	T_1: Control

Table 2 Properties of organic amendments

Name of organic amendment	Organic carbon	Total nitrogen	Exchangeable potassium	Available phosphorus	pH
Farm yard manure	16.5	0.57%	0.63%	0.26%	6.84
Poultry manure	18.5%	2.13%	0.52%	0.74%	7.67
Pressmud	12.7%	0.94%	0.76%	1.20%	7.42

Table 3 Methods of analysis

Parameters	Methods of analysis and references
Soil Texture, EC (dS/m), pH	US Salinity lab staff. (1954)
OM	Wet oxidation method (Walkley, 1947)
A_v Nitrogen	Bremner et al. (1965)
A_v Phosphorus	Olsen et al. (1954)
A_v Potassium	US Salinity lab staff. (1954)

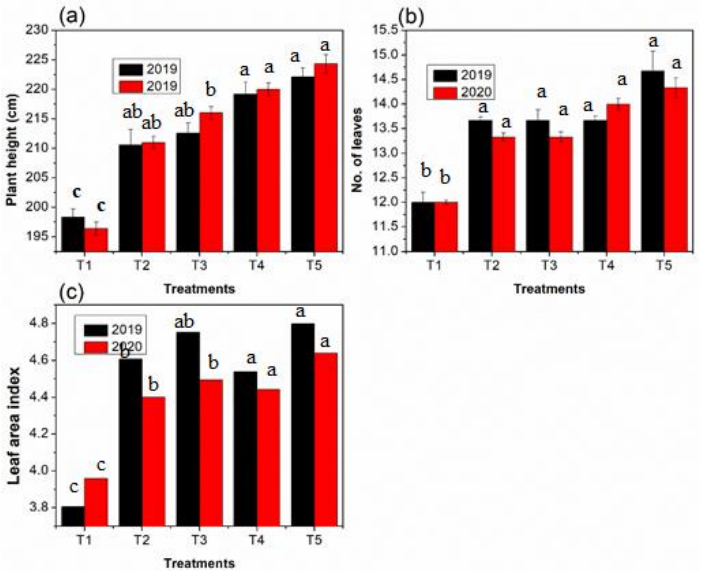

Fig. 1 Effect of organic and inorganic amendments on maize plant height (a) number of leaves per plant (b) and leaf area index (c)

Organic and inorganic amendment's effect on yield and yield attributes of maize

Cob weight (g)

The results indicated that various sources of nutrients had substantial effect on cob weight during both years (Fig. 2a). The highest cob weight (164 g and 163.67 g) was obtained from the treatment receiving NPK (T5) in both the years. Among the OMs, the treatment T3 showed maximum cob weight (132 g and 131.11 g). This was followed by T1. However, the least cob weight (124 g and 125.52 g during 2019 and 2020, respectively) was attained from the control treatment (T2) where FYM was applied.

Grain weight per ear (g)

Results showed that both inorganic and organic fertilizer has noteworthy influence on grain weight per ear. The maximum grain weight per ear (138 g and 142 g) was obtained from the treatment receiving NPK (T5) in both the years (Fig. 2b). Among the organic manures, the treatment T3 showed maximum grain weight per ear (112 g and 113.33 g). However, T3 and T2 and T1 were statistically at par without much significant difference among the treatment. The minimum grain weight per ear was recorded in treatment (T1) (107 and 107.96 g during 2019 and 2020, respectively) where nutrient was not applied.

Thousand-grain weight (g)

Results showed that both inorganic and organic fertilizer has substantial impact on thousand-grain weight. The highest 1000-grain weight was obtained from the treatment T3 and T5 as compared to control without much significant difference between the two treatments (Fig. 2c). The relatively increased thousand-grain weight in T3 (5.88% and 20.40%) and T5 (17.64% and 29.67%) as compared to control was noted during 2019 and 2020. The minimum thousand-grain weight was recorded in treatment (T1) (238 g and 240.61 g during 2019 and 2020, respectively) where nutrient was not applied.

Grain yield (kg ha^{-1})

The grain yield (GY) was considerably enhanced with the use of organic as well as inorganic fertilizers. The maximum GY (5586.62 Kg ha^{-1} and 5667 Kg ha^{-1}) was noticed in the treatment receiving NPK (T5) in both the years 2019 and 2020, which was 60.51% and 61.36% than control during 2019 and 2020, respectively (Fig. 2d). All the other treatment like T1, T2, T3 and T4 were statistically at par, having not much difference among the treatments. However, the least GY were recorded in treatment (T1) (3364.20 g and 3512 g during 2019 and 2020, respectively) where nutrient was not applied.

Biomass yield (kg ha^{-1})

The use of both inorganic and organic fertilizers showed expressive effect on biomass yield (BY). The topmost BY was gained with the treatment T3 (7630.69 and 7802 Kg ha^{-1}) and T5 (7845.12 and 8340 Kg ha^{-1}) than control in both the years 2019 and 2020 (Fig. 2e). Both treatments were statistically at par. These treatments were followed by T2 and T4. The least BY was recorded in treatment (T1) (6284.98 g and 6895 g during 2019 and 2020, respectively) where no nutrient was applied.

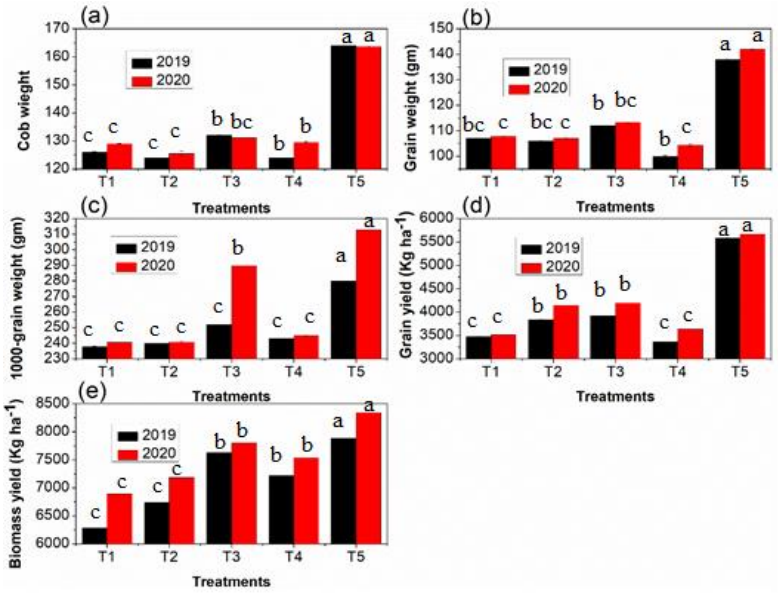

Fig. 2 Organic and inorganic amendments effect on maize cob weight (a), grain weight (b), 1000-grain weight (c), grain yield (d) and biomass yield (e)

Amendment's impact on soil characteristics

The organic amendments increased the nutritional state of the soil (Table 4). When NP levels in the several organic amendments were compared, FYM had more nutrients than PTM and PM. Research shows that soils altered with organic matter have higher levels of nutrients, particularly nitrogen, than soils fertilized with inorganic fertilizers (Khatik and Dikshit, 2001; Sullivan et al., 2003). There was also an overall decline in the nitrogen status for both the control and the treated soils. The maximum nitrogen reduction (2.26% to 1.88%) was recorded by soils treated with FYM, while the lowest (0.76 to 0.65) was reported by the control. Similar results were obtained for P and OM%. This occurred mostly because the nutrients in the organic amendments were easily absorbed by the plants or because the growth properties of maize affected the organic and inorganic amendments.

Economic analysis

As shown in Table 5, maximum BCR was obtained from T5 (1.19) where, NPK 150: 100: 60 kg ha^{-1} were applied. Subsequently, T2(1.17) and T4(1.16) showed improved BCR. However, minimum BCR was noticed in Control (1.08).

Table 4 Physico-chemical analysis of the experimental soil after harvest

Treatment	Total nitrogen (g kg^{-1})		Extractable phosphorus (mg kg^{-1})		OM %	
	Initial	Final	Initial	Final	Initial	Final
T_1: control	0.76	4.32	6.70	6.10	0.68	0.65
T_2: FYM @ 15 t ha^{-1}	2.24	2.10	10.24	9.54	0.71	0.66
T_3: PTM @ 15 t ha^{-1}	1.20	1.13	9.18	8.72	0.76	0.55
T_4: PM @ 15 t ha^{-1}	1.10	0.90	7.80	6.90	0.85	0.77
T_5: NPK 150:100: 60 kg ha^{-1}	2.76	2.15	12.76	9.65	0.89	0.81

Table 5 Economic analysis of the treatments

Treatments	Total cost (Rs.)	Total revenue (Rs.)	BCR
T1	42270	45890	1.08
T2	56120	65690	1.17
T3	59102	65980	1.11
T4	54040	63075	1.16
T5	81200	97190	1.19

Discussion

From results obtained it was noticed that inorganic fertilizer was found to be more advantageous on the growth of maize plant with respect to organic fertilizers and control. The quick release of nutrients is a well-known characteristic of inorganic fertilizers. The slow-release characteristic of organic fertilizers may account for the reduced plant height of maize grown in these treatments (Makinde et al., 2010). However, manure application can bring improvement in soil fertility, with no increasing soil salinity in such sandy soil (Wali et al., 2020). The current study's outcomes match with those of Shisanya et al. (2009), who observed increased maize PH after utilizing inorganic fertilizer. They felt that inorganic fertilizer outperformed organic fertilizer in terms of absorption because organic fertilizer must degrade and mineralize before it can be absorbed by plants. The results of the experiment demonstrate that diverse NPK fertilizers with varying ratios of potassium, phosphorus, and nitrogen may be used efficiently, and that their effectiveness in fostering plant growth is equivalent to findings from prior studies on the use of inorganic fertilizers. Furthermore, these fertilizers quickly increase the rates at which seeds germinate, which make them extremely beneficial for plant growth. Our findings support the observations made by Shisanya et al. (2009) that maize plants grew taller when inorganic fertilizers were applied. This suggests that inorganic fertilizers are useful for promoting plant growth and development.

According to the findings, inorganic fertilizer was more advantageous to maize plant growth than organic fertilizers or the control treatment, showing a better growth response to inorganic fertilizer application. The current study's findings match to those of Shisanya et al. (2009), who described that applying inorganic fertilizer increased maize plant height. They thought that because organic fertilizer must first break down and mineralize in order for plants to absorb it, inorganic fertilizer absorbs more readily than organic fertilizer. Similar to this, Gul et al. (2021) fed maize that responded to increased plant height, ear length, GY, BY, and HI after applying inorganic nitrogen (urea) and organic nitrogen in the form of PTM. The PTM, PM, and FYM were the organic fertilizers utilized. They were also sprayed on top of the soil and watered, allowing the fertilizer to permeate the soil and promote plant growth.

In terms of maize yield and its component parts, the data collected point to the most likely reasons for the high response of maize production to the applied inorganic fertilizer. According to the results, the inorganic was shown to be more successful in terms of biomass output, cob weight, grain weight per ear, and thousand-grain weight. Organic fertilizer came next, and the control came last. Cheema et al. (2010) found that utilizing at least 50% inorganic fertilizer in conjunction with organic combination resulted in greater maize grain production and yield components than using only inorganic fertilizer or combinations. Our findings are comparable with those of Farhad et al. (2013), who found the highest BY of hybrid maize by supplementing with the recommended amount of NPK for two years. Ali et al. (2016) discovered that plots with CT generated increased ear, ear length, grain number, GY, 1000 grain weight, and BY when inorganic and organic fertilizers were administered in equal amounts. Similarly, maximum BCR was observed in T5 (1.19) with respect to other tested treatments and control. The current study's findings are consistent with those of Nigussie et al. (2021), who fed maize at different amounts of inorganic and organic fertilizer and compost, and who found that the yield and chemical parameters of the soil were significantly impacted by both types of fertilizers and their interactions. They came to the conclusion that fertilizer applied in an integrated manner enhanced nitrogen uptake and promoted sustainable maize output. Reintroducing plant materials into the soil through crop residue and decomposing roots increases soil organic carbon, which in turn increases soil quality and crop yield (Jalal et al., 2020).

Conclusion

The maize experimental results showed that increasing inorganic and organic amendments (PTM, FYM, and PM) boosted crop growth and production. It was discovered that the inorganic fertilizer outperformed the organic fertilizer and control in terms of growth (PH and number of leaves per plant) and yield parameters (cob weight, grain weight per ear, thousand-grain weight, GY, and BY). The organic fertilizer treatment T3 (PTM @ 15 t ha^{-1}) generated the highest grain yield. Similarly, T5 produced a higher maximal BCR (1.17) than the other treatments and the control. In comparison to the control, organic amendments increased the chemical characteristics (NPK) of the soil and had a high nutritional content. It is critical to do thorough study on the impact of organic and inorganic fertilizers on the growth of maize seedlings in the field. Further research is required to generate fertilizer types that improve the performance of different crops intended for human consumption.

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