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Research Article

Influence of Organic Manures and Phosphorus on Maize Growth, Yield, and Soil Characteristics

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Abstract | A field experiment was conducted during kharif crop season, 2017 at the Agriculture Research Station, Swabi, to evaluate the impact of organic fertilizers and phosphorus on maize yield. The study, arranged in a randomized complete block design (RCBD) with three replications and nine treatments, used the Jalal maize variety sown at a spacing of 20 cm in 3 x 3 m plots. Farmyard manure was applied at full and half doses of 10 t ha^{-1} and 5 t ha^{-1}, respectively, while poultry manure was applied at full and half doses of 8 t ha^{-1} and 4 t ha^{-1}, one week prior to sowing. Phosphorus, derived from single super phosphate (SSP), was applied at sowing at rates of 45 and 90 kg ha^{-1}. The treatment combining 45 kg ha^{-1} phosphorus, 4 t ha^{-1} poultry manure, and 5 t ha^{-1} farmyard manure resulted in the highest plant height (177.1 cm), grain yield (3488.1 kg ha^{-1}), 1000-grain weight (231.3 g), and ear density (4.8 m^{-2}). The highest grains per ear (343.6) and ear length (15.3 cm) were recorded with 90 kg ha^{-1} phosphorus and 4 t ha^{-1} poultry manure. Post-harvest soil analysis showed a significant decrease in soil pH, an increase in organic matter, and a significant rise in soil phosphorus with 90 kg ha^{-1} phosphorus. These findings highlight that 45 kg ha^{-1} phosphorus combined with 4 t ha^{-1} poultry manure and 5 t ha^{-1} farmyard manure can enhance maize yield and improve soil health.

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Introduction

Maize (*Zea mays* L.), a globally significant high-yielding crop, is an annual, short-day, cross-pollinated plant that typically grows to a height of 3.28 to 9.84 feet, developing a single stem with 10 to 14 alternately arranged leaves. Originating in Central America, maize was introduced worldwide after the discovery of the Americas (Ezeibekwe *et al*., 2009). It is a versatile crop, used in indigenous and commercial food products such as cooking oil, livestock feed, and industrial applications like baby food, cookies, biscuits, and ice cream (Khatoon *et al*., 2010). Nutritionally, maize composed of approximately 80% starch, 10% protein, 4.8% oil, 3.3% fiber, and 2% minerals (Reddy, 2006). It is predominantly a tropical crop, but also flourishes in subtropical and temperate regions during the spring and summer seasons (Tagne *et al*., 2008).

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In Pakistan, maize ranks third in importance after wheat and rice, with extensive cultivation (1.11 million hectares) in Punjab and Khyber Pakhtunkhwa (Farhad *et al*., 2009). However, optimal yield potential remains unachieved due to limitations such as poor soil organic matter and imbalanced fertilizer use (Oad *et al*., 2004). During 2014–15, maize occupied 1140.5 thousand hectares nationally and 461.2 thousand hectares in KPK, with the Swabi district accounting for 37,195 hectares. The total production in Pakistan, KPK, and Swabi during the same period was 4936.8, 909.7, and 68.085 thousand tons, respectively, with corresponding average yields of 4321, 1965, and 1830 kg ha^{-1} (MNFSR, 2014–15).

The high cost of chemical fertilizers poses a challenge for resource-limited farmers, making organic alternatives like farmyard manure (FYM) and poultry manure (PM) more viable. FYM has demonstrated its efficacy in increasing maize yield (Anatoliy and Thelen, 2007), while PM provides readily available phosphorus (Garg and Bahla, 2008). Incorporating organic manures improves soil physical and biological properties (Belay *et al*., 2001), enhances organic matter content, and boosts soil texture, structure, water-holding capacity, and overall environmental quality (Fageria, 2012). These improvements positively influence plant growth by supplying essential nutrients, enhancing enzyme activity, and supporting chlorophyll formation (Elhindi, 2012). Phosphorus (P) is a critical macronutrient that supports early crop maturity, root development, photosynthesis, respiration, energy transfer, and cell division (Tisdal *et al*., 1993; Mengal and Kirkby, 2000). It is also integral to genetic material, such as nucleic acids (Blevins, 1999). Research shows that combining nitrogen and phosphorus fertilizers significantly improves maize quality and yield (Anwar, 1980; Javed, 1982). Moreover, integrating organic and inorganic fertilizers optimizes nutrient use efficiency, enhances soil fertility, and reduces nutrient losses, leading to sustainable crop productivity (Rautaray *et al*., 2003; Schoebitz and Vidal, 2016). For instance, phosphorus uptake by young maize increased by up to 46% when superphosphate was mixed with FYM (Sharif, 1985).

Previous studies have demonstrated the benefits of organic manures, such as FYM and PM, in improving soil health and crop productivity. However, limited research has explored the combined application of organic and inorganic fertilizers, such as single super phosphate (SSP), particularly in the agro-climatic conditions of Swabi. This gap necessitates a detailed investigation into how varying levels of SSP, when combined with organic amendments, influence maize yield, soil properties, and cost-effective fertilizer recommendations specific to this region. This study aims to address this gap by evaluating the response of maize to different levels of SSP integrated with FYM and PM, providing insights into sustainable fertilizer practices for enhanced crop productivity and soil health in the Swabi region.

Materials and Methods

Site description

The experiment titled "Effect of Organic Fertilizers and Phosphorus on the yield of Maize crop" was conducted at the Agricultural Research Station, Swabi, during the kharif season of 2017. The site is located at 72° 30' 22" E longitude and 34° 07' 30" N latitude, with an elevation of 370 meters above sea level (a.s.l.). Field preparation involved two plowing operations under optimal moisture conditions using a cultivator and rotavator. Each plot measured 3 m × 3 m, with a row-to-row spacing of 70 cm and a plant-to-plant spacing of 20 cm. Each subplot consisted of four rows.

Treatments and experimental design

The experiment was structured as a randomized complete block design (RCBD) with three replications across nine treatments. These treatments consisted of a control; farmyard manure (FYM); poultry manure (PM); single super phosphate (SSP); and combinations of SSP with FYM and/or PM. FYM was applied as a full dose at 10 tons ha^{-1} and a half dose at 5 tons ha^{-1}, while PM was applied as a full dose at 8 tons ha^{-1} and a half dose at 4 tons ha^{-1} a week before sowing. SSP was incorporated at sowing at rates of 45 and 90 kg ha^{-1}.

Agronomic parameters

Agronomic parameters recorded during the study included plant height, grain yield, thousand-grain weight, number of ears m^{-2}, number of grains ear^{-1}, and ear length. Plant height was measured at physiological maturity for five representative plants per subplot and averaged. Grain yield was calculated using grain weight from all rows in each subplot, converted to kg ha^{-1} using a standard formula. For 1000-grain weight, grains were randomly selected and weighed using a sensitive electronic balance. The number of ears per square meter was determined by counting ears in a 1 m length of each row and converting the count to ears per square meter. The number of grains per ear was calculated from five randomly selected ears per subplot, and ear lengths were measured for the same selected ears and averaged.

Soil parameters

Composite soil samples were collected from a depth of 0–20 cm before sowing and after harvest. These samples were analyzed for various physical and chemical properties. Soil pH was measured using a 1:5 soil-to-water suspension with a calibrated pH meter according to McLean's (1982) method, and EC was determined using a similar suspension with an EC meter, following the procedure described by Rhoades (1982). Organic matter content was analyzed by titration using the method of Nelson and Sommer (1996), while extractable phosphorus was determined through the AB-DTPA method (Soltanpour and Schwab, 1977) using a spectrophotometer.

Statistical analysis

The data were statistically analyzed using a two-way analysis of variance (ANOVA) to assess the effects of treatments, followed by mean comparisons using the LSD test at a 0.05 probability level (Jan *et al*., 2009).

Results

This experiment was conducted at Agriculture Research Station Swabi in July 2017 to determine the effect of different organic fertilizers and rock phosphate on maize parameters, including plant height, grain yield, thousand-grain weight, number of ears, grains ear^{-1}, ear length, and post-harvest soil properties (pH, EC, organic matter, nitrogen, phosphorus, and potassium). Soil physico-chemical characteristics prior to sowing of maize are presented in Table 1.

Table 1: *Representing the properties of soil under investigation*

S.No	Characteristics	Unit	Status
1	Organic matter	%	0.79
2	$pH_{(1:5)}$	…….	7.8
3	$EC_{(1:5)}$	dSm^{-1}	0.19
4	N (total)	%	0.13
5	Extractable P	mg kg^{-1}	2.3.

Agronomic parameters

Plant height (cm)

Phosphorus, farm yard manure and poultry manure had significant effects on plant height (Table 2 & Figure 1). Phosphorus (SSP) 45 kg ha^{-1}, 5 t ha^{-1} FYM and 4 t ha^{-1} PM incorporation produced maximum plant height (177.1 cm) followed by the use of 90 kg ha^{-1} P and 5 t ha^{-1} FYM (172.9 cm). Plant height was measured from 90 kg ha^{-1} P (168.4 cm), while the minimum plant height (155.9 cm) were recorded in control.

Grain yield (kg ha^{-1})

Statistical analysis revealed that grain yield of maize was significantly influenced by phosphorus application and various organic fertilizers (Table 2 & Figure 2). Mean table showed that application of 45 kg ha^{-1} P, 5 t ha^{-1} FYM and 4 t ha^{-1} PM produced maximum grain yield (3488.1 kg ha^{-1}), which is followed by 90 kg ha P and 4 t ha^{-1} PM (3440.5 kg ha^{-1}). Optimum grain yield obtained in plots receiving 90 kg ha^{-1} P (2936.5 kg ha^{-1}), while minimum grain yield (2210.3kg ha^{-1}) was recorded from control.

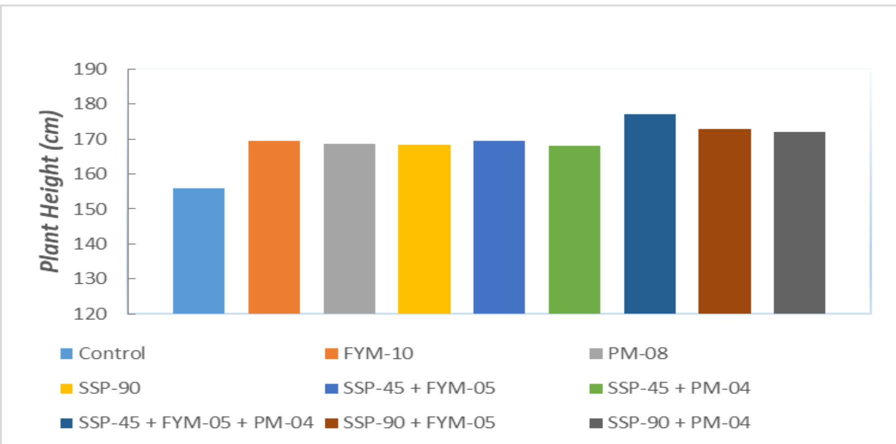

Figure 1: *Graphical representation of plant Height (cm) affected by organic manures and phosphorus fertilizers.*

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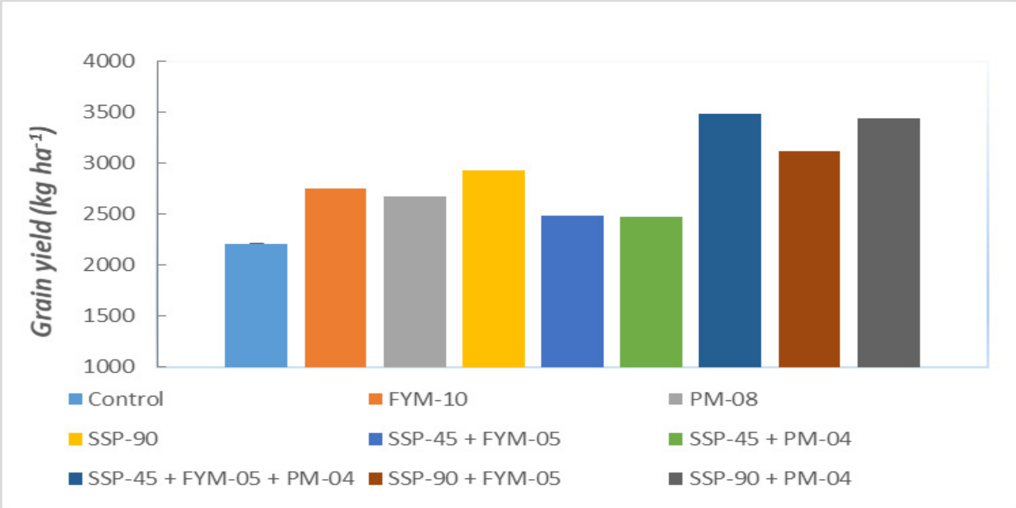

Figure 2: *Graphical representation of Grain Yield (kg ha^{-1}) affected by organic manures and phosphorus fertilizers.*

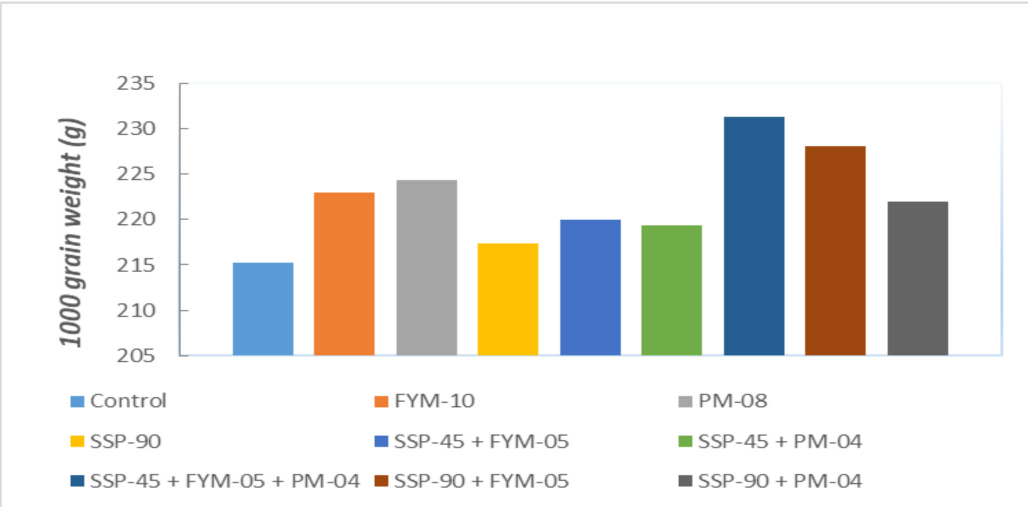

Figure 3: *Graphical representation of 1000-Grain Weight (g) affected by organic manures and phosphorus fertilizers.*

Table 2: *Effect of organic fertilizers and phosphorus on Plant height, Grain yield and 1000 grain weight of Maize crop.*

Treatments (FYM & PM- t ha^{-1}, SSP-kg ha^{-1})	Plant height (cm)	Grain yield (kg ha^{-1})	1000 grain weight (g)
Control (No application)	155.9 e	2210.3 e	215.3 e
FYM-10	169.4 bcd	2753.9 cd	223.0 bcd
PM-08	168.6 cd	2674.6cde	224.3 bc
SSP-90	168.4 cd	2936.5bcd	217.3 de
SSP-45 + FYM-05	169.6 bcd	2488.1 de	220.0 cde
SSP-45 + PM-04	168.2 d	2472.2 de	219.3 cde
SSP-45+FYM-05+PM-04	177.1 a	3488.1 a	231.3 a
SSP-90 + FYM-05	172.9 b	3123.0 abc	228.0 ab
SSP-90 + PM-04	171.9 bc	3440.5 ab	222.0 bcd
$LSD_{0.05}$	3.5	529.8	6.3

1000-Grain weight (g)

Analysis indicated the significant influence of Phosphorus and different organic fertilizers for 1000 grain weight (Table 2 & Figure 3). Mean value indicated that 45 kg ha^{-1} P, 5 t ha^{-1} FYM and 4 t ha^{-1} PM produced maximum 1000 grain weight (231.3 g), which is followed by 90 kg ha^{-1} P and 5 t ha^{-1} FYM (228 g). Amoung the FYM the optimum 1000 grain weight were recorded from 10 t ha^{-1} FYM (223 g), while lighter grains were obtained from control (215.3 g).

Number of ears m^{-2}

Data perusal (Table 3 & Figure 4) showed a significant response of phosphorus and different organic fertilizers on number of ears m^{-2}. Maximum ears m^{-2} (4.86) were counted in plots receiving 45 kg ha^{-1} P, 5 t ha^{-1} FYM and 4 t ha^{-1} PM, which is followed by 90 kg ha^{-1} P and 4 t ha^{-1} PM (4.73) ears m^{-2}. Optimum

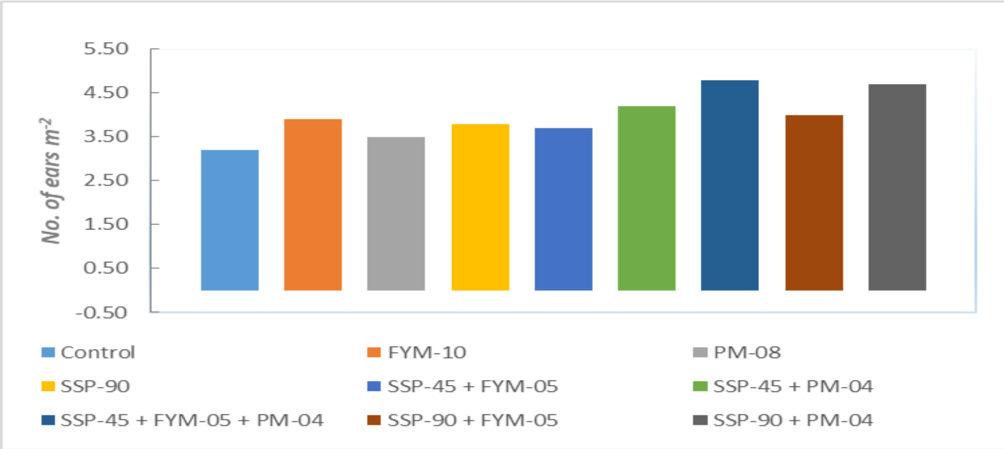

Figure 4: *Graphical representation of number of ears m^{-2} affected by organic manures and phosphorus fertilizers.*

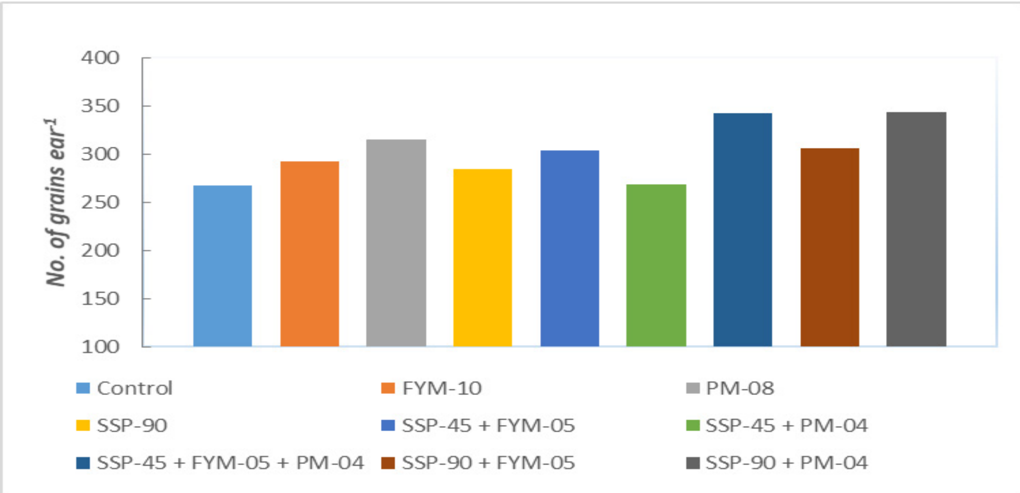

Figure 5: *Graphical representation of number of grains ear^{-1} affected by organic manures and phosphorus fertilizers.*

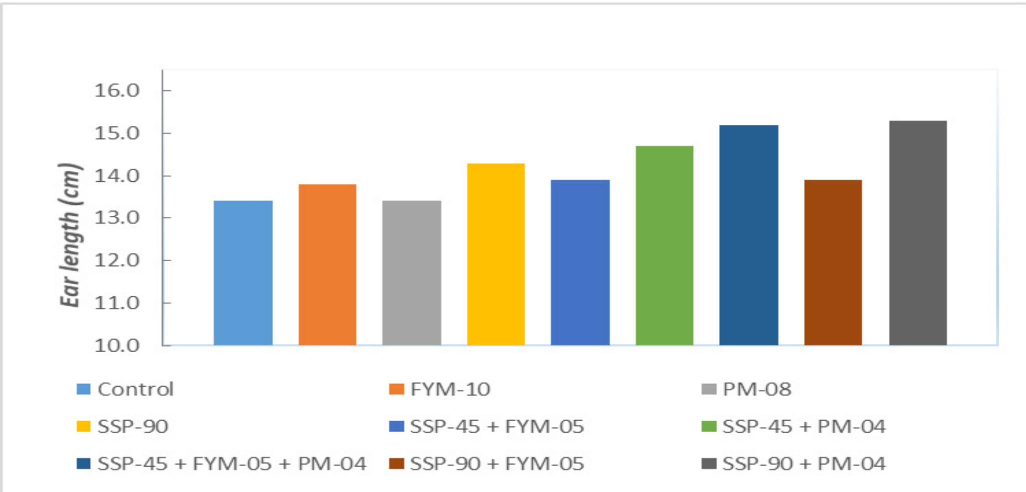

Figure 6: *Graphical representation of Ear length (cm) affected by organic manures and phosphorus fertilizers.*

ears m^{-2} (3.96) was reckoned from plots where 10t ha^{-1} FYM was used. While smallest number of ears m^{-2} (3.23) was recorded from control plots.

Number of grains ear^{-1}

Statistical analysis showed considerable influence of single super phosphate, Farm yard manure and Poultry manure, on grains per ear of maize (Table 3 & Figure 5). Maximum grains ear^{-1} (343.6) were figured out from plots receiving 90 kg ha^{-1} P and 4 t ha^{-1} PM, followed by the application of 45 kg ha^{-1} P, 5 t ha^{-1} FYM and 4 t ha^{-1} PM (342.3). Optimum number of grains (305.6) was reckoned from ears produced in plots having 90 kg ha^{-1} P and 5 t ha^{-1} FYM, while least

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grains ear^{-1} (267.6) recorded from control.

Ear length (cm)

Statistical analysis showed that different Phosphorus levels and organic fertilizers influences the length of ear (Table 3 & Figure 6). Longest ears (15.3 cm) measured in plots which had received 90 kg ha^{-1} P and 4 t ha^{-1} PM and it is followed by 45 kg ha^{-1} P, 5 t ha^{-1} FYM and 4 t ha^{-1} PM (15.2 cm).Optimum length recorded (14.3 cm) from 90 kg ha^{-1} P, while the shortest ears found in control and in the plots having 8 t ha^{-1} PM (13.4 cm).

Table 3: *Effect of organic fertilizers and phosphorus on No. of ears m^{-2}, Grains ear^{-1} and ear length of maize crop.*

Treatments (FYM & PM- t ha^{-1}, SSP-kg ha^{-1})	No. of ears m^{-2}	Grains ear^{-1}	Ear length (cm)
Control (No application)	3.2 d	267.6b	13.4 d
FYM-10	3.9 abcd	292.3ab	13.8 dc
PM-08	3.5 cd	315.0 ab	13.4 d
SSP-90	3.8 bcd	284.6 b	14.3bcd
SSP-45 + FYM-05	3.7 cd	303.6ab	13.9 cd
SSP-45 + PM-04	4.2 abc	268.0 b	14.7abc
SSP-45 + FYM-05 + PM-04	4.8 a	342.3 a	15.2 ab
SSP-90 + FYM-05	4.0 abcd	305.6ab	13.9 cd
SSP-90 + PM-04	4.7 ab	343.6 a	15.3 a
$LSD_{0.05}$	0.9	51.7	0.99

Table 4: *Effect of organic fertilizers and phosphorus on post-harvest soil pH, EC, Organic matter and extractable phosphorus of maize crop.*

Treatments (FYM & PM- t ha^{-1}, SSP-kg ha^{-1})	pH	EC (dSm^{-1})	SOM (%)	Ext. P (mg kg^{-1})
Control (No application)	7.90a	0.19 a	0.82 e	0.26d
FYM-10	7.50bc	0.13 c	0.97cd	0.43cd
PM-08	7.63abc	0.14bc	1.00 c	0.72bcd
SSP-90	7.73ab	0.15 b	0.91 d	1.09ab
SSP-45 + FYM-05	7.46 bc	0.17ab	0.99cd	0.85abc
SSP-45 + PM-04	7.60abc	0.15bc	1.01 c	1.06ab
SSP-45 + FYM-05 + PM-04	7.50 bc	0.16 b	1.10 b	1.06 ab
SSP-90 + FYM-05	7.40 c	0.17ab	1.21 a	1.22 ab
SSP-90 + PM-04	7.40 c	0.15 b	1.20 a	1.30 a
$LSD_{0.05}$	0.32	0.02	0.08	0.54

Soil parameters

Soil pH $_{(1:5)}$

Statistical analysis showed that different Phosphorus levels and organic fertilizers significantly influences the post-harvest soil pH. It is realized from the given data given in Table 4 & Figure 7 that different organic fertilizer caused a significant decrease in soil pH (range from 7.90 to 7.40). This decrease may be the H^+ ion releases by the process of decomposition of organic and inorganic inputs and fertilizers.

Soil EC (dSm^{-1})

Soil electrical conductivity (EC) are significantly influenced by application of organic fertilizer with phosphorus fertilizers as shown in Table 4 & Figure 8. The statistical analysis showed that soil EC was ranging from 0.13 dSm^{-1} in plots of FYM to 0.19 dSm^{-1} in control plots. The slight decrease occurs in soluble salts concentration due to the application organic manures.

Soil organic matter (%)

Soil organic matter (SOM) was significantly influenced by the application of organic manure and phosphorus fertilizers, as shown in Table 4 & Figure 9. The highest SOM value (1.21%) was observed with the application of 90 kg ha^{-1} P and 5 t ha^{-1} FYM, which was statistically similar to 90 kg ha^{-1} P and 4 t ha^{-1} PM (1.20%). The optimum level (1.00%) was recorded with 8 t ha^{-1} PM. The lowest SOM (0.82%) was observed in the control treatment, where no fertilizers were applied.

Extractable soil phosphorus (mg kg^{-1})

Extractable soil phosphorus after crop harvest was significantly affected by the application of organic manure and phosphorus fertilizers, as shown in Table 4 & Figure 10. The highest concentration of extractable soil phosphorus (1.56 mg kg^{-1}) was recorded in the plot treated with 90 kg ha^{-1} P, followed by 90 kg ha^{-1} P and 4 t ha^{-1} PM (1.25 mg kg^{-1}). The optimum level (0.85 mg kg^{-1}) was observed with 45 kg ha^{-1} P and 5 t ha^{-1} FYM, while the control plots had the lowest phosphorus concentration (0.26 mg kg^{-1}).

Discussions

The findings of this study underscore the synergistic benefits of combining organic and inorganic fertilizers for maize production. Plant height showed

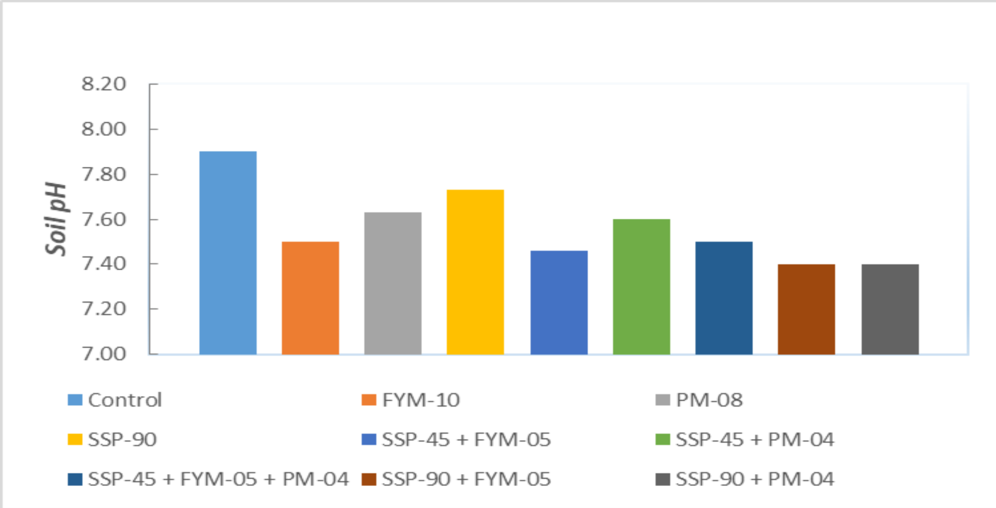

Figure 7: *Graphical representation of Soil pH affected by organic manures and phosphorus fertilizers.*

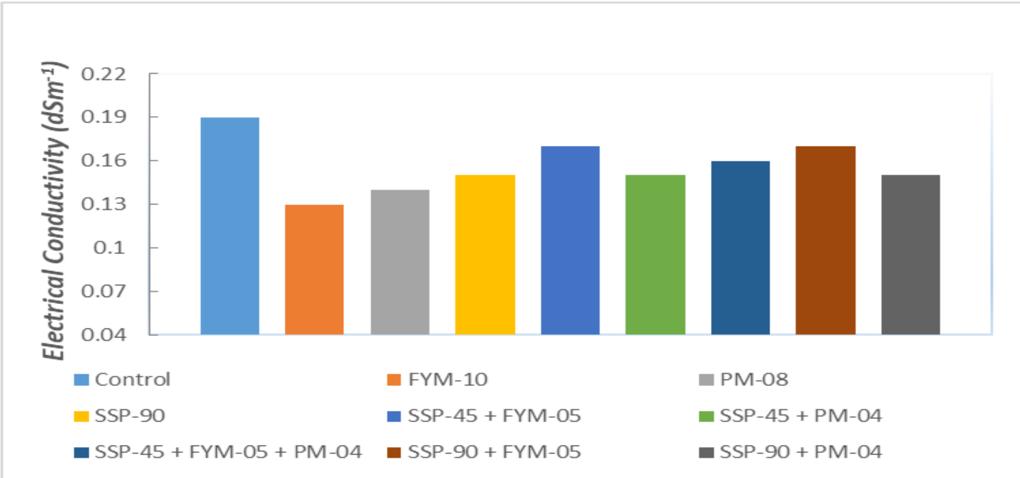

Figure 8: *Graphical representation of Soil electrical conductivity (dSm^{-1}) affected by organic manures and phosphorus fertilizers.*

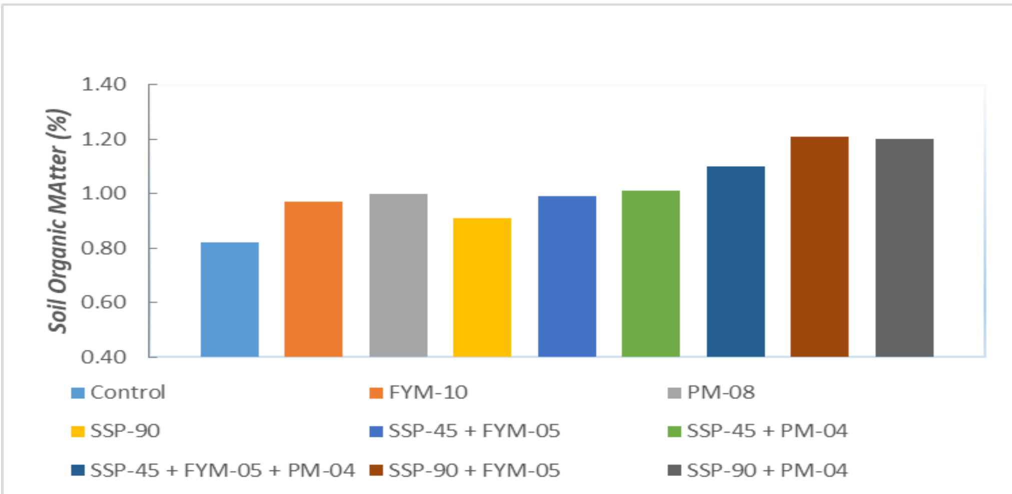

Figure 9: *Graphical representation of Soil Organic Matter (%) affected by organic manures and phosphorus fertilizers.*

significant improvement with phosphorus and manure combinations, particularly at 45 kg ha^{-1} P with FYM and PM. The results suggest that enhanced nutrient availability and improved soil structure facilitated optimal plant growth. Similar observations were made by Fageria (2012), emphasizing the role of organic inputs in enhancing soil fertility. Our results are in accordance with Iqbal *et al*. (2014) who found

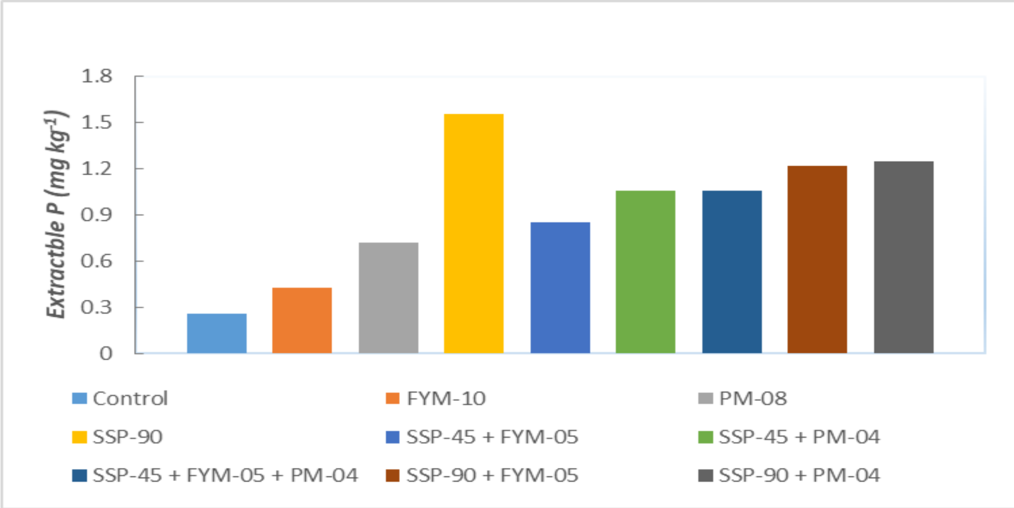

Figure 10: *Graphical representation of extractable soil phosphorus (mg kg^{-1}) affected by organic manures and phosphorus fertilizers.*

that optimum plant height in poultry manure treated plots was due to abundant and continuous nutrient provision to the root zone of the plant.

Grain yield exhibited a substantial increase with the combined application of manures and phosphorus. Treatments integrating 45 kg ha^{-1} P with 4 t ha^{-1} PM and 5 t ha^{-1} FYM achieved the highest yields. This is attributed to the improved CEC, better soil aeration, and enhanced microbial activity provided by organic matter. Sohi *et al.* (2009) and Ali *et al.* (2012) also noted that organic amendments contribute to sustained nutrient release and greater yield stability.

The higher 1000 grains weight from increased level of manure could be due to greater leaf area and leaf area index produced by these plants probably due to improved aeration, aggregate stability, hydraulic conductivity, infiltration rates, and biological activities of soil as a result of manure (Dauda *et al.*, 2008). These results are similar to the experimental report of Farhad *et al.* (2009), who obtained heavier grains from increasing poultry manure amounts.

Number of ears m^{-2} is an indispensable yield component of maize, significantly contributing to the final grain yield. It is greatly influenced by management practices, soil conditions, and environmental factors (Shah *et al.*, 2009). However, these findings contradict the report of Farhad *et al.* (2009), who observed a non-significant effect of increasing poultry manure levels on the number of ears per plant. But the finding of Achieng *et al.* (2010) and Baloch *et al.* (2015) were in agreement to our result. Increased ear length further corroborates the role of phosphorus and organic matter in enhancing reproductive growth, as supported by studies such as those by Verma *et al.* (2014). Ear length is a major contributing factor to the number of grains ear^{-1} of the maize crop. Increased level of P was found to have significantly enhanced grain yield. The conclusion of Radma and Dagash (2013) are in conformity to our finding who observed higher grain yield from increasing P levels

Post-harvest soil properties revealed improvements in SOM and extractable phosphorus levels. Rabindram and Gowda (1996) observed that a well-planned and balanced application of both organic and inorganic fertilizers improved soil organic matter (SOM) content. Similarly, Laskar *et al.* (1990) reported that phosphatic fertilizers, whether applied alone or in combination with organic manure, significantly increased the organic phosphorus content in the soil. The application of manures and phosphorus reduced soil pH slightly, enhancing nutrient availability due to release of H^+ ions during the process of nitrification (Akram, 1978). The lowest EC values in manure-treated plots suggest reduced salt accumulation, consistent with Bremner (1982). These findings highlight the dual benefits of productivity enhancement and soil health improvement.

Conclusions

The results of this study highlight the significant advantages of integrating organic and inorganic fertilizers for improving maize growth and yield. The combined application of 45 kg ha^{-1} phosphorus with 4 t ha^{-1} poultry manure and 5 t ha^{-1} farmyard manure demonstrated the highest efficacy in enhancing plant height, grain yield, 1000-grain weight, number of ears, and grains per ear. This integrated approach also improved key soil properties, including increased organic matter and extractable phosphorus, and slightly reduced pH and EC, ensuring better nutrient availability.

The findings suggest that organic amendments play a critical role in providing sustained nutrient release, improving soil structure, and fostering a conducive environment for plant growth. This is particularly evident in the enhanced grain yield and improved soil health metrics observed in the study. The synergistic effects of combining organic manures with phosphorus fertilizers align with sustainable agricultural practices, promoting long-term soil fertility and crop productivity.

Recommendations

The integration of organic and inorganic fertilizers is a promising strategy for achieving high maize productivity while maintaining soil health. Further studies focusing on different maize varieties, long-term impacts, and economic analyses are recommended to optimize these findings for broader applications.

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Novelty Statement

This study uniquely evaluates the combined and comparative effects of integrated organic fertilizers (farmyard and poultry manure) with varying phosphorus levels on maize yield and soil properties under field conditions.

Author's Contribution

Arshad Ullah: Conceptualization, Wrote original draft, resources, Methodology, Investigation, Formal analysis.
Muhammad Ilyas: Writing – review & editing, software, Resources, Investigation, Data curation and writing revised draft.
Rooh Ullah & Mujeebur Rahman: Data curation, Data interpretation, Data visualization, Collecting and tabulating the data.
Salim Saifullah & Sanam Zarif Satti: Proof reading, critical review and editing of the manuscript.

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

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

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