



Impact of enriched organic substrates and fertilizer on nutrient uptake and growth of maize (*Zea mays* L.)

Irfan Aziz^{1*}, Fahad Ali Fayyaz¹ and Azeem Khalid²

¹Department of Agronomy, PMAS, Arid Agriculture University, Rawalpindi, Pakistan

²Institute of Soil and Environmental Sciences, PMAS, Arid Agriculture University, Rawalpindi, Pakistan

*Corresponding author's email: irfaz15@yahoo.com

Abstract

Most agricultural soils are deficient in essential nutrients and consequently depend heavily on chemical fertilizers for commercial crop production. The use of organic amendments such as compost can improve soil fertility while reducing environmental hazards. Therefore, this study hypothesized that the combined application of farmyard manure (FYM), compost and humic acid (HA) could improve nutrient uptake, growth and yield of maize more effectively than their individual application. A field experiment was conducted to evaluate the effects of different organic substrates and fertilizers on nutrient uptake, growth and yield of maize (*Zea mays* L.) using a randomized complete block design (RCBD) with three replications. FYM, compost and Humic acid were applied at 20 t ha⁻¹, 8 t ha⁻¹ and 12 kg ha⁻¹, respectively, either alone or in combination. The combined application of compost + FYM + HA (T7) produced the highest plant N, P and K uptake of 1996.7, 2.88 and 232.33 mg kg⁻¹, respectively, compared with 750, 1.55 and 88.33 mg kg⁻¹,

respectively, in the unfertilized control (T0). Treatment T7 also recorded the highest germination (81%), grains cob⁻¹ (442), cob length (14.42 cm), 1000-grain weight (348.47 g), grain yield (1994.4 kg ha⁻¹) and harvest index (17.06%), whereas the corresponding values in T0 were 72%, 384.33 grains cob⁻¹, 11.72 cm, 323.33 g, 1272.2 kg ha⁻¹ and 12.07%, respectively. The highest plant height (139.40 cm) and grain rows cob⁻¹ were recorded under compost + FYM (T4), while total biomass was highest with sole compost application (11853 kg ha⁻¹). Conclusively, the combined application of compost, FYM and humic acid was the most effective treatment for enhancing nutrient uptake and major yield-related attributes of maize, demonstrating its potential as a sustainable nutrient management strategy for improving maize productivity and soil fertility. This study may also support the development of economically viable and environmentally friendly fertilizer recommendations for sustainable maize production. © 2026 The Author(s)

Keywords: Compost, Farmyard manure, Humic acid, Maize, Nutrients uptake

Citation: Aziz, I., Fayyaz, F. A., & Khalid, A. (2026). Impact of enriched organic substrates and fertilizer on nutrient uptake and growth of maize (*Zea mays* L.). *Journal of Plant Production and Sustainability*, 2(1), 12–26. <https://doi.org/10.63072/jpps.26002>

Introduction

Pakistan economy is mostly depending upon agriculture. The livelihood of most of the people depends upon agriculture directly or indirectly. It has 24% of share in our GDP, employs 37% of the total work force, and provide livelihood to 38.5% rural peoples (Aziz, 2026). It has a large contribution in the growth of major agro-based industries such as: textile, leather, dairy, food processing, paper, etc. as it provides raw materials (Iqbal et al., 2018; Hassan et al., 2022). Pakistan is a leading agricultural country expanded on the total area of 79.6 million hectares (m ha) with arid and semi-arid climate across all its regions (Roheen et al., 2023). After wheat and rice maize is main cereal and is consumed as human food, animal feed and provides raw materials for agro-based industry (Ahmad & Ahmad, 2018; Rubab et al., 2020; Mehmood et al., 2022; Azam et al., 2023; Zia et al., 2023). Compost application

has significant positive effects on crop productivity and soil fertility. It improves soil organic matter, water-holding capacity (WHC), nutrient availability, soil aggregation, and microbial activity (Ahmad & Aslam, 2018; Akram & Iqbal, 2019; Abbas, 2022). Compost also supplies valuable nutrients to plants and improves overall soil quality (Ho et al., 2022). Moreover, it promotes beneficial soil microorganisms and helps suppress plant pathogens (Shakeel et al., 2023). Consequently, compost application can enhance plant growth, crop productivity, and soil health (Oued Lhaj et al., 2025; Manhou et al., 2026).

Farmyard manure is a good alternate source for the chemical fertilizers, as it enhances organic matter of soil which is essential source of various micro and macronutrients (Chahal et al., 2020; Hussain et al., 2024; Lishan & Alemu, 2024). Farm yard manure can be used effectively as supplementation nutrient. It is actually an essential compound to effectively promote health and quality of plants by

enhancing moisture and aeration of soil if it is incorporated as additional source of manure into the soil, it has positive impacts on crop growth, along with synergistic effects of nitrogen into the FYM accumulate more total soil nitrogen and causes increase in yield of maize (Königer et al., 2021; Musa et al., 2026). Soil fertility is major problem which largely affect the productivity of maize crop in Pakistan, as majority of soil lacks certain elements including phosphorus, nitrogen, potassium, zinc and organic matter contents (Noroz et al., 2021). Nitrogen is considered as an imported component in the growth and productivity of many plants including maize. As nitrogen plays integral part in photosynthesis process and is necessary element for chlorophyll it enhances enzymatic activity to some extent. Phosphorus (P), potassium (K) and other nutrients utilization is also affected by the amount of (N) soil nitrogen (Abid & Latif, 2023). Nitrogen deficiency can also have negative effect upon the use of other favorable nutrients. Crop productivity and soil quality significantly improve by nitrogen fertilizers (Habtegebrial et al., 2007).

Now a day, the research has gained considerable interest in using organic materials (OM) in agriculture land as a main source. This is of prime importance knowing about the damaging impacts of synthetic fertilizers on environment, soil structure as well as on human health as it leads to runoff losses of nutrients to groundwater in intensive agricultural systems (Ayoola & Adeniyi, 2006; Khan et al., 2008). Organic fertilizers are environment friendly as they reduce the environmental hazards caused by using inorganic fertilizers and helps in restoring the soil fertility (Edwards & Daniel, 1992; Eghball et al., 1999; Hirzel & Walter, 2008; Abbas & Shafique, 2019). As we know about the significance of organic substances for plants, the soil has to be provided with appreciable amount of fertilizers in the form of organic manures in a way to uplift its fertility level and most importantly to enhance the nutrients uptake in plants that has significant role in its growth and development.

Despite the recognized benefits of organic amendments in improving soil fertility and crop productivity, limited research has been conducted on the comparative effectiveness of enriched compost and farmyard manure as nutrient sources for maize under the specific soil and climatic conditions of the Pothohar region of Pakistan. In particular, insufficient information is available regarding their effects on nutrient solubility, nutrient availability, growth, and yield attributes of maize in Pothohar soils. Moreover, the potential of enriched compost as an alternative or supplementary source of nutrients to reduce dependence on synthetic fertilizers has not been adequately investigated under these conditions. Therefore, a research gap exists in identifying suitable organic nutrient sources and their effective use for improving maize productivity and soil fertility in the Pothohar region. The study is significant because the declining fertility of agricultural soils, low organic matter, and increasing dependence on synthetic fertilizers are major constraints to sustainable

crop production in Pakistan. The use of enriched compost and farmyard manure may provide an environmentally friendly approach for improving soil fertility, nutrient availability, and maize productivity while recycling locally available organic resources. The findings will provide useful information for farmers, researchers, and agricultural extension workers regarding the efficient use of organic fertilizers in Pothohar soils. Therefore, the present study was planned to investigate impact of enriched compost and organic source of fertilizer on growth and yield of maize crop and to analyze the impact of organic substrates on nutrient solubility and availability in the Pothohar soils. During this study, it was also examined the best performance of organic fertilizer in Pothohar regarding its yield attributes.

Materials and Methods

Experimental site and design

The field experiment was conducted during the summer season of 2016–2017 at the research area of the National Institute of Organic Agriculture (NIOA), National Agricultural Research Centre (NARC), Islamabad, Pakistan. The experiment was designed to evaluate the effects of different organic amendments, including farmyard manure (FYM), compost, and humic acid (HA), applied individually and in combination, on the growth, yield, soil properties, and nutrient uptake of maize. The experiment was established during the last week of June. The experiment was arranged in a randomized complete block design (RCBD) with three replications. The treatments comprised FYM applied at 20 t ha⁻¹, compost at 8 t ha⁻¹, and humic acid at 12 kg ha⁻¹, either alone or in different combinations. The following treatments were evaluated:

- To: Control (no organic amendment)
- T₁: Compost (8 t ha⁻¹)
- T₂: Farmyard manure (20 t ha⁻¹)
- T₃: Humic acid (12 kg ha⁻¹)
- T₄: ½ Compost + ½ FYM
- T₅: ½ Compost + ½ Humic acid
- T₆: ½ FYM + ½ Humic acid
- T₇: ⅓ Compost + ⅓ FYM + ⅓ Humic acid

Land preparation and crop establishment

The experimental field was prepared by performing two to three plowings followed by planking using a tractor-drawn cultivator to obtain a well-prepared seedbed. Maize cultivar ‘Islamabad Gold’ was sown during the last week of June using a single-row Rabi drill. The crop was planted in rows spaced 75 cm apart, with a plant-to-plant spacing of 20 cm. Each experimental plot measured 3 m × 4 m. All other recommended crop production and management practices, including irrigation, weed control, and other cultural operations, were kept uniform across all treatments throughout the growing season. Soil samples were collected before treatment application and after maize harvest to assess changes in soil properties. Before the application of organic

amendments and establishment of the maize crop, composite soil samples were collected from the experimental field to determine the initial physicochemical and nutrient status of the soil. The soil was classified as clay loam and had a pH of 8.3, indicating an alkaline soil reaction. The initial electrical conductivity (EC) was 0.27 dS m⁻¹, while the organic matter content was 1.01%. The initial concentrations of nitrate-nitrogen (NO₃-N), extractable phosphorus (P), and extractable potassium (K) were 0.61, 5.33, and 136 mg kg⁻¹, respectively. These baseline soil characteristics were used to assess changes in soil fertility and nutrient availability following the application of the different organic amendments. The initial chemical characteristics of the experimental soil are presented in Table 1.

Table 1 Soil chemical characteristics before experiment

Soil property	Unit	Values
pH	-	8.3
EC	dS/m	0.27
Organic matter	%	1.01
NO ₃ -N	mg kg ⁻¹	0.61
Phosphorous	mg kg ⁻¹	5.33
Potassium	mg kg ⁻¹	136
Class	-	Clay loam

Soil texture, organic matter (OM), electrical conductivity (EC), pH, total nitrogen (TN), extractable phosphorus (P), and extractable potassium (K) were determined using standard laboratory procedures. The crop growth and yield parameters recorded included germination count, final plant population, number of cobs plant⁻¹, plant height, number of grains cob⁻¹, number of grain rows cob⁻¹, cob length, 1000-grain weight, grain yield, total biomass, and harvest index. In addition, nitrogen (N), phosphorus (P), and potassium (K) concentrations in maize plant tissues were determined to assess nutrient uptake.

Soil sampling and analysis

Soil samples were collected randomly from each experimental plot at a depth of 0–20 cm after crop harvest. Before the application of treatments, random soil samples were also collected from the experimental area and thoroughly mixed to obtain a representative composite sample. All soil samples were air-dried, gently crushed, and passed through a 2-mm sieve before chemical analysis. Soil chemical analyses were conducted at the Land Resource Research Institute (LRRI), National Agricultural Research Centre (NARC). Soil pH was determined using a calibrated pH meter in a 1: 1 (w/v) soil-to-distilled-water suspension. Soil electrical conductivity (EC) was measured using a calibrated electrical conductivity meter. Soil organic matter (OM) content was estimated using the dichromate wet oxidation method as described by Walkley & Black (1934). Available nitrogen (N), phosphorus (P), and potassium (K) were determined using the ammonium bicarbonate–diethylenetriaminepentaacetic acid (AB-

DTPA) extraction method proposed by Soltanpour & Schwab (1977).

Preparation of AB-DTPA solution

A 0.005 M AB-DTPA extracting solution was prepared by dissolving 79.1 g of ammonium bicarbonate and 1.97 g of diethylenetriaminepentaacetic acid (DTPA) in approximately 800 mL of deionized water. The pH of the solution was adjusted to 7.6 using 6 M HCl as the acidifying agent. The solution was then diluted to a final volume of 1 L with distilled water and thoroughly mixed.

Analysis of NO₃-N

NO₃-N standards solution of different doses (0.5, 1, 1.5, 2, 2.5 & 3 mg L⁻¹) and 1 ml of each AB-DTPA soil extracts was taken. Afterwards solution of sodium hydroxide, hydrazine sulfate, copper sulfate 3ml, 2ml and 3ml added in respective test tube well shaken. Heated these tubes @ 38°C for 20 minutes. After removing it from water bath the color development reagent NO₃-N of 3ml was added and dissolved with help of shaker. With the help spectrophotometer @ 540 nm wave length for 20 minutes for the calculation of NO₃-N. NO₃-N concentration was calculated by flowing equation:

$$\text{NO}_3\text{-N (mg L}^{-1}\text{)} = \text{Dilution variable} \times \text{NO}_3\text{-N (mg L}^{-1}\text{) extract}$$

Extractable phosphorus (P)

Extractable phosphorus (P) in the soil was determined using the ammonium bicarbonate–diethylenetriaminepentaacetic acid (AB-DTPA) extraction method. Briefly, 10 g of air-dried, sieved soil was weighed into a 250 mL Erlenmeyer flask, and 20 mL of AB-DTPA extracting solution was added. The suspension was shaken for 30 min at 250 rpm using a mechanical shaker. The extract was then filtered through Whatman No. 42 filter paper, and the clear filtrate was collected for phosphorus determination. For color development, a molybdate mixed reagent was prepared. Briefly, 0.291 g of potassium antimony tartrate was dissolved in 800 mL of deionized water, followed by the careful addition of 148 mL of concentrated H₂SO₄. The volume was adjusted as required with deionized water. A phosphorus stock solution was prepared using KH₂PO₄, from which working standard solutions containing 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 mg P L⁻¹ (ppm) were prepared. Aliquots (1 mL) of the soil extracts, phosphorus standards, and blank were transferred into test tubes. Deionized water and the mixed reagent were added as required, with 9 mL and 2.5 mL, respectively, according to the analytical procedure. The solutions were thoroughly mixed and allowed to stand for 10 min for color development. Absorbance was then measured using a spectrophotometer at 880 nm. A calibration curve was prepared by plotting absorbance against phosphorus concentration of the standard solutions. The phosphorus concentration in the soil extracts was determined from the calibration curve and expressed as

mg L⁻¹. The concentration of extractable phosphorus was calculated using the following equation:

$$P \text{ (mg L}^{-1}\text{)} = P \text{ in mg L}^{-1} \text{ in extract dilution} \times \text{factor}$$

Available potassium (K)

Available potassium (K) in the soil was determined using a flame photometer equipped with a potassium hollow cathode lamp. Briefly, 10 g of air-dried soil was weighed into a 125 mL conical flask, and 20 mL of the extracting solution was added. The suspension was shaken for 15 min at 180 cycles min⁻¹ using a reciprocal shaker. The extract was then filtered through Whatman No. 42 filter paper, and the filtrate was collected for potassium determination. Potassium standard solutions of 0, 5, and 10 mg L⁻¹ (ppm) were prepared and used to calibrate the instrument. The potassium concentration in the soil extract was measured using the flame photometer, and the available potassium content was calculated using the following equation:

$$K \text{ (ppm)} = K \text{ in extract (ppm)} \times \text{Dilution} \times \text{factor}$$

Plant tissues analysis

Plant tissue samples were collected at the harvesting stage. The concentrations of essential nutrients in the plant samples were determined following the standard procedures described in the Soil and Plant Analysis Laboratory Manual by Ryan et al. (2001).

Wet digestion

Plant samples were digested using a mixture of concentrated nitric acid (HNO₃) and perchloric acid (HClO₄) in a 2: 1 ratio following the procedure described by Ryan et al. (2001). Briefly, 0.25 g of finely ground plant material was weighed into a 50-mL digestion flask, and 10 mL of the HNO₃ acid mixture was added. The flasks were gently swirled to ensure thorough mixing and left overnight for pre-digestion. The digestion flasks were then placed on a hot plate in a digestion chamber, and the temperature was gradually increased to approximately 230 °C. Digestion was continued until the brown nitrogen dioxide (NO₂) fumes disappeared and dense white perchloric acid fumes became visible. The digest was evaporated until its volume was reduced to approximately 3–5 mL, taking care not to allow the solution to dry. The completion of digestion was indicated by the development of a clear, colorless solution. After cooling, the digest was transferred and diluted with distilled water to a final volume of 50 mL. The resulting digest was thoroughly mixed, and appropriate aliquots were used for the determination of phosphorus (P) and potassium (K) concentrations (Ryan et al., 2001).

Nitrogen determination in plant tissues

Total nitrogen (N) concentration in the plant tissues was determined using the Kjeldahl method. The analysis was

carried out according to the standard procedure described by Ryan et al. (2001). The following steps were followed:

Agronomic parameters

Agronomic parameters of maize were recorded at different growth stages. Germination count was determined by counting the number of seedlings that emerged from a randomly selected 1 m² area within each plot at the emergence stage, and the mean values were calculated. The final plant population was determined by counting the total number of plants in each plot, and the mean plant population was calculated. For plant height, five plants were randomly selected from each plot at physiological maturity. Plant height was measured from the soil surface to the uppermost part of the plant using a measuring tape, and the mean height was calculated. The number of cobs per plant was recorded from randomly selected plants in each plot, and the mean value was determined. The number of grains per cob was determined from five randomly selected plants from each plot, and the mean number of grains per cob was calculated. Similarly, five randomly selected cobs were used to determine the number of grain rows per cob, and the mean was calculated. Cob length was measured in centimeters (cm) from five randomly selected cobs per plot, and the mean cob length was recorded. The 1000-grain weight (TGW) was determined by manually counting 1000 grains collected from different cobs representing each treatment and weighing them in grams (g). Grain yield was determined for each plot and expressed initially as yield per plot. The plot yield was subsequently converted to kg ha⁻¹. For determination of total biomass, maize plants were harvested and left in the field for 7–8 days for sun-drying. The dry biomass was then weighed using a spring balance. The harvest index (HI) was calculated using the following equation:

$$HI = \frac{\text{Economic Yield}}{\text{Biomass Yield}} \times 100$$

Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) using Statistix 8.1 statistical software. The significance of treatment effects was determined at the 5% probability level. Where significant differences were observed among treatment means, means were compared using the Least Significant Difference (LSD) test at $P \leq 0.05$. The statistical analysis was performed according to the procedures described by Montgomery (2001).

Results

Soil analysis

Total nitrogen

Soil nitrogen (N) concentration is greatly influenced after the crop harvest due to remaining effect of organic fertilizer as evident from Table 2. Various treatments have significant

effect on total nitrogen contents. Application of T7 (Compost + Farm yard manure + Humic acid) gave the maximum nitrogen concentration ($1996.7 \text{ mg kg}^{-1}$) followed by T4 (Compost + FYM) (1975 mg kg^{-1}), and T5 (Compost and HA) (1810 mg kg^{-1}). The minimum nitrogen contents in the soil after maize crop harvest was (750 mg kg^{-1}) recorded in treatment T0 (Control) with no fertilizer, that was at par with treatment T3 (HA) (896.7 mg kg^{-1}) and T2 (FYM) ($1553.3 \text{ mg kg}^{-1}$).

Extractable soil phosphorus

The concentration of soil phosphorus (P) contents was also influenced after the crop harvest due to residual effect of organic fertilizer, as evident in Table 2. The maximum soil extractable P concentration (2.88 mg kg^{-1}) was determined in T7 treatment with combine application (Compost + FYM + HA), followed by treatment T4 (Compost + FYM) (2.71 mg kg^{-1}), which was at par with treatment T5 (Compost + HA) (2.63 mg kg^{-1}). The minimum P concentration (1.55 mg kg^{-1}) in soil was noted in T0 (Control) treatment having no fertilizer application, followed by treatment T3 (HA) (1.67 mg kg^{-1}) which was equal with treatment T2 (FYM) (1.75 mg kg^{-1}).

Soil potassium

Different organic fertilizer treatments significantly affected soil-extractable potassium (K), as presented in Table 2.

The application of organic amendments, particularly compost and its combinations with other organic fertilizers, enhanced the availability of K in the soil. The highest soil-extractable K concentration ($232.33 \text{ mg kg}^{-1}$) was recorded in T4 (Compost + FYM), which was statistically similar to T7 (Compost + FYM + HA), with a K concentration of $224.67 \text{ mg kg}^{-1}$. In contrast, the lowest soil-extractable K concentration (88.33 mg kg^{-1}) was observed in the control treatment (T0), which was statistically at par with T3 (HA), recording 117 mg kg^{-1} . Treatment T2 (FYM) recorded 168 mg kg^{-1} soil-extractable K.

Soil pH

Soil pH is an important soil chemical property that strongly influences nutrient availability, nutrient uptake, and plant growth. It affects the solubility and availability of essential nutrients and, consequently, their uptake by plants (Singh et al., 2025). The soil pH values recorded under different organic fertilizer treatments are presented in Table 2. The application of organic amendments resulted in a slight reduction in soil pH compared with the control treatment, indicating a modest acidifying effect of the organic materials. Treatment T1, receiving compost alone, and T7, receiving the combined application of compost + FYM + HA, recorded the same soil pH value of 7.59. These results suggest that the application of organic amendments, particularly compost-based combinations, may help regulate soil pH and improve conditions for nutrient availability and plant growth.

Table 2 Impact of organic fertilizers (Compost, FYM and Humic acid) on soil fertility after harvest in maize

Treatments	Total nitrogen (mg kg^{-1})	Extractable phosphorous (mg kg^{-1})	Potassium (mg kg^{-1})	pH value
T0	750.0 h	1.55 f	88.33 g	8.29
T1	1700.0 e	2.06 d	180.33 d	7.59
T2	1553.3 f	1.75 e	168.00 e	7.68
T3	896.7 g	1.67 e	117.00 f	8.01
T4	1975.0 b	2.71 b	232.33 a	7.65
T5	1810.0 c	2.63 bc	212.33 b	7.70
T6	1766.7 d	2.60 c	196.00 c	7.73
T7	1996.7 a	2.88 a	224.67 a	7.59

Where T0 = Control; T1 = Compost; T2 = FYM; T3 = Humic acid; T4 = Compost + FYM; T5 = Compost + Humic acid; T6 = FYM + Humic acid; T7 = Compost + FYM + Humic acid. Means having different alphabetical letters are statistically dissimilar from each other at $p \leq (0.05)$

NPK concentration in organic material

Concentration of several nutrients elements in organic materials was shown in Table 3. Total nitrogen concentration in Compost, FYM and Humic acid was found as 19000 mg kg^{-1} , 5700 mg kg^{-1} and 4600 mg kg^{-1} . The phosphorus concentration in Compost was found as 6600 mg kg^{-1} , FYM as 2600 mg kg^{-1} and Humic acid was 2100 mg kg^{-1} respectively. The concentration of Potassium in Compost was found as 17000 mg kg^{-1} , FYM 6300 mg kg^{-1} and Humic acid as 4700 mg kg^{-1} . Values of pH in compost were noted 8.15, FYM 8.19 and Humic acid 9.01, respectively.

Nitrogen in plant

Nitrogen uptake by maize plants significantly increases with the use of organic fertilizer in soil as data shown in Table 4. Plants highest N uptake (11650 mg kg^{-1}) was observed in treatment-7 (Compost+ FYM+ HA) where mixed organic substrates were applied, while T4 where combined application of (Compost + FYM) (10683 mg kg^{-1}) was made, at par with treatment 1 with sole applied compost (9797 mg kg^{-1}). The lowest uptake rate of nitrogen was reported in T0 (Control) treatment (3133 mg kg^{-1}) having no fertilizer was added which was at par in treatment T3 (HA) (5647 mg kg^{-1}) and T6 combine application (FYM and HA) (6773 mg kg^{-1}).

Table 3 Chemical analysis of NPK of organic materials

Treatment	Total nitrogen	Phosphorous	Potassium	pH value
Compost	19000	6600	17000	8.15
FYM	5700	2600	6300	8.19
Humic acid	4600	2100	4700	9.01

Phosphorus in plant

Plant normal growth required relatively large amount of phosphorus because of essential macro nutrient. Data shown in Table 4 indicated that more plant phosphorus uptake (5240 mg kg^{-1}) was noted in treatment 7 (Compost + FYM + Humic acid) which was at par with the treatment 4 with the combination (Compost + FYM) (4530 mg kg^{-1}) followed by the treatment-5 having the combine effect of (Compost + Humic acid) ($3803.3 \text{ mg kg}^{-1}$). Minimum (896.7 mg kg^{-1}) plant phosphorus was recorded in T0 (Control) without any fertilizer use which was at par with treatment T3 (HA) ($1693.3 \text{ mg kg}^{-1}$) and T2 (FYM) (2770 mg kg^{-1}) respectively.

Potassium in plant

The data presented in Table 4 show that potassium (K) uptake by the growing maize crop was significantly affected by the treatments, with a significant response observed in the control treatment. The maximum plant K uptake (20267 mg kg^{-1}) was recorded in treatment 7 having the mixed application of (Compost + FYM + Humic acid), followed by treatment T1 where (Compost) (19333 mg kg^{-1}) were applied, followed by the treatment 4 with combination of (Compost + FYM) (16633 mg kg^{-1}). The lowest plant K uptake (7000 mg kg^{-1}) was depicted in T0 treatment (Control) without application of any fertilizer which was equivalent to treatment 3 (HA) (9500 mg kg^{-1}) and T2 (FYM) (12933 mg kg^{-1}).

Table 4 Effect of organic fertilizers (compost, FYM and humic acid) on nutrients (nitrogen, phosphorus, potassium) uptake in maize

Treatments	Plant uptake nitrogen (mg kg^{-1})	Plant uptake phosphorous (mg kg^{-1})	Plant uptake potassium (mg kg^{-1})
T0	3133 h	896.7 g	7000 g
T1	9797 c	3340 d	19333 b
T2	8747 e	2770 e	12933 e
T3	5647 g	1693.3 f	9500 f
T4	10683 b	4530 b	16633 c
T5	9383 d	3803.3 c	14933 d
T6	6773 f	2523.3 e	10233 f
T7	11650 a	5240 a	20267 a

Where T0 = Control, T1 = Compost, T2 = FYM, T3 = Humic acid, T4 = Compost + FYM, T5 = Compost + Humic acid, T6 = FYM + Humic acid, T7 = Compost + FYM + Humic acid. Means which are followed by different letters are statistically different from each other at $p \leq (0.05)$

Germination count

Germination percentage depicted significant increase in various treatment of growing maize crop as data shown in Table 5. The maximum germination percentage (81%) was determined in treatment 7 having combine application (Compost+ FYM+ HA) followed by the treatment 4 where combine application (Compost + FYM) (79.66%) were used. Low germination count (72-75%) was examined in treatment T0 (Control) which was at par by treatment 3 (Humic acid) and treatment 6 combine application (FYM + HA).

Number of plants plot⁻¹

Data presented in Table 5 showed that the increased number of plants per plot (38) was noted in treatment T7

having mixed application of (Compost + FYM + Humic acid), followed by treatment-5 (Compost + HA) (37) and treatment 1 (Compost) (35). The lowest number of plants plot⁻¹ (27) were determine in (Control) T0 with no application of fertilizer, followed by the treatment 3 (HA) (30) and treatment 6 with combined application of (FYM and HA) (32).

Number of cobs plant⁻¹

Cobs per plant showed no significant increase in seven fertility treatments, as shown in Table 5. The maximum cobs/plant (1.26) was recorded in treatment 7 with (Compost + FYM + HA). Lowest number of cob/plant (1.00) was observed in T0 receiving no fertilizer. The main reason for this cob behavior was possible due to traits of cultivar which was probably regulated by inherited makeup rather than management practices.

Table 5 Effect of organic fertilizers (Compost, FYM and humic acid) on germination count, number of plants per plot and number of cobs per plant in maize

Treatments	Germination count (%)	Number of plants plot ⁻¹	Number of cobs plant ⁻¹
T0	72.00 e	27.00 g	1.00 c
T1	78.00 c	35.00 c	1.26 a
T2	77.33 c	33.00 d	1.20 ab
T3	74.66 d	30.00 f	1.06 bc
T4	79.66 b	38.00 a	1.20 ab
T5	78.00 c	37.00 b	1.20 ab
T6	75.00 d	32.00 e	1.13 abc
T7	81.00 a	38.00 a	1.26 a

Where T0 = Control, T1 = Compost, T2 = FYM, T3 = Humic acid, T4 = Compost + FYM, T5 = Compost + Humic acid, T6 = FYM + Humic acid, T7 = Compost + FYM + Humic acid. Means which are followed by different letters are statistically different from each other at $p \leq (0.05)$

Grain rows cob⁻¹

The number of grain rows per cob is an important yield-contributing trait that can directly influence maize productivity. A significant variation in the number of grain rows per cob was observed among the different fertility treatments, as presented in Table 6. The gradual release of nutrients from compost and FYM may have supplied essential nutrients throughout the crop growth period, while humic substances may have enhanced nutrient availability and uptake by improving root activity and soil conditions. Adequate availability of nitrogen, phosphorus, and potassium during the vegetative and reproductive stages may have promoted better cob development and increased the number of grain rows. The highest number of grain rows per cob was recorded in T4 ($\frac{1}{2}$ Compost + $\frac{1}{2}$ FYM), which was statistically at par with T7 ($\frac{1}{3}$ Compost + $\frac{1}{3}$ FYM + $\frac{1}{3}$ Humic acid). This indicates that the combined application of organic amendments was more effective in enhancing grain row formation than their individual application. The minimum number of grain rows per cob (9) was recorded in T0 (Control), where no fertilizer or organic amendment was applied, followed by T3 (Humic acid) with 10 grain rows per cob. Overall, the results demonstrate that the combined application of compost, FYM, and Humic acid improved this important

yield component of maize compared with the control and individual amendment treatments.

Grains cob⁻¹

Grains per cob shows significant difference in different fertilizer actions as shown in Table 6. Treatment T7 in combination with Compost + FYM + HA, attained higher grains per cob (442), followed by treatment T5 combine application (Compost + HA) (428.33) and treatment T1 (Compost) (419.33) which was at par to treatment T2 (FYM) (414.33). Lowest (384.33) grains ⁻¹cob were determined in treatment T0 (Control) with no fertilizer application.

Cob length (cm)

Cob length shows significant variance in different fertilizer treatments of maize crop as data pretend in Table 6. Highest (14.42 cm) cob length was determined in treatment T7 with combine application of Compost + FYM + HA, followed by treatment 4 with Compost + FYM (14.08 cm) and treatment 5 with Compost + HA (13.86 cm). Minimum cob length (11.72 cm) was examined in T0 (Control) treatment having no fertilizer incorporated followed by T3 treatment (HA) (12.32 cm) and treatment 6 FYM + HA (12.85 cm).

Table 6 Effect of organic fertilizers (compost, FYM and humic acid) on grain rows per cob, grains per cob and cob length in maize

Treatments	Grain rows cob ⁻¹	Grains cob ⁻¹	Cob length (cm)
T0	9 g	384.33 e	11.72 h
T1	12 cd	419.33 c	13.63 d
T2	12 de	414.33 c	13.22 e
T3	10 f	399.67 d	12.32 g
T4	14 a	435.67 ab	14.08 b
T5	13 bc	428.33 b	13.86 c
T6	11 ef	402.33 d	12.85 f
T7	13 b	442.00 a	14.42 a

Where T0 = Control; T1 = Compost; T2 = FYM; T3 = Humic acid; T4 = Compost + FYM; T5 = Compost + Humic acid; T6 = FYM + Humic acid; T7 = Compost + FYM + Humic acid. Means having different alphabetical letters are statistically dissimilar from each other at $p \leq (0.05)$

Plant height (cm)

Crop growth determined by plant height when it attains maturity. It was sufficiently increased with excessive uptake of nutrients as show in Table 7. Highest compost level contributed toward increased plant height. Plant height shows significant result over different treatments. Highest (139.40 cm) plant height was observed in treatment T4 having mixed doses of (Compost + FYM) which was at par by T7 treatment with combine doses of (Compost + FYM + HA) (136.33 cm). Lowest plant height (118.60 cm) was examined in treatment T0 (Control). Its intermediate value (127.57 cm) was observed in treatment 2 (FYM) followed by treatment 3 (HA) (121.67 cm).

Thousand grains weight (g)

The results obtained in thousand grains weight were significantly different in respect to different fertilizer doses data pretend in Table 7. The maximum 1000 grains weight (348.47 g) was examine in T7 treatment having (Compost+ FYM+ HA) were incorporated followed by T4 treatment having combine application (Compost+ FYM) (344.23 g) which was at par to the T5 treatment received (Compost and HA) (342.53 g). The lowest 1000 grains weight (323.33 g) was examine in treatment T0 (Control) having no application of fertilizer, which was statistically equivalent with treatment T3 (HA) having 1000 grains weight of (324.77 g).

Table 7 Effect of organic fertilizers (compost, FYM and humic acid) on plant height and 1000 grains weight of maize

Treatments	Plant height (cm)	1000 grains weight (g)
T0	118.60 h	323.33 f
T1	130.67 d	337.63 c
T2	127.57 e	331.10 d
T3	121.67 g	324.77 f
T4	139.40 a	344.23 b
T5	134.07 c	342.53 b
T6	124.80 f	327.60 e
T7	136.33 b	348.47 a

Where T0 = Control, T1 = Compost, T2 = FYM, T3 = Humic acid, T4 = Compost + FYM, T5 = Compost + Humic acid, T6 = FYM +

Humic acid, T7 = Compost + FYM + Humic acid. Means which are Followed by contrasting letters are statistically different from each other at $p \leq (0.05)$

Total biomass (kg ha⁻¹)

Plant biomass observed maximum significant difference in various fertilizer treatments of maize crop data shown in Table 8. The maximum biomass (11853 kg ha⁻¹) observed in treatment T1 (Compost) sole applied, followed by the treatment T7 with combine application of compost + FYM + HA (11686 kg ha⁻¹) and treatment 4 with combination of compost + FYM (11600 kg ha⁻¹). The minimum biomass (10325 kg ha⁻¹) was determine in treatment T0 (Control) without any fertilizer applied, followed by treatment 3 with (HA) (10542 kg ha⁻¹).

Grain yield (kg ha⁻¹)

Grain yield showed significant variation among the different treatment doses, as presented in Table 8. The maximum grain yield (1994.4 kg ha⁻¹) was determined in treatment T7 with combine application (Compost+ FYM+ HA) was provided, followed by the treatment T4 with combine application (Compost + FYM) (1927.8 kg ha⁻¹) and treatment T5 combine application (Compost + HA) (1847.2 kg ha⁻¹). The lowest grain yield (1247.2 kg ha⁻¹) was determine in treatment T0 (Control) with no fertilizer used, followed by the treatment 3 with HA (1419.4 kg ha⁻¹) and treatment 6 with combine application of FYM + HA (1575 kg ha⁻¹).The main reason that can increase maize grain yield was maximum number of grain per cob, number of rows, cob length as well as 1000 grains weights.

Harvest index (%)

In different fertility treatment harvest index show significant results data give in Table 8. Maximum harvest index (17.06%) was obtained in T7 treatment with combine application (Compost + FYM + HA), which was equivalent with treatment 5 (Compost + HA) (16.61%) and treatment 4 (Compost + FYM) (16.75%). Lowest (12.07%) harvest index was observed in treatment T0 (Control) having no use of any fertilizer followed by treatment 3 (HA) (13.46%).

Table 8 Effect of organic fertilizers (compost, FYM and humic acid) on biological yield, grain yield and harvest index in maize

Treatment	Biological yield (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	Harvest index (%)
T0	10325 h	1247.2 h	12.07 e
T1	11853 a	1783.3 d	15.04 c
T2	11406 d	1680.6 e	14.73 c
T3	10542 g	1419.4 g	13.46 d
T4	11600 c	1927.8 b	16.61 b
T5	11028 e	1847.2 c	16.75 ab
T6	10747 f	1575 f	14.65 c
T7	11686 b	1994.4 a	17.06 a

Where T0 = Control; T1 = Compost; T2 = FYM; T3 = Humic acid; T4 = Compost + FYM; T5 = Compost + Humic acid; T6 = FYM + Humic acid; T7 = Compost + FYM + Humic acid. Means having different alphabetical letters are statistically dissimilar from each other at $p \leq (0.05)$

Discussion

Increase in yield of maize and enhancement in soil nitrogen contents by using organic fertilizer was studied by Esilab et al. (2000). In soil, phosphorus is present as an immobile nutrient element and its dispersion is the major process of controlling movement. Its mobility is regulated by soil moisture contents (Ibrahim et al., 2022). Soil moisture contents were increased by organic manure (Boateng et al., 2006) which might be the cause of phosphorus availability in soil. Wahid et al. (2015) stated that organic fertilizer significantly improved the organic contents of phosphorus in the soil. Use of different organic materials showed the availability of soil phosphorus (Pattanayak et al., 2001; Parmer & Sharma, 2002; Singh et al., 2002; Verma et al., 2002). Aziz et al. (2010) specified that soil K contents were significantly enhanced with the application of organic manures. Swarup and Yaduvanshi (2000); (Singh et al. (2002); Verma et al. (2002) stated that utilizing organic substances helped in enhancing the potassium status of the soil. Due to process of mineralization, the soil pH values probably showed reduction which resulted in the release of H^+ ions. As such, the soil pH values showed reduction using different sources of organic fertilizer, because of releasing of H^+ ions in a process known as nitrification (He et al., 2026). The impacts of organic fertilizers depend upon soil initial pH level. Increase in application rate of organic manures showed reduction in pH values (Pattanayak et al., 2001; Yaduvanshi, 2001; Smiciklas et al., 2002).

Feil et al. (2005); Awaad et al. (2009) reported that organic fertilizer applied in combination can increase the nitrogen uptake in plants. (Aziz et al., 2006) stated that plant receiving organic fertilizer has more root growth hence it was the reason for increased P uptake in plants. These results have shown similarity in accordance with (Aziz et al., 2010). They stated that with organic fertilizer application the availability of phosphorus and potassium were increased. If the natural germination ability of seed is better, soil has appropriate organic substance, enhanced water holding capacity, soil porosity soil physical conditions, (Prasad & Sinha, 2000; Bhattacharyya et al., 2008). Findings of our study were correlated with the report of (Buriro et al., 2014). Amanullah et al. (2015) stated that maximum yield & yield attributes in maize crop, the application of compost was more useful than any other fertilizer application. Our findings are comparable with the findings of Khan et al. (2008) who stated that grains cob^{-1} shows significant improvement by applying organic fertilizer. Increase in cob length of maize crop was because of excessive applied doses of organic manures and their higher translocation of assimilates and nutrients absorption. It has been resulted that an increased cob length was due to rapidly nutrients flow and their diffusion (Sahoo & Panda, 2001). They also reported that excessive nutrients availability shows increased in length of cob.

These results are correlated with findings of Muhammad and Khattak (2009) who stated that plant

height can be improved by organic manures. Increasing plant height of growing maize crop was due to incorporated organic material (Khaliq et al., 2004). Amanullah et al. (2009) resulted that by the absorption and transfer of excessive nutrients, the highest grain weight was obtained. The organic manure incorporated in the soil is known to lower the evaporation demand of maize crop, and thereby crop needs and utilizes adequate amount of water essential for its root growth, perhaps due to softening of soil which ultimately leads the plant to proliferate its roots deeply into the moistened soil in order to fulfill its increasing water demands (Mahmood et al., 2017). Increase in TGW of maize was observed due to the excessive mass flow of nutrients and their diffusion into plant root zone because of increased compost application. These results are consistent with the findings of Imran and Khan (2015), who reported that the addition of farmyard manure (FYM) to soils with high pH can supply appreciable amounts of phosphorus (P) and enhance the availability of other essential nutrients to plants.

The reason for the increase in total biomass of maize was due to more use of nutrients from existing nutrients sink, due to continuous nutrients supply and excessive absorption of water (Swarup & Yaduvanshi, 2000; Jagadeeswari & Kumaraswamy, 2000). Net growth rate of maize crop can increase with addition of various organic substances in an experiment also has been determined and explained by (Muhammad et al., 2007). These findings are correlated with Amanullah et al. (2009) who stated that repeatedly supply of several nutrients was the main reason for significant change in its grain yield. Ibrahim et al. (2008) determined that grain yield was mostly enhanced by the addition of organic substances. Ahmad et al. (2008) stated that variation in plants ability for nutrients absorption greatly influences the growth and yield potential. These findings are supported by the previous results of Bajpai et al. (2002); Chand et al. (2002) who stated that the growth parameters of maize crop greatly affected by compost application.

Daur and Bakhshwain (2013) evaluated the effects of 6 varying treatment levels of Humic acid on maize crop growth by conducting a field trial at Agricultural Research Station in King Abdul Aziz University, Saudi Arabia. In this study the use of fertilizers was controlled, and 6 different levels of Humic acid were evaluated. Humic acid application with the dose 25 kg ha^{-1} gave maximum height 201 cm and lowest was of control 177 cm. Furthermore, Tahir et al. (2011), reported that HA enhances crop growth and its productivity, more over it also helps in soil moisture retention and mitigation against salinity. Abdel-Mawgoud et al. (2007) stated that Humic acid has great effect on plant growth. It increases plant growth by chelating and provide nutrients, thus having the ability to overcome nutrients deficiency and have positive impacts on growth, production, and improvement in the quality of various agricultural products because of having hormonal compounds.

In earlier studies, Mohamed et al. (2012) evaluated the effects of the application of HA and its various forms of calcium along with their soil interaction (pH, EC), dry weight and the nutrients uptake ability of maize (*Zea mays* L.) when sown in the salt stress conditions. To determine the application

of Humic acid on plant, four doses of Humic acid (0, 1.0, 2.0 and 3.0 g kg⁻¹) and the forms of calcium like [calcium sulphate (CaSO₄), calcium nitrate (Ca(NO₃)₂) and calcium chloride (CaCl₂)], incorporated into the soil. The results revealed that these applied doses of Humic acid brought positive changes on the availability of nitrogen and phosphorus and their plants uptake rate in comparison to control. Motaghi and Tayeb (2014) studied three different doses of the potassium fertilizer (0, 200, and 300 kg ha⁻¹) along with three different doses of Humic acid (0, 50, 100 ppm). Different parameters like total dry weight (TDW), crop growth rate (CGR), net assimilation rate (NAR) and leaf area index (LAI) observed. It estimated that consumption of Humic acid has increased at the 100ppm level of Humic acid. There was also significant improvement in leaf area index at 100 ppm Humic acid dose.

In another study, Haghighi et al. (2013) reported that there were remarkable impacts of Humic acid on the growth of plants roots, shoots, their ability to absorb nutrient e.g. N, P, K, Mg, Ca. HA don't have any dangerous impacts and it acts as environment friendly ecosystem. Vengadaramana and Jashothan (2012) reported that soil texture and organic matter also plays a great role in determining the soil water holding capacity (WHC). The pivotal aim was to improve WHC with application of various organic fertilizers. Soil samples collected from 10 different areas in the field in a way to determine the effects of compost and cow dung on water holding capacity of soils. A significant difference was observed on mean WHC of every collected soil sample in which compost and cow dung were treated separately in comparison to control treatment. So, it was observed that addition of different organic substrates doubled the WHC of soil sample. The best choice for farmers is to use organic matters rather than WHC. Optimum water use can enhance the plant growth and save the time.

In present scenario, Asri et al. (2015) studied that the concentration of N, P, K, Mn, Ca and Zn in tomato leaves was increased by adding Humic acid, especially 80 L ha⁻¹ Humic acid level provided the most important progress during the first year. In second year, they recorded that the improved concentration of N, P, K, Fe and Mn showed positive changes with the addition of Humic acid and its excessive levels caused decline in nutrients level in soil. Azeem et al. (2014) evaluated the impacts of applied HA and N on the growth, phenology and productivity of maize (*Zea mays* L.). The trial was performed at the University of Agriculture Peshawar in Autumn 2011. Two factors were studied with three different Humic acid doses (1.5, 3 and 4.5 kg ha⁻¹) along with four nitrogen doses (80, 120, 160 and 200 kg ha⁻¹). The maize crop took 57 days to appear silking at the rate of Humic acid 4.5 kg ha⁻¹, while grains ear⁻¹ was 432. The grain yield was 3602 kg ha⁻¹ at the rate of 4 kg ha⁻¹. Arif et al. (2012) performed an experiment at the field of New Developmental Farm in Agricultural University Peshawar, Pakistan. The experiment was composed of 6 different fertilizer treatments e.g. control,

nitrogen applied alone (N), biochar alone (BC), farm yard manure alone (FYM), 50 % N (mineral) in combination with 50 % BC and 50% FYM in combination with 50% BC. Maximum plant height, ear length, rows per ear and grains per ear were obtained by the application of FYM as comparison with control. Bocchi and Tano (1994) studied the effects of certain type of animal waste as fertilizer for maize crop. He found that various form of organic waste promotes the early ripening of plant, enhancing its size and grain yield.

Choudharya and Kumar (2013) investigated the effects of various doses of organic fertilizers on the production technology of maize, its economics and its responses to soil in eastern Himalayan region, India. Six treatments viz., T1: Vermi compost (VC; 2.5 Mg ha⁻¹), T2: Poultry manure (PM; 1.25 Mg ha⁻¹), T3: Swine manure (SM; 3.0 Mg ha⁻¹), T4: Cow dung manure (CDM; 10.0 Mg ha⁻¹), T5: Farm yard manure (FYM; 10.0 Mg ha⁻¹) and T6: control. Maximum plant height, number of leaves, yield and NPK uptake in treatment FYM shows significance result over the control. Buriro et al. (2014) performed an experiment to study the fodder yield of maize and its N uptake rate being influenced by the application of FYM and nitrogen rates. The used variety of maize named "Akbar" was treated with varying doses of farmyard manure (0, 8, 10 and 12 t ha⁻¹) with various N rates (0, 100, 150 and 200 kg ha⁻¹). Nitrogen uptake improved significantly with the addition of farmyard manure. Application of 12 t ha⁻¹ FYM recorded higher N uptake.

Similar results were obtained by Yadav et al. (2006) in which he also observed that use of FYM proved best for improving nutrient mobilization and uptake ability in growing maize crop. The green fodder yield of maize augmented due to application of farmyard manure. The higher yield of green fodder was determined in a treatment applied with 12 and 10 t ha⁻¹ of FYM, respectively. Aziz et al. (2010) determined that the effects of organic manures are responsible to improve the soil physical, chemical and biological properties and availability of nutrients to crops. A field experiment was performed in order to check its beneficial effects using different sources of organic fertilizers e.g. farmyard manure, poultry manure, press-mud on soil physical & chemical properties when applied to maize crop. Results showed that addition of organic source of fertilizer improved the phosphorus and potassium availability into the soil and its plants uptake, and thereby improved plant height, fresh and dry weight of roots and shoots and also leaf area. So, this improvement in maize growth was mainly due to increased availability of soil nutrients and their uptake by crop plants.

Sharif et al. (2014) investigated the impacts of organic manures e.g. farmyard manure, compost, humic acid, press-mud and compost prepared with rock phosphate on the growth and P uptake of sorghum. The organic material contents were applied prior to sowing based on P content. The results revealed the maximum plant height, its dry matter yield and emergence of sorghum in the combination treatment of farmyard manure, compost and press-mud. So, it showed that addition of different sources of organic materials improved the nutrient availability through soil and thus maximized the growth of sorghum. Nasim et al. (2012) investigated the

mutual effects of the combined application of chemical and organic fertilizer in an experiment on yield components of maize in plots which were applied at the rate of 100 kg N ha⁻¹ as urea + 100 kg N ha⁻¹ as poultry manure. The results revealed that maximum cob length (cm), cobs plant⁻¹, grains cob⁻¹, 1000-grain weight (g) of maize. He concluded that using organic source of fertilizer is very much important as it prevents the lethal effects of inorganic fertilizers on human health.

Conclusion

Different organic substrates like compost, FYM and Humic acid were used for growing maize crop. Among all these organic sources, the combination of compost, FYM and Humic acid performed the best and appeared as an alternate for chemical fertilizer to a great extent. The result suggested that use of different organic fertilizers have potential to increase the crop growth, soil nutrients level and nutrients uptake as well as environment friendly process. The research findings are helpful for farmers to reduce their dependence on chemical fertilizer. Moreover, organic sources are environment friendly, pre-requisite for keeping soil microbial biomass dynamic, and maintaining soil biological health and its quality. Based on the findings of the present study, the combined application of compost, FYM, and Humic acid is recommended for improving maize productivity and maintaining soil fertility under the agro-climatic conditions of the Pothohar region. Farmers are encouraged to incorporate locally available organic materials into their nutrient-management practices to reduce excessive dependence on synthetic fertilizers. However, organic amendments should be applied at appropriate rates according to soil fertility status and crop nutrient requirements. Further long-term field studies are recommended to evaluate the residual effects of these organic amendments on soil health, nutrient dynamics, microbial activity, and crop productivity.

Declarations

i. Ethics approval and consent to participate

Ethical approval and informed consent were not required for this study as it did not involve human participants, human data, or animals.

ii. Consent for publication

Consent for publication is not applicable.

iii. Data availability

All data generated or analyzed during this study are included in this article.

iv. Competing interests

Authors have declared that no competing interests exist.

v. Authors' contributions

I.A. designed the study and supervised the research. F.A.F. performed the experiments and collected the data. A.K. performed the statistical analysis and contributed to data interpretation. I.A. wrote the first draft of the manuscript. F.A.F. and A.K. participated in the critical revision and editing of the manuscript. All authors read and approved the final version of the manuscript.

vi. Funding

No funding was received for the design, data collection, analysis, interpretation, or writing of this research manuscript.

vii. Acknowledgement

Not applicable.

viii. SDGs addressed

Zero Hunger (SDG 2), Responsible Consumption and Production (SDG 12), SDG 15 (Life on Land)

Publisher's note: All claims shared in this article are entirely those of the authors and do not reflect the positions of their affiliated institutions, AgriBio e-Spectrum (the publisher), editors, or reviewers. Any mention or assessment of a product, as well as any claims made by its manufacturer, are not endorsed or guaranteed by the publisher.

References

- Abbas, Q. (2022). Current status, challenges and technological breakthrough of organic agriculture with a focus on Pakistan. *Advances in Agriculture and Biology*, 5(1), 1-7.
- Abbas, Q., & Shafique, A. (2019). Integrated use of organic and inorganic fertilizers improves soil health, growth and yield of wheat (*Triticum aestivum* L.). *Advances in Agriculture and Biology*, 2(1), 48-54.
- Abdel-Mawgoud, A. M. R., El-Greadly, N. H. M., Helmy, Y. I., & Singer, S. M. (2007). Responses of tomato plants to different rates of humic-based fertilizer and NPK fertilization. *Journal of Applied Sciences Research*, 3(2), 169–174.
- Abid, A. A., & Latif, A. (2023). Production and physico-chemical properties of biochar and its impact on phosphorous release for soil improvement: A review. *Advances in Agriculture and Biology*, 6(1), 17-27.
- Ahmad, M., & Ahmad, S. (2018). Evaluation of insect pest infestation and yield losses in maize crop in Maina, district Malakand. *Advances in Agriculture and Biology*, 1(1), 34-39.
- Ahmad, S., & Aslam, M. (2018). A discussion on integrated effect of compost and urea fertilizer on growth and yield of crops: An updated review. *Advances in Agriculture and Biology*, 1(1), 47-53.
- Ahmad, S., Zia-ul-Haq, M., Ali, H., Shad, S. A., Ahmad, A., Maqsood, M., & Khan, M. B. (2008). Water and radiation use efficiencies of sunflower hybrids under varying

- nitrogen rates. *Pakistan Journal of Agricultural Sciences*, 45(1), 125–134.
- Akram, Z., & Iqbal, M. T. (2019). Assessment of nitrate levels in soil and water quality for sustainable agriculture in district Muzaffargarh, Pakistan. *Advances in Agriculture and Biology*, 2(1), 25–33.
- Amanullah, Khan, I., Jan, A., Jan, M. T., Khalil, S. K., Shah, Z., & Afzal, M. (2015). Maize growth and yield response to N and compost management under conventional and deep tillage systems. *Communications in Soil Science and Plant Analysis*, 46(12), 1566–1578.
- Amanullah, Asif, M., Malhi, S. S., & Khattak, R. A. (2009). Effects of phosphorus fertilizer source and plant density on growth and yield of maize in Northwestern Pakistan. *Journal of Plant Nutrition*, 32(12), 2080–2093. <https://doi.org/10.1080/01904160903308168>
- Arif, M., Ali, A., Umair, M., Munsif, F., Ali, K., Inamullah, Saleem, M., & Ayub, G. (2012). Effect of biochar, FYM and mineral nitrogen alone and in combination on yield and yield components of maize. *Sarhad Journal of Agriculture*, 28(2), 191–195.
- Asri, F. O., Demirtas, E. I., & Ari, N. (2015). Changes in fruit yield, quality and nutrient concentrations in response to soil humic acid applications in processing tomato. *Bulgarian Journal of Agricultural Science*, 21(3), 585–591.
- Awaad, M. S., Rashad, A. A., & Bayoumi, M. A. (2009). Effect of farmyard manure combined with some phosphate sources on the productivity of canola plants grown on a sandy soil. *Research Journal of Agriculture and Biological Sciences*, 5(6), 1176–1181.
- Ayoola, O. T., & Adeniyi, O. N. (2006). Influence of poultry manure and NPK fertilizer on yield and yield components of crops under different cropping systems in south west Nigeria. *African Journal of Biotechnology*, 5(15), 1386–1392. <https://doi.org/10.5897/AJB05.221>
- Azam, M., Saeed, B., Khan, S., & Zafar, D. (2023). Exploring the effect of nitrogen levels on yield and yield attributes of diverse open-pollinated varieties (OPVs) of maize (*Zea mays*). *Advances in Agriculture and Biology*, 6(1), 61–68.
- Azeem, K., Khalil, S. K., Khan, F., Shahenshah, S., Qahar, A., Sharif, M., & Zamin, M. (2014). Phenology, yield and yield components of maize as affected by humic acid and nitrogen. *Journal of Agricultural Science*, 6(7), 286–293. <https://doi.org/10.5539/jas.v6n7p286>
- Aziz, T., Rahmatullah, Maqsood, M. A., Tahir, M. A., Ahmad, I., & Cheema, M. A. (2006). Phosphorus utilization by six Brassica cultivars (*Brassica juncea* L.) from tri-calcium phosphate; a relatively insoluble P compound. *Pakistan Journal of Botany*, 38(5), 1529–1538.
- Aziz, T., Ullah, S., Sattar, A., Nasim, M., Farooq, M., & Khan, M. M. (2010). Nutrient availability and maize (*Zea mays* L.) growth in soil amended with organic manures. *International Journal of Agriculture and Biology*, 12(4), 621–624.
- Bajpai, R. K., Upadhyay, S. K., Joshi, B. S., & Tripathi, R. S. (2002). Productivity and economics of rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping system under integrated nutrient supply systems. *Indian Journal of Agronomy*, 47(1), 20–25.
- Bhattacharyya, R., Kundu, S., Prakash, V., & Gupta, H. S. (2008). Sustainability under combined application of mineral and organic fertilizers in a rain-fed soybean–wheat system of Indian Himalayas. *European Journal of Agronomy*, 28(1), 33–46.
- Boateng, S. A., Zickermann, J., & Kornahrens, M. (2006). Poultry manure effect on growth and yield of maize. *West African Journal of Applied Ecology*, 9(1), 1–11.
- Bocchi, S., & Tano, F. (1994). Effects of cattle manure and components of pig slurry on maize growth and production. *European Journal of Agronomy*, 3(3), 235–241. [https://doi.org/10.1016/S1161-0301\(14\)80088-9](https://doi.org/10.1016/S1161-0301(14)80088-9)
- Buriro, M., Oad, A., Nangraj, T., & Gandahi, A. W. (2014). Maize fodder yield and nitrogen uptake as influenced by farm yard manure and nitrogen rates. *European Academic Research*, 2(9), 11843–11855.
- Chahal, H. S., Singh, A., Dhillon, I. S., & Kaur, J. (2020). Farmyard manure: A boon for integrated nutrient management. *International Journal of Agriculture, Environment and Biotechnology*, 13(4), 483–495. <https://doi.org/10.30954/0974-1712.04.2020.14>
- Chand, P., Singh, P. K., Govardhan, M., & Chand, P. (2002). Integrated nutrient management in rainfed castor (*Ricinus communis* L.). *Progressive Agriculture*, 2, 122–124.
- Choudhary, V. K., & Kumar, S. P. (2013). Maize production, economics and soil productivity under different organic source of nutrients in eastern Himalayan region, India. *International Journal of Plant Production*, 7(2), 167–186.
- Daur, I., & Bakhashwain, A. A. (2013). Effect of humic acid on growth and quality of maize fodder production. *Pakistan Journal of Botany*, 45(S1), 21–25.
- Edwards, D. R., & Daniel, T. C. (1992). Environmental impacts of on-farm poultry waste disposal: A review. *Bioresource Technology*, 41(1), 9–33. [https://doi.org/10.1016/0960-8524\(92\)90094-E](https://doi.org/10.1016/0960-8524(92)90094-E)
- Eghball, B., & Power, J. F. (1999). Phosphorus- and nitrogen-based manure and compost applications: Corn production and soil phosphorus. *Soil Science Society of America Journal*, 63(4), 895–901. <https://doi.org/10.2136/sssaj1999.634895x>
- Feil, B., Moser, S. B., Jampatong, S., & Stamp, P. (2005). Mineral composition of the grains of tropical maize varieties as affected by pre-anthesis drought and rate of nitrogen fertilization. *Crop Science*, 45(2), 516–523. <https://doi.org/10.2135/cropsci2005.0516>
- Habtegebrial, K., Sing, B. R., & Haile, M. (2007). Impact of tillage and nitrogen fertilization on yield, nitrogen use efficiency of tef (*Eragrostis tef* (Zucc.) Trotter) and soil properties. *Soil & Tillage Research*, 94(1), 55–63. <https://doi.org/10.1016/j.still.2006.07.002>

- Haghighi, M., Kafi, M., & Khorassani, R. (2011). Effects of humic acid on plant growth, nutrient uptake, and postharvest life of gerbera (*Gerbera jamesonii*). *Journal of Plant Nutrition*, 34(12), 1776–1786.
- Hassan, S. S., Nadim, M. A., Khan, M. I., Baloch, M. S., Abbas, R., Latif, A., & Shah, S. M. (2022). Characterization of rice germplasms based on various seedling traits and growth stages. *Advances in Agriculture and Biology*, 5(1), 20-26.
- He, S., Wei, B., Guo, H., Lin, H., Zhu, R., Zhang, X., He, S., Sun, Y., Zhou, S., Cai, A., Wang, Z., & Huang, Z. (2026). Nitrogen fertilization induces greater loss of base cations and accumulation of exchangeable acids in acidic soils than in neutral soils. *Geoderma*, 466, 117669. <https://doi.org/10.1016/j.geoderma.2025.117669>
- Hirzel, J., & Walter, I. (2008). Availability of nitrogen, phosphorus and potassium from poultry litter and conventional fertilizers in a volcanic soil cultivated with silage corn. *Chilean Journal of Agricultural Research*, 68(3), 264–273.
- Hussain, I., Saleem, S., Ullah, H., Nasir, M., Iqbal, M. U., Saleem, M., Khaliq, A., Masood, S. A., Farooq, M. S., Hanif, M., Nisa, Z. U., Jabbar, A., Ghazali, H. M. Z. U., & Khan, A. A. (2024). The role of fermented farmyard manure in promoting soil health and economic sustainability in cotton farming under changing climate. *Journal of Economic Impact*, 6(3), 273–277.
- Ibrahim, M., Hassan, A. U., Arshad, M., & Tanveer, A. (2008). Influence of organic amendments on growth, yield and quality of wheat and on soil properties during transition to organic production. *Kuwait Journal of Science and Engineering*, 35, 49–60.
- Ibrahim, M., Iqbal, M., Tang, Y.-T., Khan, S., Guan, D.-X., & Li, G. (2022). Phosphorus mobilization in plant–soil environments and inspired strategies for managing phosphorus: A review. *Agronomy*, 12(10), 2539. <https://doi.org/10.3390/agronomy12102539>
- Imran, & Khan, A. A. (2015). Influence of compost application and seed rates on production potential of late sown maize on high elevation in Swat-Pakistan. *Journal of Environment and Earth Science*, 5(5), 36-40.
- Iqbal, J., Shah, S. F. H., & Ahmad, I. (2018). Effect of sowing time, advanced genotype, and potassium application on seed cotton yield in relay cropping with wheat. *Advances in Agriculture and Biology*, 1(1), 15-22.
- Jagadeeswari, P. V., & Kumaraswamy, K. (2000). Long-term effects of manure-fertilizer schedules on the yield of and nutrient uptake by rice crop in a permanent manurial experiment. *Journal of the Indian Society of Soil Science*, 48(4), 833–836.
- Khaliq, T., Mahmood, T., Kamal, J., & Masood, A. (2004). Effectiveness of farmyard manure, poultry manure and nitrogen for corn (*Zea mays* L.) productivity. *International Journal of Agriculture & Biology*, 6(2), 260–263.
- Khan, H. Z., Malik, M. A., & Saleem, M. F. (2008). Effect of rate and source of organic material on the production potential of spring maize (*Zea mays* L.). *Pakistan Journal of Agricultural Sciences*, 45(1), 40–43.
- Köninger, J., Lugato, E., Panagos, P., Kochupillai, M., Orgiazzi, A., & Briones, M. J. I. (2021). Manure management and soil biodiversity: Towards more sustainable food systems in the EU. *Agricultural Systems*, 194, 103251. <https://doi.org/10.1016/j.agsy.2021.103251>
- Lishan, T., & Alemu, F. (2024). Elucidating sole application of farmyard manure and blended NPSB fertilizer effects on soil properties at Bench Shako and West Omo zone, South West Ethiopia. *Heliyon*, 10(1), e22908. <https://doi.org/10.1016/j.heliyon.2023.e22908>
- Mahmood, F., Khan, I., Ashraf, U., Shahzad, T., Hussain, S., Shahid, M., Abid, M., & Ullah, S. (2017). Effects of organic and inorganic manures on maize and their residual impact on soil physico-chemical properties. *Journal of Soil Science and Plant Nutrition*, 17(1), 22–32.
- Manhou, K., Hmouni, D., Moussadek, R., Zouahri, A., Yachou, H., Oued Lhaj, M., Sanad, H., Ghanimi, A., & Dakak, H. (2026). Compost application enhances soil quality, growth, and yield of durum wheat under saline conditions. *Scientific Reports*, 16, 7643. <https://doi.org/10.1038/s41598-026-36306-7>
- Mehmood, K., Nasreen, S., Latif, A., & Shah, A. N. (2022). Growth of maize is improved by the combined use of natural and synthetic nutritional sources of potassium: A review. *Advances in Agriculture and Biology*, 5(1), 8-15.
- Mohamed, W. H. (2012). Effects of humic acid and calcium forms on dry weight and nutrient uptake of maize plant under saline condition. *Australian Journal of Basic and Applied Sciences*, 6(8), 597–604.
- Montgomery, D. C. (2001). *Design and analysis of experiments* (5th ed.). John Wiley & Sons.
- Motaghi, S., & Tayeb, S. (2014). The effect of different levels of humic acid and potassium fertilizer on physiological indices of growth. *International Journal of Biosciences*, 5(2), 118-124.
- Muhammad, D., & Khattak, R. A. (2009). Growth and nutrient concentration of maize in pressmud treated saline-sodic soils. *Soil and Environment*, 28(2), 145–155.
- Muhammad, S., Khattak, R. A., & Khan, M. J. (2007). Changes in crop growth rate and net assimilation rate of maize as affected by organic and inorganic combinations. *Pakistan Journal of Agricultural Sciences*, 44(2), 231–237.
- Musa, F. O., Abdalla, M. A., Yousif, K. M., Doka, A. M., Alotaibi, K. D., Abdelmalik, A. M., Almeaiweed, N. H., & Abdelfadeel, I. A. (2026). Valorization of farmyard manure compost as a sustainable amendment for rehabilitating degraded non-cracking soils. *Processes*, 14(4), 724. <https://doi.org/10.3390/pr14040724>
- Nasim, W., Ahmad, A., Khaliq, T., Wajid, A., Munis, M. F. H., Chaudhry, H. J., Maqbool, M. M., Ahmad, S., & Hammad, H. M. (2012). Effect of organic and inorganic

- fertilizer on maize hybrids under agro-environmental conditions of Faisalabad-Pakistan. *African Journal of Agricultural Research*, 7(17), 2713–2719. <https://doi.org/10.5897/AJAR11.2255>
- Noroz, M. M., Shah, A. N., & Latif, A. (2021). Role of adaptation strategies for climate change and nutrients management tools in Gilgit Baltistan's agriculture. *Advances in Agriculture and Biology*, 4(1), 14-21.
- Ouelid Lhaj, M., Moussadek, R., Mouhir, L., Sanad, H., Manhou, K., Iben Halima, O., Yachou, H., Zouahri, A., & Mdarhri Alaoui, M. (2025). Application of compost as an organic amendment for enhancing soil quality and sweet basil (*Ocimum basilicum* L.) growth: Agronomic and ecotoxicological evaluation. *Agronomy*, 15(5), 1045. <https://doi.org/10.3390/agronomy15051045>
- Parmer, D. K., & Sharma, V. (2002). Studies on long-term application of fertilizers and manure on yield of maize-wheat rotation and soil properties under rain-fed conditions in Western Himalayas. *Journal of the Indian Society of Soil Science*, 50(3), 311–312.
- Pattanayak, S. K., Mishra, K. N., Jena, M. K., & Nayak, R. K. (2001). Evaluation of green manure crops fertilized with various phosphorus sources and their effect on subsequent rice crop. *Journal of the Indian Society of Soil Science*, 49(2), 285–291.
- Prasad, B., & Sinha, S. K. (2000). Long-term effects of fertilizers and organic manures on crop yields, nutrient balance, and soil properties in rice-wheat cropping system in Bihar. In I. P. Abrol, K. F. Bronson, J. M. Duxbury, & R. K. Gupta (Eds.), *Long-term soil fertility experiments in rice-wheat cropping systems* (pp. 105–119). New Delhi, India: Rice-Wheat Consortium for the Indo-Gangetic Plains.
- Roheen, A., Baloch, M. S., Ishaq, M., Abbas, R., Khan, Z., Ammar, M., Nouman, M., & Ali, W. (2023). Evaluating the rice genotypes at various growth stages under agro-climatic conditions of Dera Ismail Khan. *Advances in Agriculture and Biology*, 6(1), 40-46.
- Rubab, S., Fayyaz, S., & Asmatullah. (2020). Plant parasitic nematodes associated with wheat and maize. *Advances in Agriculture and Biology*, 3(1), 8-17.
- Ryan, J., Estefan, G. & Rashid, A. (2001). *Soil and plant analysis laboratory manual*. 2nd edn. Aleppo, Syria: International Center for Agricultural Research in the Dry Areas (ICARDA).
- Sahoo, S. C., & Panda, M. M. (2001). Effect of phosphorus and detasseling on yield of baby corn (*Zea mays* L.). *The Indian Journal of Agricultural Sciences*, 71(1), 21–22.
- Shakeel, M., Mehmood, K., Hayat, R., & Malik, K. (2023). Effect of biochar-based rhizobium biofertilizer on groundnut production. *Advances in Agriculture and Biology*, 6(1), 47-53.
- Sharif, M., Arif, M., Burni, T., Khan, F., Jan, B., & Khan, I. (2014). Growth and phosphorus uptake of sorghum plants in salt affected soil as affected by organic materials composted with rock phosphate. *Pakistan Journal of Botany*, 46(1), 173–180.
- Singh, K., Singh, S. K., & Bikramaditya. (2025). Influence of soil pH on nutrient availability and plant growth. *Journal of Science Innovations and Nature of Earth*, 5(1), 105–108.
- Singh, S., Singh, R. N., Prasad, J., & Kumar, B. (2002). Effect of green manuring, FYM and biofertilizer in relation to fertilizer nitrogen on yield and major nutrient uptake by upland rice. *Journal of the Indian Society of Soil Science*, 50(3), 313–314.
- Smiciklas, K. D., Walker, P. M., & Kelley, T. R. (2002). *Utilization of compost (food, paper, landscape and manure) in row crop production*. Department of Agriculture and Health Sciences, Illinois State University, USA.
- Soltanpour, P. N., & Schwab, A. P. (1977). A new soil test for simultaneous extraction of macro- and micro-nutrients in alkaline soils. *Communications in Soil Science and Plant Analysis*, 8(3), 195–207. <https://doi.org/10.1080/00103627709366714>
- Swarup, A., & Yaduvanshi, N. P. S. (2000). Effect of integrated nutrient management on soil properties and yield of rice in alkali soils. *Journal of the Indian Society of Soil Science*, 48(2), 279–282.
- Tahir, M. M., Khurshid, M., Khan, M. Z., Abbasi, M. K., & Kazmi, M. H. (2011). Lignite-derived humic acid effect on growth of wheat plants in different soils. *Pedosphere*, 21(1), 124–131. [https://doi.org/10.1016/S1002-0160\(10\)60087-2](https://doi.org/10.1016/S1002-0160(10)60087-2)
- Vengadaramana, A., and Jashothan, P.T.J. (2012). Effect of organic fertilizers on the water holding capacity of soil in different terrains of Jaffna peninsula in Sri Lanka. *Journal of Natural Product and Plant Resources*, 2(6), 700-703.
- Verma, T. S., Suri, V. K., & Paul, J. (2002). Prescription-based fertilizer recommendations for rice, maize and wheat in different agro-climatic zones of Himachal Pradesh. *Journal of the Indian Society of Soil Science*, 50(3), 272–277.
- Wahid, F., Sharif, M., Khan, M. A., Ali, A., Khattak, A. M., & Saljoqi, A. R. (2015). Addition of rock phosphate to different organic fertilizers influences phosphorus uptake and wheat yield. *Ciência e Técnica Vitivinícola*, 30(3), 90-100.
- Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1), 29–38. <https://doi.org/10.1097/00010694-193401000-00003>
- Yadav, R. K., Purushotham, S., & Thenua, O. V. S. (2006). Effect of farmyard manure and inorganic fertilizers on growth, nutrient uptake, and fodder yield of maize (*Zea mays* L.). *Indian Journal of Agronomy*, 51(3), 204–207.
- Yaduvanshi, N. P. S. (2001). Effect of five years of rice-wheat cropping and NPK fertilizer use with and without organic and green manures on soil properties and crop yields in a

- reclaimed sodic soil. *Journal of the Indian Society of Soil Science*, 49(4), 714–719.
- Zia, M. A., Shoukat, S., Arif, M., Ahmad, B., Nawaz, A. F., Bahadur, A., Zakria, M., Khan, H. S., Khan, S., Suleman, M., & Ali, S. (2023). A discussion on maize transformation during the last two decades (2002–2022): An update on present trends and future prospects. *Advances in Agriculture and Biology*, 6(1), 1-10.



Copyright: © 2026 by the author(s). This open access article is distributed under a Creative Commons Attribution License (CC BY 4.0), <https://creativecommons.org/licenses/by/4.0/>