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Examining the Impact of Microbial Compost from Anaerobic Digestion on Soil Fertility and Maize Crop Nutrient Uptake

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ABSTRACT

This research study was to evaluate the effects of combining microbial compost and mineral fertilizer on soil properties, maize growth, and nutrient uptake. Therefore, after selecting normal soil, 10 kg of soil was placed in each pot. Nine treatments with three replications were applied by using a Completely Randomized Design (CRD) for the study layout. The results revealed that the maximum plant height (101.73 cm), shoot fresh weight (69.36 g), shoot dry weight (128.6 g), root fresh weight (1.68 g), and root dry weight (0.89 g), as well as the highest content of nitrogen (1.66%), the highest phosphorus concentration (1.04%), and the maximum potassium concentration (2.13%) were noted in SF+MM + ½ NPK, while contents of iron (80.2 mg/kg), zinc (98.46 mg/kg), copper (78.66 mg/kg), and manganese (67.7 mg/kg) were also recorded in SF+MM + ½ NPK compared to other treatments. After harvesting maize crops, the lowest pH (7.27), highest EC (0.38 dS/M), and the highest contents of organic matter (1.03%) were recorded in SF+MM + ½ NPK. Maximum nitrogen content in soil (37 mg/kg), phosphorus content in soil (19.7 mg/kg), and potassium content in soil (105.8 mg/kg) were recorded in T8, while maximum contents of iron (4.88 mg/kg), zinc (1.80 mg/kg), copper (0.51 mg/kg), and manganese (1.95 mg/kg) were recorded in SF+MM + ½ NPK. The combination of SF+MM + ½ NPK showed to be the most effective treatment, whereas the usage of compost and chemical fertilizer alone remained the least effective.

INTRODUCTION

Maize (Zea mays L.) is one of the most widely grown cereals in Pakistan with a yield of 3.45 million tons collected from 0.939 million hectares. It is a significant cereal crop that is used for raw materials, people, and animals in a wide range of industries. It belongs to the family Gramineae (Shehzad et al., 2019). It is considered the most significant and extensively utilized cereal for both human consumption and animal feed, having its origins in Central America. It has been grown all over the world because of its broad tolerance to a variety of growing conditions, including temperate and tropical ones. After rice and wheat, it is the 3rd most essential cereal crop in Pakistan. Of this crop, 97% are produced twice a year in Punjab and once a year in KPK, with the remaining two provinces providing 2–3% of the total production.

By 2030, there is anticipated to be 8.3 billion people on the planet. Such a population needs to be supplied by increasing the production of food crops and applying fertilizer efficiently, such as in bio-organic farming, to provide crops with the best nutrients and prevent the degradation of soil (Population by World Data Lab, 2020). Maize is a crop already adapted to many soil types, drought-tolerant, and growth on poor fertile soil (Tang et al., 2020; Zhang et al., 2020; Zhang et al., 2019).

Despite Pakistan's low-resource farmers frequently use fertilizer inconsistently, well-fertilized crops typically yield the highest yields. The main challenges limiting the productivity of calcareous soil plants in Pakistan include poor agricultural methods and management, as well as a deficiency in minerals, specifically N, P, micronutrients, and soil organic matter. Nutrient use efficiency aims to enhance the plants growth and fertility in calcareous soil, minimizing field nutrient losses, and enhancing the overall performance of bio-organic fertilizers by providing crops with the most economical feeding attainable (Hafez et al., 2019).

For a long time, chemical fertilizers have been utilized to enhance agricultural yields. However, modern agricultural trends are concentrated on finding alternatives to chemical fertilizers because they can be costly to buy, harm the environment, and decline soil quality when applied incorrectly (Almamori and Abdul-Ratha, 2020).

Additionally, the world needs to produce high-quality food while sustainably maintaining soil biodiversity. Furthermore, in international markets, high-quality organic food demands high costs. Crop yields may rise if low-cost nutrient sources like bio-fertilizers (microbial inoculants) and organic wastes like compost are used as an alternative to chemical fertilizers. The application of organic waste increases the soil's organic carbon content, while microbial activity encourages the soil to absorb nitrogen and phosphorus. However, soil bacteria are essential for supplying and recycling nutrients that support plant growth. Their quantity and activity could be an indicator of the environmental conditions and soil quality (Singh et al., 2020).

Their free-living or symbiotic associations with plant roots increase agricultural productivity, improve soil quality, and enhance plant nutrient absorption (Bashan et al., 2004; Galindo, 2020).

Soil organic matter augmentation is a key factor in enlightening soil fertility and productivity (Hashemabadi et al., 2018).

Compost, the primary source of soil organic matter, has been applied as a soil supplement in the agricultural industry because of its agronomic advantages and significance for environmental preservation. The purpose of this study is to assess how microbial compost from anaerobic digestion affects soil fertility, with a particular emphasis on how it affects the amount of organic matter and nutrient availability in calcareous soils. Microbial compost's impact on maize crop growth and nutrient uptake will be evaluated, and its efficacy in promoting crop production and nutrient efficiency will be compared to that of conventional chemical fertilizers.

OBJECTIVES

To investigate the impact of compost produced using microbial inoculants (*Acidithiobacillus thiooxidans*, *Acidithiobacillus ferrooxidans*, *Methanosarcina thermophila*, *Methanobacterium thermophila*, and *Methanobacterium beijingense*) on soil fertility and nutrient uptake in maize crops.

MATERIALS AND METHODS

Site Description and Treatments

A pot experiment was conducted at the Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, within a greenhouse environment for sixty days to assess the impact of nutrient uptake by plants and the concentrations of such nutrients in compost-amended soil. The soil was collected from the PMAS Arid Agriculture University sieved (2mm) and 10kg of soil was filled in each pot to accommodate 9 treatments with 3 replications. The seeds were sown in the pot on 19 May 2022 in the Greenhouse research site in Pir Mehr Ali Shah Arid Agriculture University Rawalpindi. The following treatments were used in this experiment. T1; Control, T2: Organic waste (10t/ha), T3: *Acidithiobacillus thioxidans /Acidithiobacillus ferroxidans (10t/ha),* T4: *Methanosarcina* *thermophila / Methanobacterium thermophila / Methanobacterium beijingense (10t/ha),* T5*: Acidithiobacillus thioxidans/ Acidithiobacillus ferroxidans + Methanosarcina thermophila/Methanobacterium beijingense (10t/ha) T6: Organic waste +1/2NPK, T7: Acidithiobacillus thioxidans /Acidithiobacillus ferroxidans + 1/2 NPK, T8: Methanosarcina thermophila / Methanobacterium beijingense + 1/2NPK and T9: Acidithiobacillus thioxidans / Acidithiobacillus ferroxidans + Methanosarcina thermophila / Methanobacterium beijingense +* 1/2NPK. But these treatments are mentioned as a following treatment:

T1: Control, T2: CW (10t/ha), T3: SF (10t/ha), T4: MM (10t/ha), T5 : SF+MM (10t/ha), T6 : CW+ ½ NPK, T7 : SF+ ½ NPK, T8 :MM + ½ NPK and T9 : SF+MM + ½ NPK

Statistical Analysis

Analysis of Variance (ANOVA) was conducted on all data sets (Steel et al., 1997) utilizing Statistics 8.1 software. Means were compared using the Least Significant Difference test.

RESULTS AND DISCUSSIONS

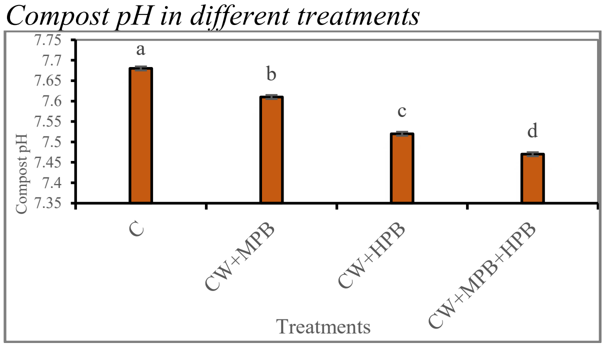
Compost Analysis

pH in Compost

The pH levels fluctuated during the composting process, as shown in Fig 2. Initially, all treatments had a pH between 7.46 and 7.68. T2 (CW+MPB) is non-significant to T3 (CW+HPB), whereas Control (T1) is significant to T2 (CW+MPB), T3 (CW+HPB), and T4 (CW+MPB+HPB). Zhang claimed that the pH had a major impact on the microorganisms' activity and that a pH range of 7.46 to 7.68 was ideal for microbial activity (Zhang et al., 2019).

Figure 1

Compost pH in different treatments

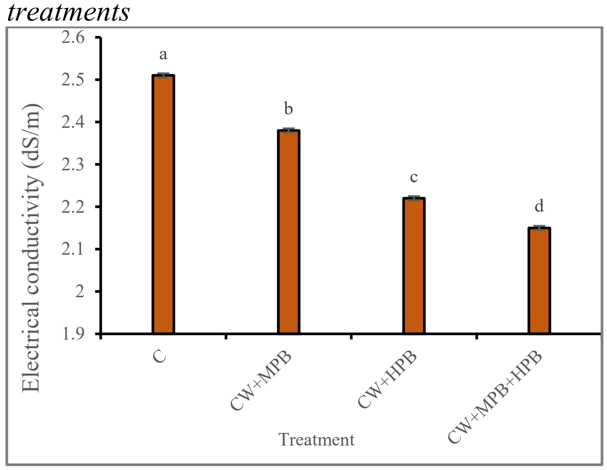


Electrical Conductivity in Compost (dS/m)

The EC of the compost mixture suggests that there are soluble salts present, either in large amounts or in small amounts. The results regarding electrical conductivity as affected by different treatments have been presented in Figure 2. It was observed that there were noticeable differences among the four treatments. Excess soluble salt can cause phytotoxicity in plants. T_1 (Control) evaluated the highest EC value of 2.51 dSm^{-1}, whereas T_4 (CW + MPB + HPB) evaluated the lowest value of 2.15 dSm^{-1}. T_4 (CW+MPB+HPB) is significa2nt to T_1 (Control), T_2 (CW+MPB), and T_3 (CW+HPB). while T_2 (CW+MPB), is non-significant to T_3(CW+HPB). Bernal et al. (2017) also showed similar results. The EC observed the salinity levels in the composting process, notifying that application to the soil may harm plant growth (Awasthi et al., 2018). EC showed the salinity content of compost material as well as the presence of soluble salts in the form of carbonates, bicarbonates, and sulfate of sodium, potassium, calcium, and magnesium. Additionally, EC indicates the compost's quality for plant growth.

Figure 2

Electrical conductivity of different compost treatments

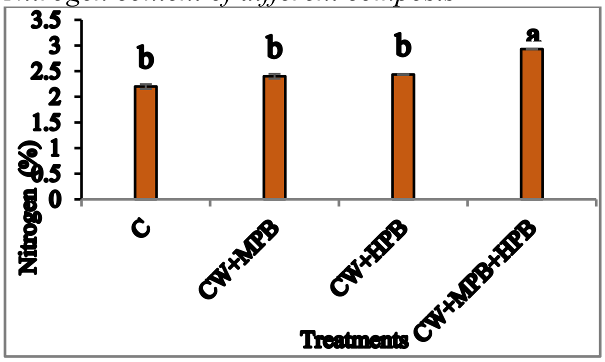


Total Nitrogen Contents in Compost

The nutrient composition of compost produced by anaerobic digestion is presented in Figure 3. The results for nitrogen discovered that the lowest value of nitrogen 2.2% was recorded in control, while the maximum value of nitrogen 2.93% was recorded in CW+HPB+MPB followed by 2.43% in CW+HPB. In CW+HPB+MPB compost nitrogen content was significant to Control. Nitrogen is a vital element for healthy plant growth. Often regarded as the most crucial factor in promoting plant development, it is a key component of chlorophyll, the molecule responsible for the green color in plants matter. These results closely aligned with the findings of (Yadav et al., 2022).

Figure 3

Nitrogen content of different composts

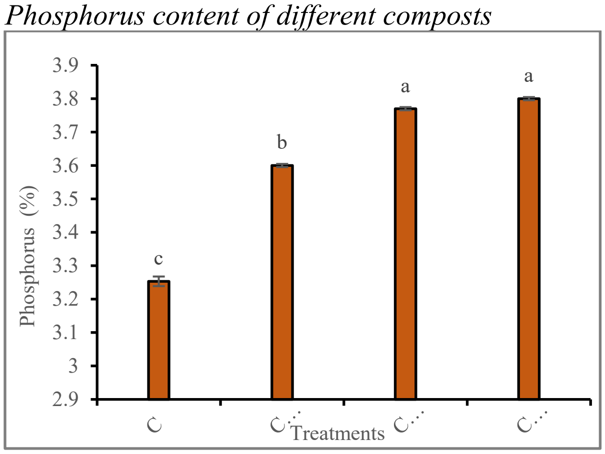


Total phosphorus Contents in Compost

Figure 4 displays the results for the compost's phosphorus content. Anaerobic composting produced compost with nutritional levels that were assessed. According to the phosphorus content results, the control treatment had the lowest phosphorus content (0.25%), while CW+MPB+HPB had the greatest phosphorus level (0.89%). The decomposition of OM throughout the composting method and the phosphorus concentration in the compost mixture were the primary causes of the increase in the total P level. Because the compost mixture's organic C material decomposed, the heaping volume decreased but the P content remained constant, allowing for the recognition of the concentration effect (Noor et al., 2023).

Figure 4

Phosphorus content of different composts

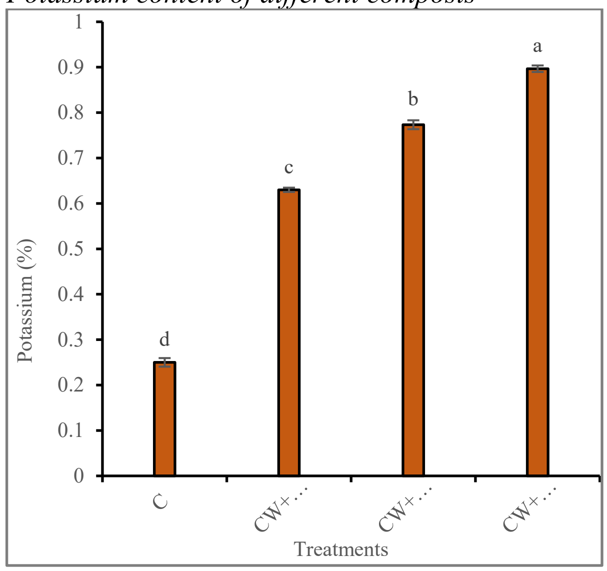


Total Potassium Content in Compost

The results of the potassium content of compost have been presented in Figure 5. The results for potassium revealed that the highest value of potassium in CW+HPB+MPB was 0.89%, while the mean lowest value of potassium in Control was 0.25% while the potassium contents of the other two composts were between these two ranges. From the beginning to compost maturity, the total K content increased. Bustamante reports that the potassium content of compost produced from winery and distillery waste increased from 32 g kg-1 to 46 g kg-1 over the period from the initial to maturity stages of composting (Pinto et al., 2023).

Figure 5

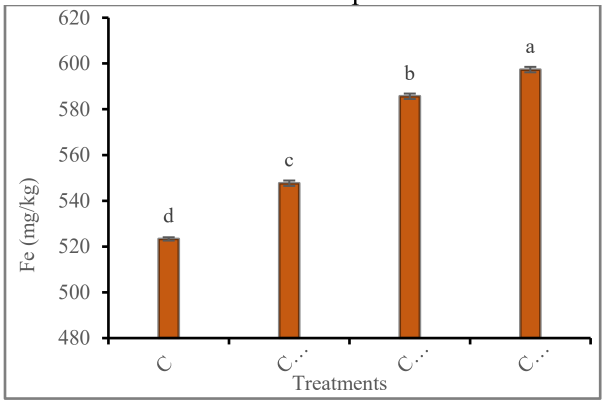
Potassium content of different composts



Iron Contents in Compost

The results of the iron content of compost have been presented in Figure 6. The highest iron content in compost was recorded as 597.33 mg/kg in T4 CW+MPB+HPB while the lowest value of iron in compost was recorded as 523.33 mg/kg in Control. Iron plays a crucial role in the development of plants. It supports the main metabolic activities. The iron content of compost was found to be within safe limits of compost. Iron is important for the processes of respiration, photosynthesis, and nitrogen assimilation. Iron is required for practically every plant's metabolic function. However, the presence of Fe substances in excess amounts may have hazardous consequences for plants (Almamori and Abdul-Ratha, 2020; Khan et al., 2016).

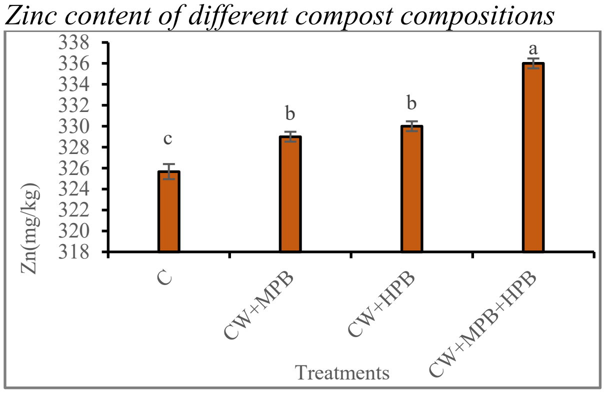
Figure 6
Iron content of different Compost



Zinc

The results of the zinc content of compost have been presented in Figure 7. The maximum value of zinc in compost was recorded as 336 mg/kg in CW+MPB+HPB while the minimum value of zinc in compost was recorded as 325.6 mg/kg in Control. Zinc plays a crucial role in plant health growth. Zinc is important for plant growth. It assists in the synthesis of hormones and the expansion of internodes. The zinc content of all composts was well below the acceptable limits for organic manures. Zinc is needed for the processes of respiration, photosynthesis, and nitrogen assimilation (Mahmood et al., 2017) .

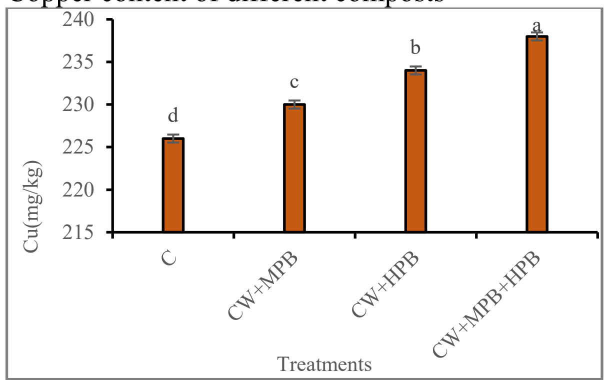
Figure 7
Zinc content of different compost compositions



Copper

The results of the copper content of compost have been presented in Figure 8. The mean maximum value of copper in compost was recorded as 238.3mg/kg in CW+MPB+HPB while the minimum value of copper in compost was documented as 226mg/kg in Control. The micronutrient that plants only need in relatively small amounts is copper. It plays a crucial role in photosynthesis and plant respiration, and it activates several enzymes plants. It shows that the compost product's micronutrient Cu content satisfies the requirements of the standard value. These substances are crucial to the processes of respiration, photosynthesis, and nitrogen assimilation (Tahir et al., 2022).

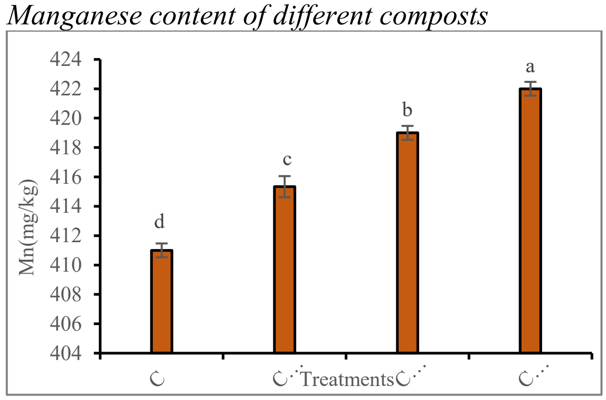
Figure 8
Copper content of different composts



Manganese

The results of the manganese content in compost have been presented in Figure 9. The mean maximum value of manganese in compost was recorded as 422 mg/kg in T4 CW+MPB+HPB, while the minimum value of manganese was recorded as 411.3 mg/kg in Control. The element that promotes photosynthesis in plants is magnesium, which is the main ingredient in chlorophyll. Ribosome particle stability and nucleic acid structure both rely on it. This indicates that the compost product's micronutrient Mn content satisfies the requirements of the standard value. These substances are crucial to the processes of respiration, photosynthesis, and nitrogen assimilation (Khan et al., 2016).

Figure 9
Manganese content of different composts



Greenhouse Experiment

A pot experiment was conducted at Pir Mehr Ali Shah Arid Agriculture University Rawalpindi campus in the greenhouse for 60 days to evaluate the effect of plant micronutrient uptake and concentrations in compost-amended soil. The soil was collected from the University of Arid Agriculture, sieved (2mm) and 10kg of soil was filled in each pot to accommodate 9 treatments with 3 replications.

Soil Analysis Before Sowing

Before planting a maize crop, a preliminary Physio-chemical assessment of the soil was conducted to identify its general performance. The study suggests the soil to be a silty clay loam. The soil used to have a pH of 7.8. This soil has an EC of 0.32dSm^{-1}. While extractable potassium was 127 mg/kg and available phosphorus was 8.24 mg/kg, respectively. Since the pH and EC of the soil were within normal limits of less than 8.5 and less than 4dSm^{-1}, respectively. It was neither sodic nor saline. In the tested soil, extractable K was sufficient (>80 mg/kg), but available phosphorus was in the insufficient range (10 mg/kg).

Following treatments were used in this experiment. T_1; Control, T_2: Organic waste (10t/ha) ,T_3: *Acidithiobacillus thioxidans /Acidithiobacillus ferroxidans (10t/ha)* , T_4 : *Methanosarcina thermophila / Methanobacterium*

thermophila / Methanobacterium beijingense

(10t/ha) , T_5 *: Acidithiobacillus thioxidans/ Acidithiobacillus ferroxidans + Methanosarcina thermophila/Methanobacterium beijingense (10t/ha)* T_6 *: Organic waste +1/2NPK* , T_7 *: Acidithiobacillus thioxidans /Acidithiobacillus ferroxidans + 1/2 NPK* , T_8 *: Methanosarcina thermophila / Methanobacterium beijingense + 1/2NPK and* T_9 *: Acidithiobacillus thioxidans / Acidithiobacillus ferroxidans + Methanosarcina thermophila / Methanobacterium beijingense +* 1/2NPK. But these treatments were mentioned as a following treatment:

T1: Control, T2: CW (10t/ha), T3: SF (10t/ha), T4 : MM (10t/ha), T5 : SF+MM (10t/ha), T6 : CW+ ½ NPK, T7 : SF+ ½ NPK, T8 :MM + ½ NPK and T9 : SF+MM + ½ NPK

Table 1

Physico-chemical analysis of soil used for growing maize crop

Parameters	Units	Values
Soil Texture	-	Silty clay loam
Ph	-	7.8
EC	dS m^{-1}	0.32
Organic Matter	%	0.75
NO_3-N	mg kg^{-1}	4.02
Available P	mg kg^{-1}	8.24
Extractable K	mg kg^{-1}	127
Zn	mg kg^{-1}	1.74
Fe	mg kg^{-1}	2.24
Mn	mg kg^{-1}	1.82
Cu	mg kg-1	1.16

Table 2

Impact of Compost Application on Maize

Treatments	Plant Height (cm)	Fresh Shoot weight (g)	Dry Shoot weight (g)	Fresh Root weight (g)	Dry Root weight (g)
Control	62.067 ^{h}	36.26 ^{i}	13.2 ^{g}	0.97 ^{g}	0.44 ^{h}
CW (10t/h)	63.2g^{h}	38.46 ^{h}	14.3 ^{f}	1.01 ^{f}	0.51 ^{g}
SF(10t/ha)	68.06^{f}	45.63 ^{f}	17.23 ^{e}	1.25 ^{e}	0.68 ^{e}
MM(10t/ha)	87.06^{d}	48.8 ^{e}	20.26 ^{d}	1.34 ^{d}	0.75 ^{d}
SF+MM(10t/ha)	75.10^{g}	57.3^{d}	23.33 ^{c}	1.44 ^{c}	0.79 ^{c}
CW+1/2NPK	65.43^{c}	41.43^{g}	15.2 ^{f}	1.24 ^{e}	0.63 ^{f}
SF+1/2NPK	65.43^{c}	60.66 ^{c}	24.16 ^{c}	1.53 ^{b}	0.83 ^{b}
MM+1/2NPK	96.20^{b}	64.6 ^{b}	25.53 ^{b}	1.65 ^{a}	0.78 ^{c}
SF+MM+1/2NPK	101.73^{a}	69.36 ^{a}	28.6 ^{a}	1.68 ^{a}	0.89 ^{a}

Plant height (cm)

Table 2 illustrates the plant height data for maize under different treatments. Plant height varied significantly between the treatments. The SF + MM + 1/2 NPK treatment produced the tallest maize plants (101.73 cm), followed by MM + 1/2 NPK (96.20 cm). At 62.07 cm, the plants in the control group were the shortest. Except for CW + 1/2 NPK and SF + 1/2 NPK, all treatments produced significantly taller plants than the control. Combining compost application with chemical fertilizers proved to be more effective. These findings were also supported by previous studies. The recommended dosage of NPK and compost greatly improved the agronomic performance of maize and soil health (Baghdadi et al., 2018; Singh et al., 2022; Tahir et al., 2022).

Fresh Shoot and Dry Shoot Weight (g)
The results of the study indicated that both fresh and dried shoot weights showed notable differences across the treatments listed in Table 2. In the SF+MM+1/2NPK treatment, fresh shoot weights ranged from 69.36 g to 36.26 g, whereas the control and SF+MM+1/2NPK treatments displayed dry shoot weights between 13.2 g and 28.6 g. Notably, the SF+MM+1/2NPK treatment achieved the maximum fresh shoot weight at 69.36 g. This treatment likely provided the ideal nutrient balance for enhancing plant growth, along with NPK fertilizer's delivery of essential nutrients and the contributions of the organic amendments to soil health. Supporting this observation, research shows that introducing compost can boost maize yields for feed purposes. (Abdulbaki, 2019; Coulibaly et al., 2019).

Fresh and Dry Root (g)
Table 2 in the study displays significant differences in fresh and dry root weights across various treatments. Treatments that included organic amendments along with NPK fertilizer yielded the highest root growth. Specifically, the SF+MM+1/2NPK treatment recorded fresh root weights between 0.97 g to 1.68 g, while its dry root weights ranged from 0.44 g to 0.89 g. The statistical analysis verified the significance of these differences. Our results align with those of Sabah et al. (2018), which indicated that the combined use of small amounts of inorganic fertilizers and compost enhances maize production characteristics. Additionally, an increase in root growth was observed when compost was utilized alongside mineral fertilizers (Rani et al., 2022).

Table 3
Effect of Compost on macronutrients and micronutrients on maize crop

Treatments	Total N(%)	P(%)	K(%)	Fe(mg/kg)	Zn(mg/kg)	Cu(mg/kg)	Mn(mg/kg)
Control	0.56 ^{g}	0.47^{g}	0.87^{h}	41.16 ^{fg}	39.13^{h}	36.33^{f}	28.7 ^{g}
CW (10t/h)	0.97^{d}	0.50^{g}	0.95^{g}	44.2 ^{ef}	52.3^{f}	41.33^{e}	31.3 ^{fg}
SF(10t/ha)	0.8^{e}	0.56^{e}	1.15^{f}	44.83 ^{e}	54^{f}	59.66^{d}	37.1^{f}
MM(10t/ha)	0.69 ^{f}	0.69^{e}	0.92 ^{g}	40.43 ^{g}	48.9^{g}	60.66^{d}	44.2^{d}
SF+MM(10t/ha)	1.48 ^{c}	0.76^{d}	1.49^{d}	50.56 ^{d}	79.2^{d}	59.33^{d}	55.4^{c}
CW+1/2NPK	0.97^{d}	0.62^{f}	1.43 ^{e}	48.8^{d}	64.3^{e}	62^{d}	33.5^{f}
SF+1/2NPK	1.58 ^{b}	0.88^{c}	1.76^{c}	58.86 ^{c}	89.66^{c}	68.66^{c}	58.3 ^{c}
MM+1/2NPK	1.6 ^{b}	0.95^{b}	1.89 ^{b}	64.5^{b}	92.63^{b}	73.33^{b}	62.3 ^{b}
SF+MM+1/2NPK	1.66 ^{a}	1.04^{a}	2.13 ^{a}	80.2 ^{a}	98.46 ^{a}	78.66 ^{a}	67.7 ^{a}

Total Nitrogen Contents in Plants (%)
Table 2 presents the analysis results, showcasing notable differences in total nitrogen (N) concentrations among the treatments. Total nitrogen levels ranged from 0.56% to 1.66%. The SF+MM+1/2NPK treatment achieved the highest concentration at 1.66%, whereas MM+1/2NPK and SF+1/2NPK had lower values. In contrast, the Control showed the lowest nitrogen level at 0.56%. Statistical analysis confirmed that these increases were significant, indicating that the nitrogen content in plants was strongly influenced by the various treatment conditions. Microbial activity provides crucial carbon, nitrogen, and phosphorus from biomass to the plants. Furthermore, agricultural soils contain both organic and inorganic sulfur forms. Past research shows that organic manure typically mineralizes over several crop seasons. Therefore, to ensure consistent annual yield improvements, it is necessary to apply organic manure for multiple consecutive years. Our results are also supported by the findings of (Sarwar et al., 2020).

Total Phosphorus Contents in Plants(%)
Table 2 displays significant variations in total phosphorus (P) levels across treatments, ranging from 0.47% in the Control group to 1.04% in the SF+MM+1/2NPK group. Statistical analysis confirmed these differences as significant, indicating that the treatments influenced phosphorus levels in the plants. Additionally, the study showed that using compost improved soil quality by increasing organic matter, which resulted in higher levels of phosphorus, calcium, magnesium, and potassium. This shows that organic manure could effectively replace inorganic fertilizers without reducing yield, contributing to a

reported increase in maize fodder by 32% to 35% (Tahir et al., 2022).

Total Potassium Contents in Plants (%)
The findings of this study indicate significant differences in potassium (K) levels across the various treatments, ranging from 0.87% in the Control group to 2.13% in the SF+MM+1/2NPK treatment. Statistical analysis verifies that these differences are substantial, highlighting the impact of different nutrient management strategies on potassium uptake by plants. Previous studies have also reported enhanced potassium levels in maize plants as a result of combining compost with mineral nutrition sources (Fiyyaz et al., 2021).

Iron Contents in Plants (mg/kg)
The study results reveal substantial variation in iron (Fe) content across treatments; as shown in Table 2, the values ranged from 41.16 mg/kg in the control group to 80.2 mg/kg in the SF+MM+1/2NPK treatment. Statistical analysis illustrated the significant impact of different treatments on the plants' iron uptake. The control treatment had the lowest iron level at 41.16 mg/kg, lacking any additional fertilizers or amendments. This suggests that iron availability was restricted in natural soil conditions without external additions, as the soil likely did not contain sufficient bioavailable iron to promote healthy plant growth. Iron is vital for the integrity and functioning of chloroplasts and is key to chlorophyll production in plants (Rout and Sahoo, 2015; Wang et al., 2022).

Zinc Contents in Plants (mg/kg)
The study's results display considerable variations in zinc (Zn) levels across the treatments, with the control group showing a value of 39.13 mg/kg and the SF+MM+1/2NPK treatment reaching 98.46 mg/kg, as outlined in Table 2. The statistical analysis demonstrates that these differences are statistically significant, indicating that different nutrient management practices can effectively enhance the zinc uptake in plants. Furthermore, the results specify that applying zinc fertilizer to the soil over several growing seasons can result in not only higher yields but also improved zinc availability for maize, contingent on the soil's initial zinc content (Liu et al., 2017).

Copper Content in plants (mg/kg)
The study shows considerable differences in copper (Cu) levels among various treatments, with values ranging from 36.33 mg/kg in the control group to 78.66 mg/kg in the SF+MM+1/2NPK treatment. These differences are statistically significant, demonstrating that different nutrient management strategies enhance copper absorption in plants. Copper (Cu) is vital for several processes, including growth hormone synthesis, internode elongation, and various enzymatic functions (Awasthi et al., 2022).

Manganese Contents in Plants (mg/kg)
The analysis of manganese (Mn) concentration across various treatments revealed significant differences in Mn levels. The SF + MM + 1/2 NPK treatment achieved the highest Mn concentration at 67.7 mg/kg, compared to 28.7 mg/kg in the Control group. Treatments with Mn levels above 37.1 mg/kg demonstrated a marked increase relative to the control. Manganese plays a vital role in plant growth and development, underscoring its potential benefits for enhancing crops and promoting sustainable agriculture. In 2016, Mn content in plants was 37% and 25% greater than the multi-year average, while in 2013, the recorded levels were 13 mg/kg, 29 mg/kg, and 40 mg/kg (Arif et al., 2022; Dragicevic et al., 2022).

Soil Analysis after Maize Harvesting

Table 4

Effect of Compost Application on Soil Fertility

Treatment	pH	EC	OM(%)	NO_3-N(mg/kg)	P(mg/kg)	K(mg/kg)
Control	7.83^{a}	0.28^{de}	0.74^{g}	21.6^{e}	12.1^{e}	50.2^{i}
CW (10t/h)	7.64^{c}	0.25^{e}	0.80^{f}	24 d^{e}	12.7^{de}	58.5^{h}
SF(10t/ha)	7.63^{c}	0.30^{cd}	0.81^{f}	26.6^{cd}	15^{c}	66.8^{g}
MM(10t/ha)	7.54^{d}	0.31^{cd}	0.83^{ef}	27.6^{c}	16.5^{bc}	75.3^{e}
SF+MM(10t/ha)	7.44^{e}	0.33^{bc}	0.85^{e}	25^{cd}	16.4^{bc}	82.3^{g}
CW+1/2NPK	7.7^{b}	0.29^{d}	0.90^{d}	27.6^{c}	14.6^{cd}	70.2^{f}
SF+1/2NPK	7.3^{f}	0.35^{ab}	0.95^{c}	31.3^{b}	17.6^{b}	89.5^{c}
MM+1/2NPK	7.34^{f}	0.36^{a}	0.99^{b}	38^{a}	18.4^{ab}	99.6^{b}
SF+MM+1/2NPK	7.25^{g}	0.38^{a}	1.03^{a}	37^{a}	19.7^{a}	105.8^{a}

pH in Soil

Soil pH indicates its level of acidity or alkalinity, illustrated in Table 4, and is vital for nutrient availability. The soil's pH was analyzed following the maize crop harvest. An analysis of variance confirmed the quality of the pH data across different treatments. Results indicated that the different treatments significantly influenced the pH of the soil. Particularly, the Control treatment recorded the highest soil pH at 7.83, indicating a slightly alkaline condition. In contrast, pH values generally decreased across most treatments. Thus, it is evident that applying organic compost to the soil consistently reduces pH, regardless of the type used (Karami et al., 2012; Mahmood et al., 2017).

Electrical Conductivity in Soil (dS/m)

Table 4 illustrates the variations in soil electrical conductivity (EC) among different treatments, highlighting the impacts of both organic and inorganic substance amendments. The control group exhibited the lowest EC values at 0.28 dS/m, closely followed by CW (10t/ha) at 0.25 dS/m, indicating that these treatments successfully maintain low soil salinity. Organic amendments, such as SF (10t/ha) and MM (10t/ha), resulted in a slight increase in EC to 0.30 dS/m and 0.31 dS/m, likely due to soluble ions released from decomposed organic matter. The combination of SF and MM (10t/ha) further raised the EC to 0.33 dS/m, demonstrating an additive effect. In contrast, the application of inorganic fertilizer (1/2 NPK) led to a significant increase in soil EC. Combinations like SF + 1/2 NPK (0.35 dS/m) and MM + 1/2 NPK (0.36 dS/m) produced similar EC levels, while SF + MM + 1/2 NPK resulted in the highest reading at 0.38 dS/m, indicating a cumulative effect from the combination of organic and inorganic inputs on soil salinity. The findings reveal statistical differences suggesting that these combined treatments could enhance nutrient availability but may also pose a risk of salinity buildup in sensitive soils. These insights are vital for effective soil management. In regions with low salinity, using SF + MM + 1/2 NPK is beneficial for increasing soil fertility and crop productivity (Singh et al., 2020; Yadav et al., 2022).

Organic Matter Contents in Soil (%)

Table 4 highlights significant variations in the content of soil organic matter (OM) across treatments. The combination of SF + MM + 1/2 NPK achieved the highest OM level at 1.03%, while the control group recorded the lowest at 0.74%. When CW, SF, and MM were applied at 10t/ha, OM increased slightly to 0.80%, 0.81%, and 0.83%, respectively. The combination of SF and MM at this rate increased OM to 0.85%. Incorporating 1/2 NPK improved results, with CW + 1/2 NPK at 0.90%, SF + 1/2 NPK at 0.95%, and MM + 1/2 NPK at 0.99%, surpassing other treatments. The SF + MM + 1/2 NPK mix showed excellent synergy, yielding the highest organic matter content. These findings highlight the advantages of organic and inorganic amendments for boosting soil organic matter (OM), enhancing nutrient cycling and organic matter breakdown. This approach illustrates how SF + MM + 1/2 NPK increases organic matter, improving soil fertility and structure. While supporting sustainable agriculture, careful management is essential to reduce environmental risks from inorganic inputs fertilizers. Sarwar et al. (2020) also indicated that using compost enhanced soil organic matter, leading to increased concentrations of phosphorus, calcium ions, magnesium ions, and potassium.

Nitrate -Nitrogen Content in Soil (%)

Table 4 presents nitrate-nitrogen (NO_3-N) concentrations in the soil for each treatment. The control exhibited the lowest level at 21.6 mg/kg, whereas MM + 1/2 NPK recorded the highest concentration at 38 mg/kg. Individually, CW (10t/ha), SF (10t/ha), and MM (10t/ha) had NO_3-N contents of 24 mg/kg, 27 mg/kg, and 27.6 mg/kg, respectively. The SF + MM combination yielded 25 mg/kg, similar to SF alone. Adding 1/2 NPK significantly raised NO_3-N levels: CW + 1/2 NPK at 27.6 mg/kg, SF + 1/2 NPK at 31.3 mg/kg, and MM + 1/2 NPK at 38 mg/kg. SF + MM + 1/2 NPK reached 37 mg/kg, similar to MM + 1/2 NPK. These findings suggest that combining organic amendments with inorganic fertilizers enhances soil NO_3-N levels. The highest values in SF + MM + 1/2 NPK and MM + 1/2 NPK indicate a synergistic effect on nitrogen availability. Single organic amendments showed minimal impacts on NO_3-N. Using these combinations can enhance nitrogen uptake and soil fertility; management is crucial to prevent environmental harm and nitrogen leaching.

This research aligns with earlier studies by Sarwar (2005), Sabah et al. (2016), and Sarwar et al. (2020), highlighting that compost enhances soil organic matter. The observations indicated that adding organic amendments boosts nitrogen levels, thereby improving soil quality. Numerous studies confirm that organic amendments elevate nitrogen concentrations in the soil (Kebede et al., 2023; Sabir et al., 2015).They discovered that total nitrogen levels in soil increased by 60% when amended with organic solid waste and by 40% with manure, compared to untreated soil. Furthermore, the application of food waste compost at a rate of 15t/ha improved the nitrogen content of the soil compared to other treatments (Kelley et al., 2020).

Olsen Phosphorus Content in Soil(%)

Table 4 shows the variation in soil phosphorus (P) among treatments; the control group had the lowest (12.1 mg/kg), while SF + MM + 1/2 NPK had the highest (19.7 mg/kg). Single applications of CW (10t/ha), SF (10t/ha), and MM (10t/ha) yielded P levels of 12.7 mg/kg, 15 mg/kg, and 16.5 mg/kg, respectively. The SF + MM combination (10t/ha) yielded 16.4 mg/kg. Adding 1/2 NPK further increased P levels: CW + 1/2 NPK reached 14.6 mg/kg, SF + 1/2 NPK increased to 17.6 mg/kg, and MM + 1/2 NPK reached 18.4 mg/kg. Of all combinations, SF + MM + 1/2 NPK had the highest phosphorus content, indicating that combining organic amendments with inorganic fertilizers enhances soil P availability. Single organic amendments moderately increased P, likely due to phosphorus release from organic matter breakdown. The addition of 1/2 NPK significantly boosted P levels, peaking in SF + MM + 1/2 NPK, reflecting a synergistic effect. This combination improved phosphorus release from organic materials and the solubility of mineral phosphorus from fertilizer. These strategies enhance soil fertility and ensure sufficient phosphorus for crops, but balanced application is crucial to minimize potential environmental impacts like phosphorus runoff.

The findings align with those of researchers who discovered that a higher rate of organic amendment application leads to a linear increase in soil availability (Agegnehu et al., 2015). It was also shown that composting food waste boosts soil nitrogen (N), phosphorus (P), and potassium (K) levels, fostering a conducive soil environment for plant growth. Food waste compost displayed greater average levels of available phosphorus compared to leaf and yard compost, owing to its nutrient-dense composition. A comparable finding was noted by (Zahrim et al.). Nigussie et al. (2012) indicated that applying municipal solid waste compost significantly raised the available P levels.

Extractable Potassium Content in Soil(%)

Table 4 demonstrates that soil potassium (K) levels varied significantly among the treatments, with the control group showing the lowest level at 50.2 mg/kg. Among the individual organic amendments, city waste (CW) raised K levels to 58.5 mg/kg, while SF and MM reported even higher levels of 66.8 mg/kg and 75.3 mg/kg, respectively. The combination of organic amendments further boosted soil K, as illustrated by SF + MM, which increased K to 82.3 mg/kg. Treatments that included 1/2 NPK fertilizer along with organic amendments resulted in the most notable enhancements in soil K. Specifically, CW + 1/2 NPK reached 70.2 mg/kg, whereas SF + 1/2 NPK and MM + 1/2 NPK elevated K to 89.5 mg/kg and 99.6 mg/kg, respectively. The peak K level of 105.8 mg/kg was attained with SF + MM + 1/2 NPK, demonstrating a synergistic effect of combining various organic amendments with inorganic fertilizer. These results highlight the success of integrated nutrient management in enhancing soil potassium levels(Nigussie et al., 2012; Shaaibu and Rabiu, 2023).

Table 5

Effect of compost application on soil micronutrients

Treatment	Fe(mg/kg)	Zn (mg/kg)	Cu(mg/kg)	Mn(mg/kg)
Control	3.89 i	1.21 i	0.11 i	0.25 i
CW(10t/ha)	3.98 h	1.31 h	0.15 h	0.30 h
SF(10t/ha)	4.30 f	1.45 f	0.20 g	1.10 g
MM(10t/ha)	4.45 e	1.49 e	0.26 e	1.15 f
SF+MM(10t/ha)	4.60 d	1.56 d	0.24 f	1.20 e
CW+1/2NPK	4.24 g	1.37 g	0.20 g	1.80 b
SF+1/2NPK	4.68 c	1.69 c	0.40 c	1.51 c

MM+1/2NPK	4.74 [b]	1.74 [b]	0.46 [b]	1.37 [d]
SF+MM+1/2NPK	4.88 [a]	1.80 [a]	0.51 [a]	1.95 [a]

Iron Content in Soil (mg/kg)
The findings show differences in soil iron (Fe) levels across treatments in Table 5. The control had the lowest Fe concentration at 3.89 mg/kg. Among single amendments, CW raised Fe slightly to 3.98 mg/kg, while SF and MM increased it to 4.30 mg/kg and 4.45 mg/kg, respectively. The combination of SF and MM (SF + MM) further raised Fe to 4.60 mg/kg, indicating synergy. Treatments with organic amendments plus 1/2 NPK fertilizer yielded better results. CW + 1/2 NPK increased Fe to 4.24 mg/kg, while SF + 1/2 NPK and MM + 1/2 NPK elevated Fe to 4.68 mg/kg and 4.74 mg/kg, respectively. The highest Fe level of 4.88 mg/kg was observed with SF + MM + 1/2 NPK. These results demonstrate the effectiveness of integrated nutrient management, particularly combining organic amendments with inorganic fertilizers to enhance soil Fe availability. These results closely aligned with the findings of Almamori and Abdul-Ratha (2020) and Rout and Sahoo (2015).

Zinc Content in Soil (mg/kg)
The findings reveal varying soil zinc (Zn) levels across different treatments, as detailed in Table 5. The control group showed the lowest Zn concentration at 1.21 mg/kg. Among the single organic amendments, CW increased Zn to 1.31 mg/kg, while SF and MM elevated it to 1.45 mg/kg and 1.49 mg/kg, respectively. The combination of SF and MM resulted in a Zn level of 1.56 mg/kg. Treatments incorporating organic amendments with 1/2 NPK fertilizer displayed significant Zn enhancements, with CW + 1/2 NPK reaching 1.37 mg/kg, SF + 1/2 NPK at 1.69 mg/kg, and MM + 1/2 NPK at 1.74 mg/kg. The highest Zn concentration, at 1.80 mg/kg, was observed in the treatment SF + MM + 1/2 NPK. These results highlight the effectiveness of integrated nutrient management, especially the combination of various organic amendments with inorganic fertilizers, in increasing soil Zn levels, which is vital for maize growth and improves protein content quality. Zn plays a crucial part in photosynthesis and the mechanism by which plants make proteins (Cakmak, 2008). These results were in close conformity with the findings of Shehzad et al. (2019) and Yadav et al. (2022).

Copper Content in Soil (mg/kg)
The results indicate significant differences in soil copper (Cu) concentrations for various treatments shown in Table 5. The control group recorded the lowest level at 0.11 mg/kg. Upon adding CW, Cu levels increased to 0.15 mg/kg, while SF and MM further raised it to 0.20 mg/kg and 0.26 mg/kg, respectively. The combination of SF and MM resulted in a concentration of 0.24 mg/kg. Treatments combining organic amendments with 1/2 NPK fertilizer displayed higher Cu concentrations: CW + 1/2 NPK at 0.20 mg/kg, SF + 1/2 NPK at 0.40 mg/kg, and MM + 1/2 NPK at 0.46 mg/kg. The peak concentration, 0.51 mg/kg, was observed with SF + MM + 1/2 NPK. These results underline the significance of integrated nutrient management, showcasing the advantages of utilizing both organic and inorganic fertilizers to improve soil copper availability. Organic manures are acknowledged as excellent carriers of micronutrients and help minimize nutrient loss and leaching from the soil. The application of compost significantly benefits soil copper levels, particularly when two types of compost are mixed or when composts are applied alongside inorganic fertilizers. Organic manures are recognized as valuable sources of micronutrients, also aiding in the reduction of nutrient loss and leaching from the soil. These results were in close conformity with the findings of Nadeem et al. (2017) and Yadav et al. (2022).

Manganese Content in Soil (mg/kg)
Table 5 displays the differences in soil manganese (Mn) levels among the treatments. The control exhibited the lowest Mn concentration at 0.25 mg/kg. CW increased Mn to 0.30 mg/kg among single organic amendments, while SF and MM raised it to 1.10 mg/kg and 1.15 mg/kg, respectively. Combining SF and MM further enhanced Mn to 1.20 mg/kg, indicating a synergistic effect. Treatments combining organic amendments with 1/2 NPK fertilizer significantly improved soil Mn. CW + 1/2 NPK achieved 1.80 mg/kg, whereas SF + 1/2 NPK and MM + 1/2 NPK raised Mn to 1.51 mg/kg and 1.37 mg/kg, respectively. The highest Mn level, 1.95 mg/kg, was in the SF + MM + 1/2 NPK treatment. These

findings demonstrate that integrated nutrient management enhances soil Mn content, especially by combining organic and inorganic fertilizers. Due to the significant change in magnesium during the weathering process, the amount of magnesium in the soil fluctuated greatly between 0.05-0.5% (Gransee & Fuhrs,2013). One of the basic nutrients, magnesium is crucial for the photosynthesis of plants and the process by which carbohydrates are divided into different compounds (Farhat et al., 2016). These results were in close conformity with the findings of Yadav et al. (2022) and Nadeem et al. (2017).

CONCLUSION

There were nine treatments with 3 replications. T1: Control, T2: CW (10t/ha), T3: SF (10t/ha), T4 : MM (10t/ha), T5 : SF+MM (10t/ha), T6 : CW+ ½ NPK, T7 : SF+ ½ NPK, T8 :MM + ½ NPK and T9 : SF+MM + ½ NPK . The layout of this research was CRD. Soil samples were analyzed before crop sowing and after crop harvest. Compost and plant samples estimated after 60 days were also subjected to Chemical analysis. Out of nine treatments, SF+MM + ½ NPK was found to be a better treatment. The highest NPK contents and micronutrients Cu, Zn, Fe, and Mn in plants and soil were from the same treatments. Soil samples were collected both before and after the crop was sown. Then, soil samples were tested for various chemical characteristics including EC and pH and macronutrients like N, P, K, and micronutrients like Zn, Cu, Mn, and Fe. The highest NO3-N (38 mg/kg), extractable P (19.7 mg/kg) and extractable K (98.4 mg/kg) of soil were noted in T9 (SF+MM+1/2NPK) and decreased up to NO3-N (21.6 mg/kg), extractable P (12.1 mg/kg) and extractable K (39.13 mg/kg) followed by T1 (Control). Plant samples were obtained at the fodder stage to examine macronutrients and micronutrients. Statistics were applied to the data to compare various treatments. The results revealed that the maximum plant height (101.73 cm), shoot fresh weight (69.36 g), shoot dry weight (128.6 g), root fresh weight (1.68 g), and root dry weight (0.89 g), as well as the highest content of nitrogen (1.66%), the highest phosphorus concentration (1.04%), and the maximum potassium concentration (2.13%) were noted in SF+MM + ½ NPK, while contents of iron (80.2 mg/kg), zinc (98.46 mg/kg), copper (78.66 mg/kg), and manganese (67.7 mg/kg) were also recorded in SF+MM + ½ NPK compared to other treatments. After harvesting maize crops, the lowest pH (7.27), highest EC (0.38 dS/M), and the highest contents of organic matter (1.03%) were recorded in SF+MM + ½ NPK. Maximum nitrogen content in soil (37 mg/kg), phosphorus content in soil (19.7 mg/kg), and potassium content in soil (105.8 mg/kg) were recorded in T8, while maximum contents of iron (4.88 mg/kg), zinc (1.80 mg/kg), copper (0.51 mg/kg), and manganese (1.95 mg/kg) were recorded in SF+MM + ½ NPK. From the pot experiment, it was noted that the compost (CW+ HPB+MPB) with ½ NPK gave better results in terms of soil and plant nutrients.

REFERENCES

Abdulbaki, A. S. (2019). The efficacy of poultry manure on the growth and yield of two capsicum species: Capsicum annuum and Capsicum frutescens. *FUDMA JOURNAL OF SCIENCES* 3, 28-32.

Agegnehu, G., Bass, A. M., Nelson, P. N., Muirhead, B., Wright, G., & Bird, M. I. (2015). Biochar and biochar-compost as soil amendments: Effects on peanut yield, soil properties and greenhouse gas emissions in tropical North Queensland, Australia. *Agriculture, Ecosystems & Environment*, *213*, 72–85. https://doi.org/10.1016/j.agee.2015.07.027

Almamori, H. A., and Abdul-Ratha, H. A. (2020). Effect of addition of vermicompost, bio and mineral fertilizer on the availability of some nutrients in soil and potato yield. *Iraqi Journal of Agricultural Sciences* 51. https://doi.org/10.36103/ijas.v51i2.992

Arif, Y., Singh, P., Siddiqui, H., Naaz, R., & Hayat, S. (2021). Transition metal homeostasis and its role in plant growth and development. *Microbial Biofertilizers and Micronutrient Availability*, 159-178. https://doi.org/10.1007/978-3-030-76609-2_8

Awasthi, M. K., Awasthi, S. K., Wang, Q., Wang, Z., Lahori, A. H., Ren, X., Chen, H., Wang, M., Zhao, J., & Zhang, Z.

(2018). Retracted: Influence of biochar on volatile fatty acids accumulation and microbial community succession during biosolids composting. *Bioresource Technology*, *251*, 158-164. https://doi.org/10.1016/j.biortech.2017.12.037

Awasthi, S., Chauhan, R., & Srivastava, S. (2022). The importance of beneficial and essential trace and ultratrace elements in plant nutrition, growth, and stress tolerance. *Plant Nutrition and Food Security in the Era of Climate Change*, 27-46. https://doi.org/10.1016/b978-0-12-822916-3.00001-9

Baghdadi, A., Halim, R. A., Ghasemzadeh, A., Ramlan, M. F., & Sakimin, S. Z. (2018). Impact of organic and inorganic fertilizers on yield and quality of silage corn in intercropped system with soybean. https://doi.org/10.7287/peerj.preprints.26905v1

Bashan, Y., Holguin, G., & De-Bashan, L. E. (2004). *azospirillum*-plant relationships: Physiological, molecular, agricultural, and environmental advances (1997-2003). *Canadian Journal of Microbiology*, *50*(8), 521-577. https://doi.org/10.1139/w04-035

Bernal, M. P., Sommer, S. G., Chadwick, D., Qing, C., Guoxue, L., & Michel, F. C. (2017). Current approaches and future trends in compost quality criteria for agronomic, environmental, and human health benefits. *Advances in Agronomy*, 143-233. https://doi.org/10.1016/bs.agron.2017.03.002

Coulibaly, S. S., Kouassi, K. I., Koffi, K. K., & B. I. A. Zoro. (2019). Effect of compost from different animal manures on maize (Zea mays) growth. *Journal of Experimental Biology and Agricultural Sciences*, *7*(2), 178–185.

Dragicevic, V., Stoiljkovic, M., Brankov, M., Tolimir, M., Tabaković, M., Dodevska, M. S., & Simić, M. (2022). Status of essential elements in soil and grain of organically produced maize, spelt, and soybean. *Agriculture*, *12*(5), 702. https://doi.org/10.3390/agriculture12050702

Fiyyaz, M., Sarwar, G., Sabah, N., Tahir, M. A., Aftab, M., Manzoor, M. Z., Hussain, S., Zafar, A., Shehzad, I., & Riaz, A. (2021). Integration of mineral fertilizer and poultry manure for improving soil health and maize growth under calcareous soil environment. *Pakistan Journal of Agricultural Research*, *34*(3). https://doi.org/10.17582/journal.pjar/2021/34.3.495.500

Galindo, F. S., Teixeira Filho, M. C., Buzetti, S., Santini, J. M., Boleta, E. H., & Rodrigues, W. L. (2020). Macronutrient accumulation in wheat crop (*Triticum aestivum* L.) with <i>Azospirillum brasilense</i> associated with nitrogen doses and sources. *Journal of Plant Nutrition*, *43*(8), 1057-1069. https://doi.org/10.1080/01904167.2020.1727511

Hafez, M., Popov, A. I., & Rashad, M. (2022). The biological correction using humic substances, Vermicompost, and Azospirillum as an optimum way of optimizing plant production and enhancing soil micronutrients in arid regions. *The Open Agriculture Journal*, *16*(1). https://doi.org/10.2174/18743315-v16-e2204180

Hashemabadi, D., Sabzevari, F., Kaviani, B., & Ansari, M. H. (2018). Organic N-fertilizer, rhizobacterial inoculation and fungal compost improve nutrient uptake, plant growth and the levels of vindoline, ajmalicine, vinblastine, catharanthine and total alkaloids in *Catharanthus roseus* L. *Folia Horticulturae*, *30*(2), 203-213. https://doi.org/10.2478/fhort-2018-0018

Karami, A., Homaee, M., Afzalinia, S., Ruhipour, H., & Basirat, S. (2012). Organic resource management: Impacts on soil aggregate stability and other soil physico-chemical properties. *Agriculture, Ecosystems & Environment*, *148*, 22-28. https://doi.org/10.1016/j.agee.2011.10.021

Kebede, T., Diriba, D., & Boki, A. (2023). The effect of organic solid waste compost on soil properties, growth, and yield of Swiss chard crop (Beta vulgaris L.). *The Scientific World Journal*, *2023*, 1-10. https://doi.org/10.1155/2023/6175746

Kelley, A., Wilkie, A. C., & Maltais-Landry, G. (2020). Food-based composts provide more soil fertility benefits than cow manure-based composts in sandy soils. *Agriculture*, *10*(3), 69. https://doi.org/10.3390/agriculture10030069

Khan, R., Gul, S., Hamayun, M., Shah, M., Sayyed, A., Ismail, H., & Gul, H. (2016). Effect of foliar application of zinc and manganese on growth and some biochemical constituents of Brassica junceae grown under water stress. *J. Agric. Environ. Sci*, *16*, 984-997.

Liu, D., Zhang, W., Yan, P., Chen, X., Zhang, F., & Zou, C. (2016). Soil application of zinc fertilizer could achieve high yield and high grain zinc concentration in maize. *Plant and Soil*, *411*(1-2), 47-55. https://doi.org/10.1007/s11104-016-3105-9

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*, (ahead), 0-0. https://doi.org/10.4067/s0718-95162017005000002

Nadeem, M., Zaman, R., & Saleem, I. (2017). Boardroom gender diversity and corporate sustainability practices: Evidence from Australian securities exchange listed firms. *Journal of Cleaner Production*, *149*, 874-885. https://doi.org/10.1016/j.jclepro.2017.02.141

Nigussie, A., Kissi, E., Misganaw, M., & Ambaw, G. (2012). Effect of Biochar Application on Soil Properties and Nutrient Uptake of Lettuces (Lactuca sativa) Grown in Chromium Polluted Soils. *J. Agric. & Environ. Sci*, *12*(3), 369–376. http://www.idosi.org/aejaes/jaes12(3)12/14.pdf

Noor, R. S., Sun, Y., Aslam, W., & Umair, M. (2023). Sustainable production and characterization of integrated composting systems of organic biomass and inorganic amendments. *Biomass Conversion and Biorefinery*, *14*(21), 27317-27333. https://doi.org/10.1007/s13399-023-03883-w

Pinto, R., Correia, C., Mourão, I., Moura, L., & Brito, L. M. (2023). Composting waste from the white wine industry. *Sustainability*, *15*(4), 3454. https://doi.org/10.3390/su15043454

Rani, B. S., Chandrika, V., Reddy, G. P., Sudhakar, P., Nagamadhuri, K., & Sagar, G. K. (2021). Weed dynamics and nutrient uptake of maize as influenced by different weed management practices. *Indian Journal Of Agricultural Research*, (Of). https://doi.org/10.18805/ijare.a-5500

Rout, G. R., & Sahoo, S. (2015). Role of iron in plant growth and metabolism. *Reviews in Agricultural Science*, *3*(0), 1-24. https://doi.org/10.7831/ras.3.1

Sabir, M., Zia-ur-Rehman, M., Hakeem, K. R., & Saifullah. (2015). Phytoremediation of metal-contaminated soils using organic amendments. *Soil Remediation and Plants*, 503-523. https://doi.org/10.1016/b978-0-12-799937-1.00017-6

Sarwar, G., Schmeisky, H., Hussain, N., Malik, M. A., Manzoor, M. Z., Zafar, A., & Murtaza, G. (2020). Impact of compost to produce rice-wheat crops from saline sodic soil. *Journal of Pure and applied Agriculture*, *5*(1).

Shaaibu, H., & Rabiu, H. M. (2023). Effects of npk and poultry manure rates on growth performance and yield of soybean (Glycine Max L. Merril). *FUDMA JOURNAL OF SCIENCES*, *7*(5), 64-70. https://doi.org/10.33003/fjs-2023-0705-1228

Shehzad, I., Sarwar, G., Manzoor, M. Z., Mujeeb, F., Zafar, A., & Khadija, F. (2019). Variations in nutrient concentrations of maize as affected by different levels of brackish water under normal soil conditions. *Journal of Pure and applied Agriculture*, *4*(1).

Singh, A., Kumari, R., Yadav, A. N., Mishra, S., Sachan, A., & Sachan, S. G. (2020). Tiny microbes, big yields: Microorganisms for enhancing food crop production for sustainable development. *New and Future Developments in Microbial Biotechnology and Bioengineering*, 1-15. https://doi.org/10.1016/b978-0-12-820526-6.00001-4

Singh, R., Kumar, R., Kumar, N., Singh, D., & Pathak, P. K. (2022). Synergism of organic manure and Mycorrhizae along with inorganic fertilizers on crop growth and yield of maize. *International Journal of Environment and Climate Change*, 1763-1772. https://doi.org/10.9734/ijecc/2022/v12i1131161

TAHIR, S. M., MANZOOR, M. Z., ZAFAR, A., & SHEHZAD, I. (2022). Evaluating the combined effect of compost and mineral fertilizers on soil health, growth and mineral acquisition in maize (Zea mays L.). *Pak. J. Bot*, *54*(5), 1793-1801.

Tang, Y., Zhang, F., Engel, B. A., Liu, X., Yue, Q., & Guo, P. (2020). Grid-scale agricultural land and water management: A remote-sensing-based multiobjective approach. *Journal of Cleaner Production*, *265*, 121792. https://doi.org/10.1016/j.jclepro.2020.121792

Wang, L. K., Wang, M. S., Hung, Y., Li, K. H., Aziz, H. A., Yusoff, M. S., & Palaniandy, P. (2022). Vermicomposting process for treating agricultural and food wastes. *Handbook of Environmental Engineering*, 173-203. https://doi.org/10.1007/978-3-031-03591-3_3

Yadav, A., Swaroop, N., Ravindra, J., and Thomas, T. (2022). Effect of different levels of NPK and zinc on physico-chemical properties of soil, growth and yield attributes of maize (Zea mays L.) var. KM20.

Zahrim, A. Y., Darwis, M., Samantha, D., Hasanah, A. S., Aqeela, S. N., Junidah, L., ... & Mariani, R. (2021, October). Composting of food waste in passive aerated bioreactor with turning mode. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1195, No. 1, p. 012001). IOP Publishing.

Zhang, Q., Liu, H., Wu, X., & Wang, W. (2020). Identification of drought tolerant mechanisms in a drought-tolerant maize mutant based on physiological, biochemical and transcriptomic analyses. *BMC Plant Biology*, *20*(1). https://doi.org/10.1186/s12870-020-02526-w

ZHANG, W., WANG, C., XUE, R., & WANG, L. (2019). Effects of salinity on the soil microbial community and soil fertility. *Journal of Integrative Agriculture*, *18*(6), 1360-1368. https://doi.org/10.1016/s2095-3119(18)62077-5