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# A Combined application of compost and mineral fertilization enhances plant growth and soil fertility in calcareous clay loam soils

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## Abstract

Pot experiment was implemented to investigate the effect of compost soil application with and without mineral fertilizers on the plant growth and fertility of calcareous clay loam soils. Randomized complete block design with four replication was used to evaluate the following treatments: i) Control with no compost or fertilizer addition (C); ii) Compost at a rate of 20 ton $ha^{1}$ (Co); iii) Mineral NPK fertilizer as di-ammonium phosphate and potassium sulfate at a rates of 700 kg and 500 kg $ha^{-1}$, respectively; (F) and iv) Combined compost and mineral fertilization (CoF). Pots filled with 4 kg soil and seeded with maize were periodically watered to reach field capacity water content. At flowering stage samples of soil and plants were taken were for analysis. The results indicated that application of compost with and/or without mineral fertilizer significantly increased plant growth and nutrients uptake. Moreover, soil organic matter, cation exchange capacity and nutrient contents were also significantly increased by the same treatments. However, the positive effect of the combined compost and mineral fertilization was better than the effect of separate application of each. The obtained results highly recommend the combined application of compost and mineral fertilizers.

**Keywords:** Compost, Mineral fertilizer, Maize, Calcareous soil.



## Introduction

Soil degradation caused by natural and/or anthropogenic activities is a major worldwide problem that spread at an alarming rate, threatening global food production system. It was estimated that 52 percent of agricultural land world-wide is moderately or severely degraded, (FAO, 2021). One of the consequences of soil degradation is the shrinkage in agricultural soils and the loss of soil organic matter (OM), fertility, and productivity (Maximillian et al., 2019), which is considered vital for sustaining global food security (UN, 2022).

Therefore, increasing food production can mainly be achieved through increasing productivity of the existing land, which can be achieved through intensification with intensive use of agricultural inputs such as mineral fertilizers. Intensification, however, may lead to degradation and deterioration of soil OM, soil fertility and other negative impact on the soil quality (Gupta, 2019; Chang et al., 2021). Although, soil fertility and soil OM are vital components of soil health, but unfortunately have been depleted by intensive farming and/or mismanagement practices. (AbdelRahman et al., 2022). The decline in soil OM decreases soil fertility, water holding capacity, biodiversity and aggregation and structure formation. (Eden et al., 2017).

Intensive use of mineral fertilizers may lead to negative impact on the environment and may lead to soil nutrient imbalances and decline in soil OM (Penuelas et al., 2020; Penuelas et al., 2023). When applied with organic fertilizer however, mineral fertilizer besides supplying plant nutrients tend to enhance the availability of nutrients contained in organic sources. On the other hand, fertilization with organic fertilizers will enhance soil OM, improve soil fertility and create more favorable soil conditions (Eden et al., 2017).

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Eco-intensification instead is a recommended approach for integrated nutrient management to sustain food production while mitigating adverse environmental effect (Oyetunji et al., 2022). With regards to nutrients management, this can be achieved through adoption the 4R Nutrient stewardship concept, which imply the application of the right sources, rate, time, and place of nutrient application (Rusan, 2018). The right source of nutrient should consider the complementary use of both mineral and organic sources that suit and match the local soil, plant, and climate characteristics (Rusan, 2017, 2023). It has been reported that application of organic fertilizers in synchronization with inorganic fertilizer enhances soil structure, soil OM and soil microbial activities which consequently improve nutrient use efficiency. In addition, combined application of compost and inorganic fertilizers improves nutrient retention and supply and improves soil fertility and crop productivity.

Compost of animal and crop residue organic wastes is rich in OM and contained plant nutrients, therefore, can be used as an organic fertilizer, separately and/or in combination with mineral fertilizers (Adewopo et al. 2014). This is of more importance under arid and semiarid conditions, where soil OM play a vital role in enhancing soil water holding capacity and enhances mitigation and adaptation to climate change condition (Amundson et al. 2015). Besides, compost is less expensive than traditional organic fertilizers and mineral fertilizers. therefore, compost use might partially substitute the recommended rate of mineral fertilizer, thereby reducing production cost and potentially increasing farmers' income (Zaki et al., 2018).

Composts made from plant and livestock organic wastes have been commonly investigated and used as a more economically beneficial organic fertilizer for improving soil fertility and crop production (Hernández Rodríguez et al., 2017; Zaki et al., 2018; Banuwa et al., 2020). Limited research has been conducted on the use of plant and food-based compost made from municipal organic waste. Therefore, the objective of this study was to determine the positive effect of combined application of plant and food-based compost and mineral fertilizers in comparison with their individual applications on plant growth and soil parameters under calcareous clay loam soils.

## Material and Methods

A greenhouse pot experiment was conducted to determine the effect of compost fertilization with and without mineral fertilizer on plant growth and soil properties under calcareous clay loam soil. The soil was collected from the Research Center at Jordan University of Science and Technology (JUST). The air-dried and sieved through a 5 mm sieve soil was analyzed for texture by hydrometer method (Gee et al., 1986); bulk density by the core method (Blake and Hartge, 1986); soil pH and soil EC were measured on 1:1 soil : water suspension (Mclean, 1982 and Rhoades, 1982a, respectively); OM using Walkley–Black method (Nelson and Sommers, 1982); cation exchange capacity (CEC) by Rhoades (1982b); total N by Kjeldahl (Nelson and Sommers, 1980); available P by extraction with sodium bicarbonate (Olsen et al. 1954); exchangeable K by extraction with 1 M $NH_4OAc$ (Thomas 1982); $CaCO_3$ by acid neutralization (Richards, 1954); heavy metals (Fe, Mn, Zn) by DTPA-extractable microelements (Lindsay and Norvell, 1978). Soil properties are shown in Table 1.

Table 1. Soil characteristics before conducting the experiment.

| | Value |
|---|---|
| Soil pH | 8.18 |
| Soil EC, dS $m^{-1}$ | 0.61 |
| CEC, Cmol $kg^{-1}$ | 34.32 |
| OM, % | 1.18 |
| $CaCO_3$, % | 13.38 |
| Soil N, % | 0.01 |
| Soil P, mg $kg^{-1}$ | 7.10 |
| Soil K, mg $kg^{-1}$ | 452 |
| Bulk density, g $cm^{-3}$ | 1.38 |
| Soil Texture | Clay Loam |

Randomized complete design was used to investigated the following treatments in four replications:

1. Control (C)
2. Application of Compost (Co)
3. Application of NPK (F)
4. Application of Compost and NPK (CoF)

Every pot (22.5 cm top diameter x 16.5 cm bottom diameter x 18 cm hight) was filled with 4 kg air-dried soil. According to the treatment, N and P were added to each pot as di-ammonium phosphate, $(NH_4)_2HPO_4$ (DAP) while potassium as potassium sulfate, $K_2SO_4$ (PS). The recommended rate of DAP and PS were applied based on local experience at a rate of 700 kg and 500 kg per hectare, respectively. Compost of municipal organic waste was applied at a rate of 20 tons ha$^{-1}$. Four seeds of maize were seeded in each pot. After germination plants were thinned to three similar plants per pot. Pots were watered periodically to reach the field capacity water content. Time of irrigating plants was determined by weighing each pot every two days and adding water to achieve the initial wet weight of the 100% field capacity.

Table 2. Compost characteristics.

| Properties | Values |
|---|---|
| pH | 7.90 |
| EC, dS m$^{-1}$ | 2.51 |
| OM, % | 60.13 |
| Bulk density, g cm$^{-3}$ | 0.46 |
| N, % | 2.22 |
| Soil P, mg kg$^{-1}$ | 0.58 |
| Soil K, mg kg$^{-1}$ | 1.42 |

After the beginning of flowering stage observed after 8 weeks of growth, the above ground plants were harvested, fresh weight was measured, then were oven-dried at 70°C and the oven dry weight was determined. Thereafter, the oven dried plants with a laboratory mill with 0.5 mm sieve were milled to a fine powder. The milled plant samples were analyzed for total N using a modified micro-Kjeldahl digestion procedure (Bremner and Mulvaney, 1982), dry ash digestion total P using Vanadate–Molybdate–Yellow method and total K with the flame photometry (Chapman and Pratt, 1961). The soil from each pot was thoroughly mixed and a representative sample was obtained and sieved through 2 mm sieve and analyzed for pH, EC, N, P, K as mentioned above.

General linear model (GLM) analysis was used to statistically analyze all data collected from this search with SAS version 9.0 (2002) software. Means subjected to analysis of variance (ANOVA) were according to Least Significant Difference LSD method at five percent level of significance P≥0.05.

# Results

## Plant Growth and Nutrient Uptake

Treatments effect on plant growth is presented in Figure 1. The control treatment, where no mineral fertilizers or compost were added resulted in the lowest plant height and dry weight. Addition of compost (Co) resulted in higher plant height and dry weight compared to the control but remained lower than that obtained with mineral fertilizers application (F) and combined application of mineral fertilizers and compost (CoF). This suggest that the positive effect of compost application alone, was not equivalent to the effect of application of recommended mineral fertilizers, suggesting the compost does not provide all nutrients required by the plant. However, when both mineral fertilizers and compost were simultaneously applied, they resulted in the highest plant growth. Similar trends were obtained with treatments effect on the content and uptake of macronutrients which are presented in Figure 2 and Figure 3. Plant content and uptake of nitrogen (N), phosphorous (P) and potassium (K), obtained with mineral fertilizers application were higher compared to the compost treatment but remained lower that that obtained with combined application (CoF).

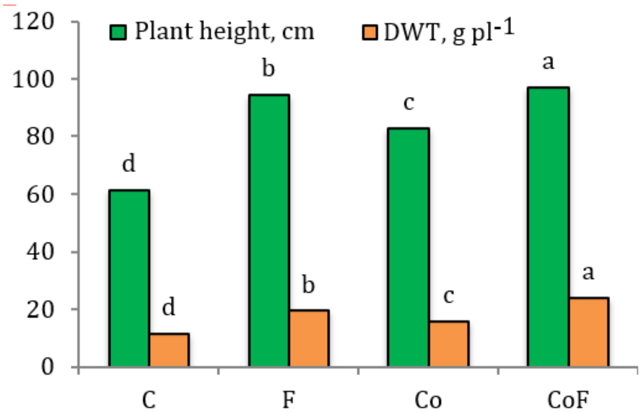


Figure 1. Plant growth parameters as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

The positive impact of combined application of mineral fertilizers and compost on plant growth and plant nutrient suggest the complementary and supplementary positive effect of compost when applied simultaneously with mineral fertilizers. Such effect could be attributed to the positive effect of compost on the soil biological, chemical, and physical properties due to high porosity and low bulk density of the compost, as well as the positive effect of the high OM of the compost.

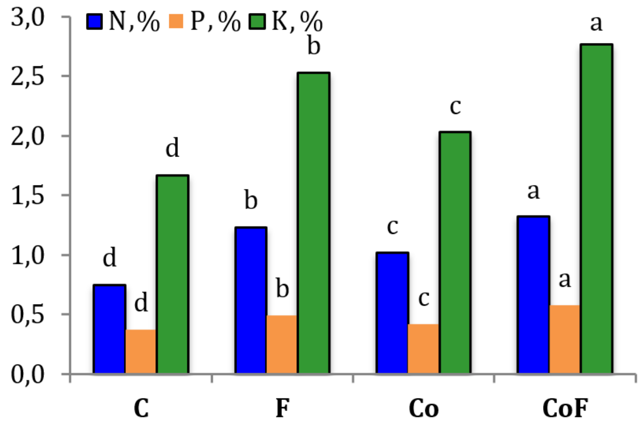


Figure 2. Plant macronutrient content as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

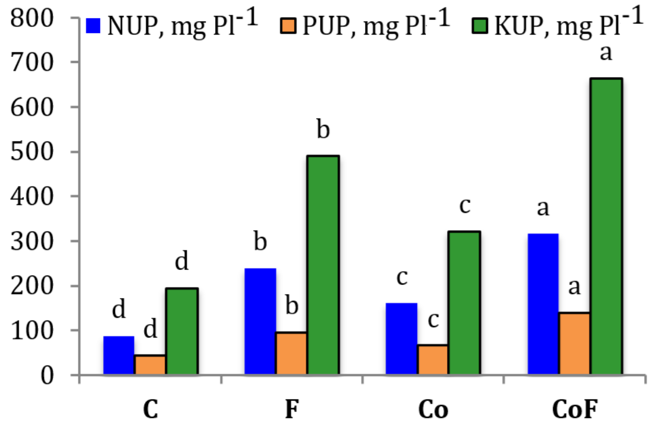


Figure 3. Plant macronutrient uptake (UP) as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

Plant content and uptake of micronutrients as influenced by the investigated treatments are shown in Figure 4 and Figure 5. Unlike the trend with macronutrients, the application of compost alone resulted in higher content and uptake of iron (Fe), manganese (Mn) and zinc (Zn) compared to the mineral fertilizers application. This can be expected due to partially due to the micronutrients content of the added compost and partially due to the indirect effect of the organic compounds contained in the added compost which enhances solubility and availability of the soil micronutrient through chelation reactions. Combined application of mineral fertilizers and compost resulted on additional positive effect on plant micronutrients content and uptake, which may suggest the complementary and supplementary positive effect of combined application of mineral fertilizers and compost.

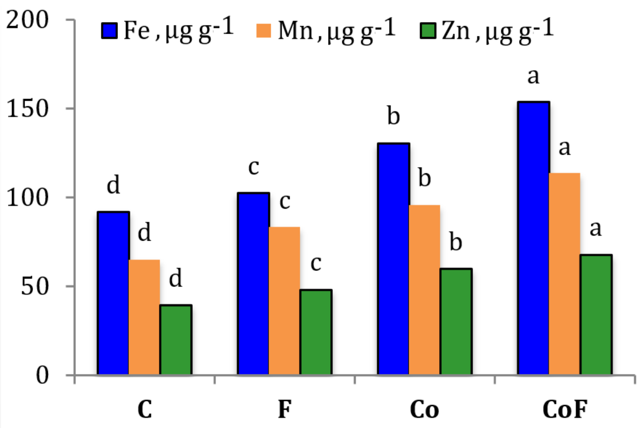


Figure 4. Plant micronutrient content as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

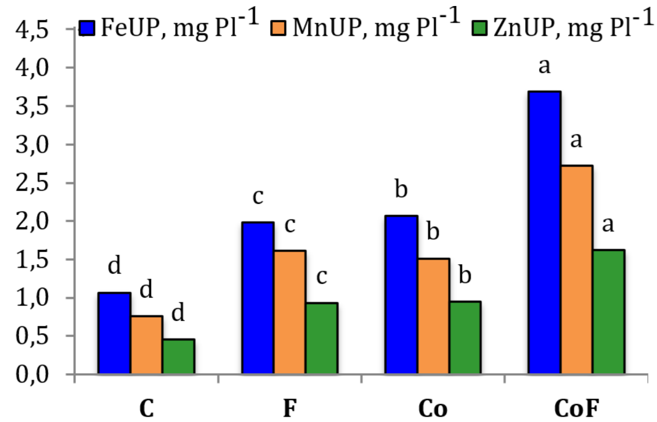


Figure 5. Plant micronutrient uptake (UP) as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

## Soil Properties

The treatment effect of soil pH and soil EC (Electrical conductivity) are shown in Figure 6 and Figure 7, respectively. Soil pH was lowered similarly by the application of mineral fertilizer and compost whether they were applied separately or simultaneously compared and remained higher than that obtained with the control. However, the increase in soil EC by compost application with and without mineral fertilizer, is attributed to the relatively high EC of the compost (2.5 dS $m^{-1}$).

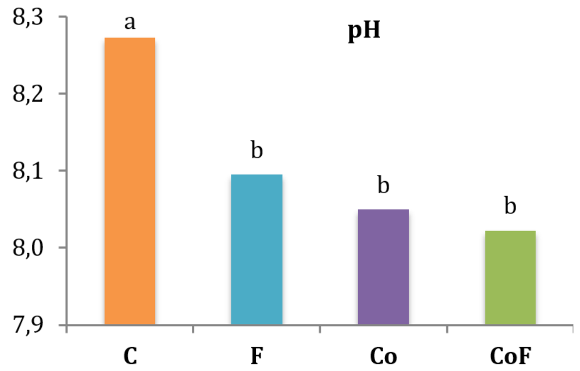


Figure 6. Soil pH as affected by compost and mineral fertilization application. Columns with similar letters are not significantly different at P≤0.05

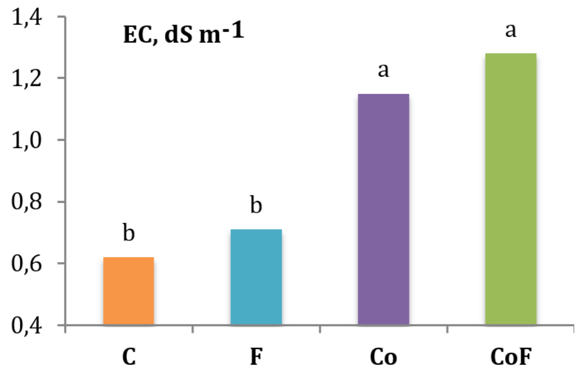


Figure 7. Soil EC as affected by compost and mineral fertilization application. Columns with similar letters are not significantly different at P≤0.05

Soil OM (Figure 8) and soil cation exchange capacity (CEC) (Figure 9) were increased with separate application of compost and with combined application of mineral fertilizer and compost. The high percentage of OM of compost (60.3%) resulted in increasing the soil OM with comport application. OM has a strong effect on several properties of soil including increasing the CEC, which was observed in this study following compost application. On the other hand, compost application decreased soil bulk density (Bd%) (Figure 10), which is attributed to the higher porosity and lower bulk density of the applied compost.

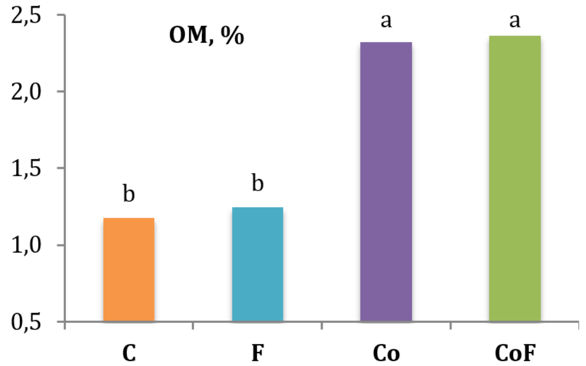


Figure 8. Soil organic matter (OM) as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

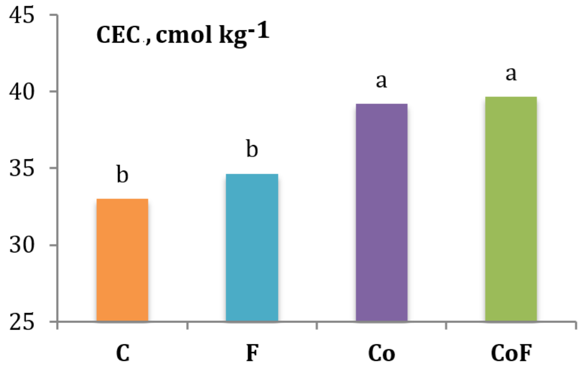


Figure 9. Soil CEC as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

Soil N, P and K contents as influenced by the treatments are shown in Figure 11, Figure 12, and Figure 13, respectively. Soil N was the lowest for control and significantly increased with compost application. The application of mineral fertilizer with and without compost resulted similarly in higher soil N compared to the control and compost treatments. Similar trends were observed with treatments effect on soil K. On the other hand, soil P was affected differently. The control resulted in the lowest soil P level. However, soil P increased by the application of mineral fertilizer, then by compost, then by combined compost and mineral fertilization.

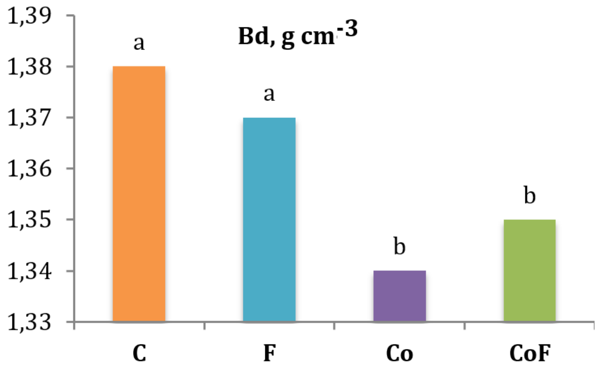


Figure 10. Soil Bulk density as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

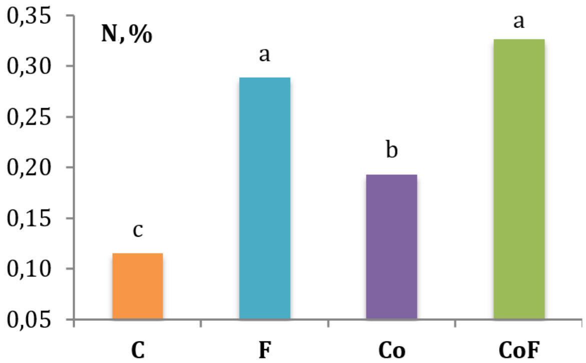


Figure 11. Soil N as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

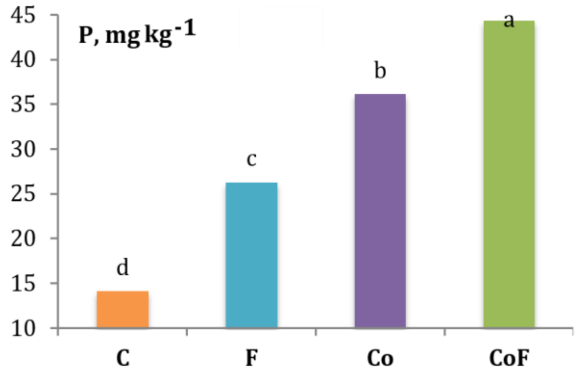


Figure 12. Soil P as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

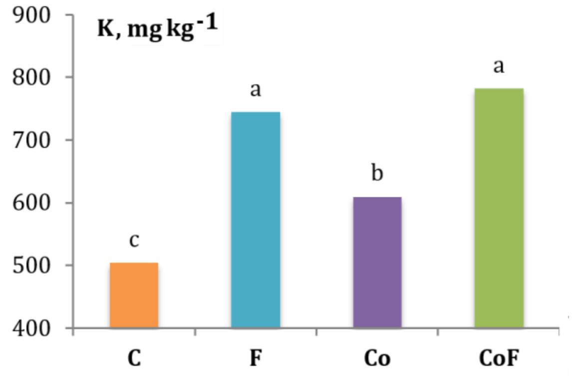


Figure 13. Soil K as affected by compost and mineral fertilization. Columns with similar letters are not significantly different at P≤0.05

## Discussion

The complementary use of mineral and compost resulted in the highest plant growth and nutrient uptake, suggesting the advantage of their combined and complementary use. Although, the separate application of mineral fertilizer or the separate addition of compost increased plant growth parameters and soil fertility compared to the control, however, neither of them achieved these parameters as their combined use did. Compost fertilization proved to increase crop yields, increase soil OM, improve water holding capacity, lower soil bulk density and decrease soil erosion rate (Al-Rumaihi et al., 2020; Petrescu-Mag et al., 2020).

Nutrient uptake increased with both compost and mineral fertilization whether they were applied individually or in combination. Other researhcers (Malézieux and Bartholomew, 2003) found that plant uptake of N, P, K Fe and Zn by pinapple increases with compost application . Nardi et al. (2002) reported that the released humic substances during mineralization of compost stimulate root growth and proliferation and improves plant growth and nutrient uptake.

Nevertheless, applying compost alone did not increase nutrient uptake to the extent achieved with mineral fertilizer, indicating that compost alone cannot supply all plant nutrient requirements, unless applied with mineral fertilizers. Thus, compost will partially provide the crops with their nutrient requirement and will partially substitute and compensate for the use of mineral fertilizers. Nardi et al., (2002) reported that compost application compensated for 40% of the fertilizer requirement of crop.

As for plant micronutrient (Fe, Mn and Zn) uptake, it was observed that the highest uptake was with combined application. Their uptake with separate application of compost was higher than the control and even than the separate application of mineral fertilizers. The organic compounds provided by compost application could be attributed to the enhancement of the availability of the indigenous soil micronutrients through chelating them into available forms to plant uptake (Rusan et al., 2017).

Several researchers reported the beneficial use of composts of various sources of organic waste as a soil amendment and a source of nutrients and OM to enhance yield and soil fertility (Cahyono et al., 2020). Other researchers attributed the benefit of compost application to the direct effect by supplying nutrient and/or to the indirect effect thought enhancing soil microbial activities and other soil fertility parameters such as water holding capacity, soil structure and others (Zaki et al., 2018; Banuwa et al., 2020). Compost is considered a slow-release fertilizer, and therefore, minimizes losses and enhances nutrient use efficiency. So is highly recommended to apply it in combination with soluble mineral fertilizers as was reported by several scientest (Adugna, 2016; Ning et al., 2017). As for the increase in soil EC associated with compost application, which was obtained in our study, it can be explained by the relatively high compost EC and by the release of minerals during mineralization (Liu et al., 2011). Soil EC increased with compost application was reported by other researchers (Sarwar et al., 2010). Other researchers explained the increase in soil EC with compost application to the release of mineral ions during compost decomposition and mineralization (Hemidat et al., 2018, 2022).

Soil fertility attributes have positively been affected by compost application. Our study demonstrated the positive effect of compost application with and without mineral fertilizers on soil pH, OM, CEC, and bulk density. One of the main benefits of compost soil application is the increase in soil OM, which has several positive effects on various soil biological, chemical, and physical properties of the soil (Bhatacharyya et al., 2008; Efthimiadou et al., 2010). Other investigators have reported an increase in soil OM and NUE with combined organic and inorganic fertilization (Liu et. al., 2008), and attributed that to the high organic content of the compost as well as to the positive effect of organic matter on enhancing the bioavailability of other mineral nutrients..

The high OM content and low bulk density of the applied compost explained the positive effect on these attributes of the soil. Decreased soil bulk density and increased soil OM obtained in our study, due to lower bulk density and higher OM of the applied compost with and without mineral fertilizers, favorably influences soil physical conditions and plant growth (Leroy, et al., 2008). Soil CEC increase with compost application was attributed to the high CEC of the humic compounds and carboxyl and phenolic functional groups of the compost (Wichuk and McCartney, 2010). Other researchers reported a decrease in soil bulk density and improved soil aggregation with compost application (Cahyono et al., 2018), owing to the positive effect of organic matter on soil physical properties.

Soil nitrogen (N) and potassium (K) contents were lower with compost application compared to the control but were higher than those obtained with the combined aaddition of compost and mineral fertilizers. As for soil P unlikely, it was increased more by separate application of compost than by mineral fertilization. It is not clear why soil P was affected differently compared to soil N and soil K, but one of the possible explanations could be the indirect positive of organic compounds provided by compost on the enhancement of availability of the unavailable forms of soil P. It has been reported that organic compounds in the soil tend to coat soil P and prevent it from being precipitated into unavailable forms. These findings agree with the findings of other researchers, who reported an increase in soil N, P and K with combined organic and inorganic fertilization compared with control and mineral fertilization (Herencia et al., 2009). In addition, other researcher reported an increase in soil P, K and micronutrients with compost application (Sarwar et al., 2010).

The increase in soil nutrients with compost application could be attributed to the release of nutrient from compost to the soil during mineralization of compost (Adugna et al., 2016) and/or indirectly due to positive effect of compost on soil fertility. The increase in soil OM obtained with compost application farther enhances use efficiency of the jointly applied mineral fertilizers and increased nutrients content in the soil (Bhattacharyya et al., 2008; Bouajila and Sanaa, 2011).

## Conclusion

The obtained results in this study recommend that the complementary use of compost and inorganic fertilizers has synergistic and positive effects on plant growth, nutrient uptake, and soil fertility parameters. Plant dry biomass, as well as macronutrient and micronutrient uptake were significantly increased with combined application of compost and mineral fertilizers. The lowest plant height and dry weight were obtained in the control followed by the mineral fertilizer's treatment. Compost application with and/or without mineral fertilizers favorably decreased soil bulk density. Additionally, compost application can partially substitute for the use of expensive inorganic fertilizers, thereby enhancing farmers' income and promoting the sustainability of food production system. Since the use of the compost made from municipality waste does not have high acceptance by farmers and local communities, it is recommended for future research to include the study of social factors affecting the adoption of the use of such compost.

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