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IMPACT OF COMPOST APPLICATION ON SOIL AND ZUCCHINI YIELD

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Abstract

The field experiments were conducted in 2024. The soil type is classified as alluvial-meadow with a light mechanical composition. The crop grown was Cucurbita pepo var. giromontia (zucchini). Four variants of compost treatment were developed, with a tested compost application rate of 5 t/da. The treatments included: Variant 1 (control) - untreated soil; Variant 2-20% of the optimal compost rate; Variant 3-50% of the optimal rate; and Variant 4-100% of the optimal rate. The compost used in the experiment was prepared from urban waste provided by the `Capital Waste Treatment Enterprise.` Compost analysis revealed a nitrogen (N) concentration of 16.2 mg/kg, phosphorus (P) at 2.183 g/kg, and potassium (K) at 7.52 g/kg. Measurements included climate data, biometric parameters, and yield. The results showed that the highest compost application rate (Variant 4) had a depressive effect on plant development, suggesting that excessive compost may hinder growth. The study aimed to evaluate the influence of different compost treatments on the yield and quality of zucchini.

Key words*: compost treatment, zucchini yield, urban area.*

INTRODUCTION

Soil fertility management is a key factor in sustainable agriculture, influencing both crop productivity and environmental health. Among the various soil amendments, compost has gained significant attention as an organic and eco-friendly option for enhancing soil properties and improving crop yields (Zaccardelli, M. et al., 2021). Compost application can improve soil structure, increase water retention, enhance microbial activity, and provide essential nutrients for plant growth.

According to Manohara, B. et al. (2014) solid waste management is a major challenge in urban areas, especially with rapid population growth due to rural-to-urban migration. Increased consumption and industrial activities have led to higher waste generation, and improper disposal contributes to air and water pollution, posing environmental and health risks. The primary goal of urban waste management is to collect, treat, and dispose of waste efficiently and sustainably.

Municipal solid waste (MSW), commonly known as trash or garbage, includes domestic, commercial, institutional, and municipal waste. Proper treatment is crucial, with various traditional and modern methods used depending on waste type. Composting remains a widely practiced method, converting organic waste into a nutrient-rich soil conditioner. However, compost stability is essential, as chemically unstable compost can be harmful to plants due to the release of toxic compounds like ammonia and organic acids.

Many other authors are conducted experiment using municipality compost made from solid waste for growing vegetables. Their findings suggest that, Municipal solid waste compost (MSWC) enhances soil quality by increasing organic matter, which provides several benefits, and boosting total nitrogen, though to a lesser extent. Additionally, MSWC poses a lower risk of nitrate leaching compared to synthetic fertilizers, particularly during the winter season (Cao, X. et al., 2023; Rahman, M. M. et al., 2020; Small G. E. et al., 2024)

Zucchini (*Cucurbita pepo* var. *giromontia*), a widely cultivated vegetable, requires well-balanced soil nutrients to achieve optimal yield and quality. However, conventional farming practices often rely on synthetic fertilizers, which can lead to soil degradation and environmental pollution over time. The use of compost as an alternative or supplement to chemical fertilizers offers a sustainable

approach to improving soil health while maintaining high crop productivity.

This study aims to evaluate the impact of MSWC application on soil properties and zucchini yield. Specifically, it investigates how compost influences soil nutrient content, moisture retention, and biological activity, as well as its effects on plant growth, fruit yield, and quality. By assessing these factors, this research provides insights into the potential benefits of compost in sustainable zucchini production.

MATERIALS AND METHODS

The study took place in 2024 in a suburban region of Sofia city, Bulgaria on the Vrajdebna experimental field hostile to the University of Forestry. The soil type use for the experiment is alluvial-meadow soil.

The compost used as a soil amendment was provided for the experiment by the Sofia Municipality.

Four variants of MSWC treatment were developed, with a tested compost application rate of 5 t/da. The treatments included:

Variant 1 (control) - untreated soil;

Variant 2 - 20% of the optimal compost rate;

Variant 3 - 50% of the optimal rate;

Variant 4 - 100% of the optimal rate.

The optimal rate of compost application for vegetable crops is 5 t/da and was selected based on the literature review (Gravuer, K., & Gunasekara, A., 2016). Each variant was tested in three replicates

Tested crop was *Cucurbita pepo var. giromontia* (zucchini). The preparation of the experimental field and incorporation of soil amendments were conducted during the third decade of March. The amendments were evenly distributed across the experimental plots according to the calculated application rates, followed by plowing to a depth of 15 cm.

Three planting beds were established, where zucchini was sown following the standard double-row belt cultivation system. The sowing took place on May 10, 2024, using a hill-planting method, with a row spacing of 60 cm and 50 cm between plants within the row. The planting arrangement followed a double-row belt system with a spacing scheme of 100+60/50 cm.

The experimental plots were irrigated using a drip irrigation system, with water supply regulated based on the hourly flow rate. The water source for the study was a borehole. No fertilizers were applied during the crop's vegetation period to assess the effects of compost application on plant growth without additional nutrient inputs.

Meteorological data were systematically recorded throughout the experiment. Precipitation levels were measured daily using a standard rain gauge, while average daily temperatures during the crop's vegetation period were documented.

Soil and plant tissue analyses were performed in a certified laboratory following standardized and approved methodologies. Yield assessment was conducted by evaluating the quantity and quality of harvested fruits from ten randomly selected plants per replication.

Before the field experiment was established, samples of the used ameliorant were taken. The compost was obtained from composting urban plant residues and was provided for the purposes of the study by the Sofia Waste Treatment Plant IBT Hhan Bogrov.

Laboratory analyses were performed for the content of essential nutrients and heavy metals. The data from the agrochemical analysis are shown in Table 1.

Table 1. Agrochemical analysis of the imported compost

Total N, %	Total P, g/kg	Fe, g/kg	Zn, g/kg	Mg, g/kg	Ca, g/kg	K, g/kg
1.62	2.183	5.499	0.075	4.309	29.043	7.526
Pb, g/kg	Cu, g/kg	Mn, g/kg	Cd, g/kg	Cr, g/kg	Ni, g/kg	
0.0128	0.0242	0.285	0.0012	0.018	0.007	

The total N content of 1.62% is considered moderate too good for compost, making it a suitable source for improving soil nitrogen content. The phosphorus and potassium content are low compared to plant requirements and is below the recommended levels for compost used as a primary source of phosphorus. Insufficient potassium can limit the effect of potassium application, especially in potassium-loving crops. The compost has a high calcium content of 29.043 mg/kg, indicating a good supply of this element, making the compost suitable for

improving soil structure and balancing pH. The high Ca content is probably due to the use of pH-regulating improvers in the composting process. The compost has a good supply of Mg, but low in P and K, demonstrating its potential as an organic fertilizer. The reported values of iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) are within the limits of the norms for maintaining plant growth.

The content of heavy metals such as lead (Pb – 0.0128 mg/kg), cadmium (Cd – 0.00125 mg/kg), chromium (Cr – 0.018 mg/kg) and nickel (Ni – 0.007 mg/kg) is minimal, confirming the safety of the compost for agricultural use. The analysis shows that the compost is suitable for improving soil fertility, although the relatively low levels of phosphorus, potassium and zinc may require additional fertilization for optimal results.

RESULTS AND DISCUSSIONS

The average monthly air temperature for the growing season in 2024 for the Vrajdebna region is above the average climate norm for the last 30 years.

It has been established that for the months of April and from June to August 2024, the average temperatures exceed the maximum average monthly value for the last 30 years (Figure 1). These higher temperatures in combination with the lower amounts of precipitation outline more extreme conditions for agricultural crops grown without irrigation measures

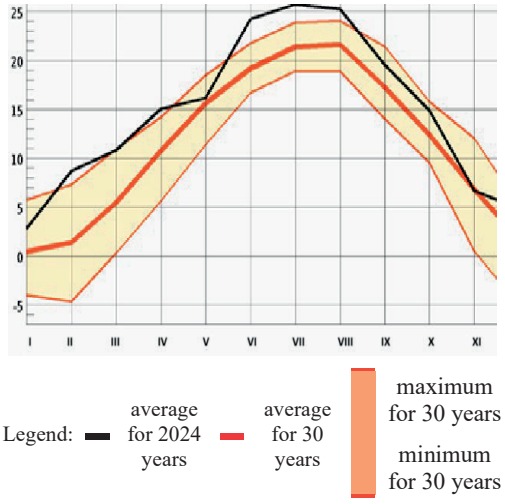

Figure. 1 Average monthly air temperature (^{O}C)

The dynamics of monthly precipitation shows lower amounts of precipitation for the months of the growing season compared to the precipitation for the last 30 years (Figure 2). Only in the months of May and November 2024 did the amounts of precipitation exceed the calculated average climatic norm for 30 years. The longer the blue stripes, the greater the fluctuations in monthly precipitation over the last 30 years, this was found most clearly for the month of May. During the remaining growing months, the amount of precipitation is more constant, with fluctuations over the last 30 years in the range of 50-100 mm. The indicated conditions resuppose the cultivation of more drought-resistant agricultural crops.

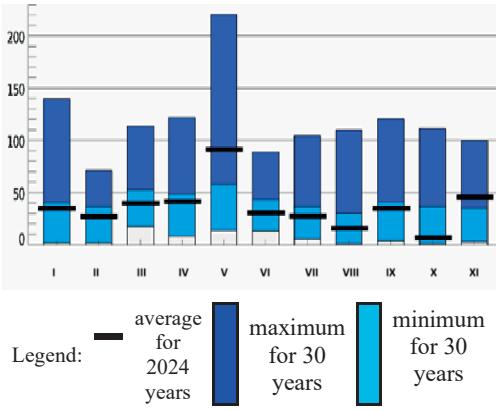

Figure 2. Monthly precipitation (mm)

The average annual precipitation in the city and its surrounding areas is approximately 550-600 mm. A precipitation availability curve was constructed based on a 38-year dataset (Figure 3). Analysis of the obtained data indicates that the year 2024 is characterized by a precipitation availability of 81.51%, classifying it as an average to dry year. In terms of precipitation patterns, 2024 closely resembles the years 2012 and 1998. The total recorded annual precipitation for Sofia in 2024 was 530.9 mm.

Soil nutrient availability plays a crucial role in the growth, development, and yield of zucchini (*Cucurbita pepo* var. *giromontia*). Essential macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), along with secondary and micronutrients, directly influence plant health, fruit quality, and productivity (Rekaby, S. A. et al., 2023).

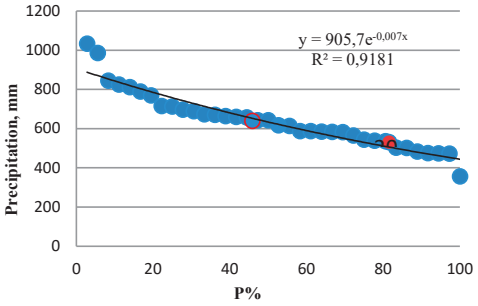

Figure. 3. Curve of precipitation availability for the period 1987-2024

The Table 2 presents data on key soil parameters at a depth of 0-40 cm. The humus content is relatively low, falling below the optimal range of 2-3% typically recommended for vegetable crops. This low humus level may restrict the soil's capacity to retain water and essential nutrients. To enhance soil fertility, the incorporation of organic amendments, such as compost, is advised to increase humus content.

Table 2. Agrochemical characteristics of the soil before planting the zucchini

Depth, cm	Humus, %	pH H_2O	NH_4-N, g/kg	NO3-N, g/kg	P_2O_5, g/100 g	K_2O, g/100 g
0-40	1.73	7.3	0.0413	0.0168	0.046	0.022
Fe, g/kg	**Zn, g/kg**	**Mg, g/kg**	**Ca, g/kg**	**K, g/kg**	**Pb, g/kg**	
21.82	0.048	3.175	4.385	2.115	0.019	
Cu, g/kg	**Mn, g/kg**	**Cd, g/kg**	**Cr, g/kg**	**Ni, g/kg**		
0.032	0.456	0.0015	0.0216	0.0121		

The soil exhibits a neutral pH, which is conducive to zucchini cultivation. A neutral pH optimizes the availability and absorption of both macronutrients and micronutrients, while also fostering beneficial microbiological activity within the soil.

Ammonium (NH_4^+) and nitrate (NO_3^-) nitrogen levels are high, indicating a favorable immediate nitrogen supply for the plants. The presence of both ammonium and nitrate forms suggests a well-balanced nitrogen availability, which is essential for healthy plant growth.

The data on the availability of easily accessible phosphorus indicate a sufficient supply in the soil, supporting the nutrient needs of the crop. Potassium levels in the initial sample are also adequate, ensuring optimal fruit formation for zucchini.

Overall, the soil is in good agrochemical condition for zucchini cultivation. While the low humus content may pose a challenge, the remaining soil indicators - pH, nitrogen, phosphorus, and potassium - fall within the ideal ranges for supporting optimal plant growth.

A higher Fe content is observed, but this is common for soils in urban environments, where it is related to natural origin and the influence of building materials. There are no indications of pollution. The content of heavy metals is very low, with values significantly below the permissible concentrations for urban soils.

The ammonium nitrogen (NH_4-N) content fluctuates across the treatments, with the highest value in Variant 2 (0.0413 g/kg) and the lowest in Variant 3 (0.0147 g/kg) (Table 3). The nitrate nitrogen (NO_3-N) levels remain relatively stable, except for a slight increase in Variant 3. These results suggest that compost application influences nitrogen availability, with excessive nitrogen possibly being subject to leaching or volatilization. Precipitation, combined with maintaining optimal soil moisture, is the likely cause of nitrogen leaching along the profile. Haofeng, Lv. et al. (2021) identified excessive irrigation as the main factor contributing to substantial nitrogen leaching, emphasizing the need for efficient irrigation management strategies.

Available phosphorus content is highest in Variant 4 (0.0545 g/kg), demonstrating the beneficial effect of MSWC application in increasing phosphorus availability. Potassium levels also increase with higher compost rates, reaching a maximum in Variant 4 (0.0268 g/kg) (Table 3).

Iron concentrations remain relatively stable across treatments, with minor fluctuations.

Magnesium levels show minor variations, while calcium content increases with compost application, peaking in Variant 4 (4.421 g/kg). Calcium is vital for cell wall integrity and fruit quality.

The highest calcium content, introduced into the soil through amendments, strongly influences zucchini yield and overall plant development.

Table 3. Agrochemical characteristics of the soil after zucchini harvesting

Variants	NH4-N g/kg	NO3-N g/kg	P2O5	K2O	Fe g/kg
Var.1	0.027	0.0112	0.05	0.0145	21.777
Var.2	0.0413	0.01	0.0464	0.0148	20.857
Var.3	0.0147	0.015	0.0436	0.0212	21.147
Var.4	0.0308	0.01	0.0545	0.0268	21.399
Variants	**Zn g/kg**	**Mg g/kg**	**Ca g/kg**	**K g/kg**	**Pb g/kg**
Var.1	0.049	3.172	4.214	1.964	0.0193
Var.2	0.046	2.946	4.093	1.834	0.0189
Var.3	0.045	2.923	4.005	1.825	0.0146
Var.4	0.048	3.053	4.421	2.002	0.0178
Variants	**Cu g/kg**	**Mn g/kg**	**Cd g/kg**	**Cr g/kg**	**Ni g/kg**
Var.1	0.031	0.457	0.0043	0.022	0.012
Var.2	0.028	0.444	0.0043	0.0205	0.011
Var.3	0.029	0.443	0.0014	0.0199	0.0112
Var.4	0.03	0.447	0.004	0.0207	0.0114

Heavy metal concentrations remain within safe limits, confirming that MSWC application does not pose significant contamination risks.

The obtained data provide insights into the nutrient composition of zucchini fruits across different compost application treatments.

The nitrogen content varies between 2.45% (Var. 3) and 2.91% (Var. 1), indicating that excessive compost application (Var. 3) may have led to a dilution effect, resulting in lower nitrogen accumulation in the fruit. Variant 4, with the highest compost application, shows a relatively high N content (2.89%) (Table 4).

Table 4. Agrochemical characteristics of the zucchini fruits

Variants	Total N%	Total P g/kg	Fe g/kg	Zn g/kg	Mg g/kg	Ca g/kg	K g/kg
Var.1	2.91	7.843	0.119	0.042	1.114	1.071	34.542
Var.2	2.69	6.699	0.107	0.06	1.105	1.169	33.128
Var.3	2.45	7.908	0.083	0.028	1.105	1.352	46.056
Var.4	2.89	7.598	0.129	0.038	1.216	1.42	46.359

The phosphorus content is highest in Var. 1 (7.843 g/kg) and lowest in Var. 2 (6.699 g/kg). Phosphorus is essential for energy transfer and root development, and its reduction in Var. 2 might have impacted plant vigor. The highest compost rate (Var. 3) did not show a significant increase in phosphorus content, which may suggest limited phosphorus availability due to potential nutrient imbalances. The high phosphorus content in the soil is also observed in the fruits.

Calcium levels increase with higher compost application, reaching 1.42 g/kg in Var. 4. This is consistent with findings that compost amendments can enhance calcium availability. However, excessive Ca can interfere with K uptake, which might influence fruit quality. This data for Ca content corresponding to those obtained from soil analyses Table 4.

These results indicate a nutrient imbalance, which directly affects yield.

The yield of zucchini varies greatly. V1 has the highest yield of 6700.94 kg/da, which suggests that the conditions or technology used in this variant are the most effective. In the variant with 20% compost rate, V2 shows 25.4% lower yield than V1, V3 has an even lower yield, 42.1% less than V1. This may indicate increasing limitations in the conditions or factors limiting productivity. V4 has the lowest yield (2807.92 kg/da), which is 58.1% lower than the best variant (V1) (Figure 4).

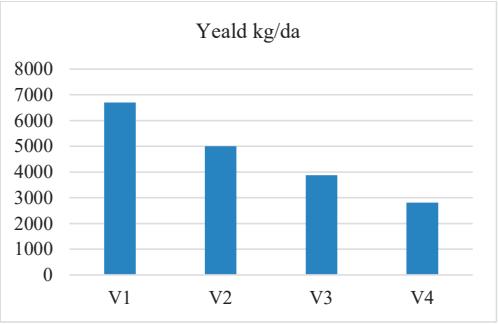

Figure. 4. Yield from field trial with zucchini 2024

The difference was statistically significant (F 3.32=2.94, P<.05).

The same trend is observed when counting the number of fruits harvested, the difference was statistically significant (F 3.36=4.37, P< 0.0099).

However, an excessive calcium supply can interfere with potassium uptake, as previously observed by Bradley and Hosier (1999). Potassium deficiency symptoms, including dull green leaves, chlorotic interveinal spots, and eventual leaf browning and shedding, were evident in Variant 4. This treatment exhibited the most stunted growth, characterized by small, underdeveloped pale green leaves and the lowest recorded yield. These findings highlight the need for a balanced nutrient supply, as excessive calcium application can have adverse effects on plant health and productivity. On the other hand,

when calcium-containing ameliorants are overdosed, the excess affects the absorption of K and Zn. In case of zinc deficiency, spots are observed on the upper leaves, chlorosis and reduced yields, with the yield decreasing by 25%. Similar results have been described by Ma'ruf, A., & Syahminar, S. (2024).

In a greenhouse study on zucchini, M. Tolba et al. (2021) investigated the effects of five different compost application levels. The findings demonstrated a decline in yield with increasing compost rates and revealed a statistically significant linear correlation between total potassium uptake by plants and the dry weight of the fruits.

Monitoring the quality of zucchini, particularly in terms of nitrate accumulation, is essential for consumer safety and public health. Zucchini, like other leafy and fruiting vegetables, can accumulate nitrates under certain growing conditions, posing potential health risks if consumed in excess. According to research by Putnik-Delić, M. et al. (2023), nitrate accumulation in vegetables can result from multiple factors, including the application of nitrogen-based fertilizers, organic matter decomposition, and environmental conditions such as temperature and soil moisture. Proper nutrient management and optimized agricultural practices are crucial for minimizing nitrate buildup, ensuring the production of high-quality and safe zucchini for consumption.

Nitrate levels in all variants were below the permissible values of 200-400 mg/kg, making them safe for consumption. Compost may have contributed to the accumulation of nitrates to varying degrees in the different variants, depending on the application rate and the degree of decomposition of the organic material (Figure 5).

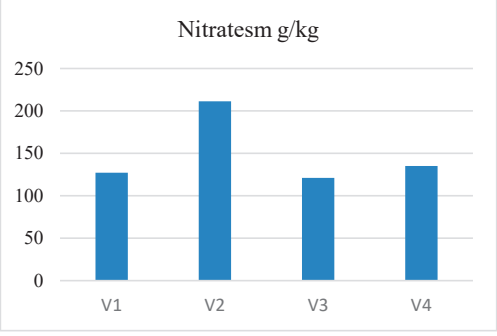

Figure 5. Nitrate content in zucchini fruits

The sugar content in zucchini (*Cucurbita pepo var. giromontia*) fruits is a key indicator of fruit quality, influencing taste, market value, and consumer preference.

Variant 1 has the lowest total sugar content (2.16%), which may be due to more intensive growth and higher yield, which dilute the available sugar reserves in the fruit. V4 shows the highest value (2.83%), which suggests weaker vegetative development or accumulation of more sugars due to stress. In V4, where the yield is lowest, the sugar content is highest (Figure 6).

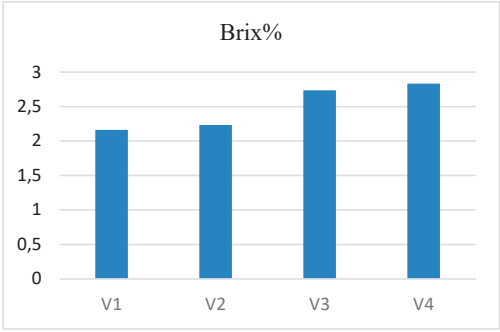

Figure 6. Sugar content in zucchini fruits

The high K content in combination with P is the main reason for the accumulation of more sugars in V4. K is involved in activating enzymes responsible for photosynthesis and starch synthesis, such as sucrose synthase and starch synthase. Higher K availability in V3 and V4 is associated with increased soluble sugars, which enhances fruit taste, sweetness, and consumer preference.

The interaction between potassium and phosphorus plays a crucial role in determining the sugar content and starch accumulation in zucchini fruits.

CONCLUSIONS

The findings of this study demonstrate that the climatic conditions in the studied region are favourable for zucchini cultivation. The urban environment does not contribute to heavy metal contamination of the soil or zucchini fruits, ensuring their safety for consumption.

A thorough understanding of the agrochemical composition of compost prior to its incorporation into the soil is essential for

achieving balanced fertilization and optimizing nutrient availability for vegetable production. The study confirms that increasing compost application leads to higher calcium levels, with a peak of 1.42 g/kg in Variant 4. This aligns with existing research indicating that compost amendments improve calcium availability. However, excessive calcium can negatively affect potassium uptake, which may have implications for fruit development and overall crop quality.

Furthermore, the interaction between potassium and phosphorus is a key factor influencing sugar content and starch accumulation in zucchini fruits. Proper nutrient management strategies are crucial to maintaining an optimal balance between these elements, ensuring high-quality fruit production with desirable taste and texture.

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