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The effect of a fertilizer derived from plant seed extracts on tomato plants in Diyala Governorate with nanometric zinc oxide (ZnO)

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Abstract

Biochar is a compound that was extracted from orang seeds with good purity using a combustion process, where the entire seed was burnt at a high temperature, then crushed and turned into powder. Infrared, ultraviolet, and GC-MS analyses were performed on it. along with other physical properties such as color and solubility. Additionally, nanosized zinc oxide was prepared beforehand. A study was conducted on it at the nursery of the College of Education for Pure Sciences/University of Diyala, from 20/2/2025 to 25/4/2025, to examine the effect of fertilization with biochar on some growth characteristics of tomato plants. The results indicated that fertilization with 150 mg/L of nanosized zinc oxide yielded the highest averages in all traits, including plant height, fresh weight, dry weight, and leaf chlorophyll content, which were 26.2 cm, 10.867 g, 6.600 g, and 76.733 SPAD units, respectively.

Keywords: Biochar, chlorophyll, fertilization, plant growth, tomato (*Solanum lycopersicum*)

Introduction

Biochar is an organic compound. Biochar is a charcoal-like material produced from plant material such as grass (Abd El-Mageed et al., 2022a, Yixia, 2021) and agricultural and forest residues that are decomposed at high temperatures, often during renewable energy production (Aghoghovwia et al., 2022a). During this process, the physical and chemical properties of the plant material are transformed into a highly porous, stable, carbon-rich material known as biochar (Sohi et al., 2010). Recent research suggests that this material has the potential to be used as a soil amendment and as a substrate amendment in agriculture and horticulture and may improve several physical, chemical, and biological properties of soil and substrate (Jahromi et al., n.d.).

Regarding physical properties, biochar is characterized by its black color, high permeability, light weight, fine grains, and large surface area. It increases microbial activity, soil water retention (Ali et al., 2017), and nutrient retention (Tang et al., 2022). It often reduces the use of fertilizers and chemicals (Mansoor et al., 2021), improves soil health, and leads to increased yields. (Siltecho et al., 2022) There are several ways to add biochar to the soil. (Zhang et al., 2021) These methods include laying bands, uneven ground food production (Skjemstad et al., 2002), processing, and agricultural use. Biochar can also be used alone or in conjunction with the source code manure, compost, manure, and seeds (Eckmeier et al., 2007). Biochar properties (Brantley et al., 2015) usage depends entirely on agriculture (Duku et al., 2011). Ambient temperature and soil pH play a significant role in the ability of biochar to maintain its health. Most researchers focused on the production of inorganic forms of N as NO_3^- and NH_4^+ (Aghoghovwia et al., 2022b).

The high negative charges and surface area result in higher cation adsorption than other organic

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materials, with the cations acting as bridges that promote soil cohesion. As a result, when biochar is applied to clayey soils, aeration and water flow are improved. (Arias et al., 2023)

(Liang et al., 2006) Activated carbon and biochar are carbonaceous materials that are of great interest in the world of environmental technology and have been studied for many years for various purposes. It is not possible to clearly distinguish between these two materials, and the terms are not yet widely accepted in this world. However, there is a growing discrepancy between studies on these materials: adsorption and processing are part of activated carbon and can be addressed by biochar research. Therefore, studying and understanding the differences between activated carbon and biochar is important for designing new types of research on carbonaceous materials (Hagemann et al., 2018).

The term "biochar" refers to a group of substances. However, the benefits of biochar production and use can only be achieved when biochar is viewed as a systematic approach. A variety of biomasses can be produced using different types of biomass, each with its own opportunities and limitations. Some biomass is a valuable commodity for other purposes, such as food or wood, or has environmental value for soil conservation, shade, or windbreaks. In each case, the use or misuse of biomass must be critically assessed. (Abd El-Mageed et al., 2022b) When biomass is heated to its pyrolysis temperature. (Glaser & Birk, 2012)

Initially limited to agriculture, biochar now has diverse applications, allowing this plant-based raw material to fully utilize its positive properties. Even in industrial applications, the carbon extracted from the atmosphere in the form of carbon dioxide can be stored for a long time or at least used as an alternative to fossil fuels. However, biochar is so expensive that no farmer can afford to spread 10 tonnes or more per hectare on their fields. (Widowati et al., 2024) Unlike coal, which is usually used as fuel, biochar is used as a soil conditioner to help with plant growth, for agricultural purposes, and for carbon capture and storage. (Abd El-Mageed et al., 2022a).

Preparation and application of Biochar

Tomato (Solanum lycopersicum L.) is classified in the Solanaceae family. With high levels of nutrition and medicinal value, tomatoes are one of the most significant vegetable crops grown throughout the world. They are natural sources of important nutrients such as carbohydrates, potassium, and ascorbic acid, in combination with several antioxidants like tocopherol and lycopene (Renna et al., 2018). Tomato fruits are known to have multiple health benefits, including reducing cancer risk, preventing scurvy, and maintaining vascular health (Rathod et al., 2023).

Informal statistics have shown that a tomato crop after potatoes is highly consumed by humans (Olaniyi et al., 2010). Egypt is currently one of the top five world producers of tomatoes after China, India, Turkey, and the United States (Abdelkader et al., 2022). The tomato is known by many names; like in the Mexican language it is “Tomatle,” which can be translated to “fruit with a bulge” or swelling fruit (The Origins of Tomatoes, n.d.), and the Italians called it “Pomodoro,” which translates to “golden apple” (Naika et al., 2005). Later on, the English name "tomato" predominantly caught on.

Nanoparticles are molecules and materials that are engineered to a size range of approximately 1-100 nanometers. Given their distinct features, nanomaterials—in aggregate with conventional and regional approaches—are facilitating creative energetic applications that are pervasive in several dimensions of science, including agricultural sciences. These cannot be sustained and ensure global food security without modern and innovative technologies (Raliya et al., 2018). Nanoscience and its applications have become an important area of science in modern times because it has transformed contemporary science. In agriculture, various aspects ranging from the health of soil to the supply of nutrients to plants, control over plant pests, and optimization in use of water and nano fertilizer are benefitted by nanostructure-based methods to enhance quality and productivity of crops for sustainable agriculture (Fellet et al., 2021).

Nano fertilizers are potential substitutes for traditional chemical fertilizers. Additionally, their use can significantly reduce environmental risks. Many reports have shown that nano fertilizers enhance crop yields by stimulating seed germination, photosynthesis, protein and carbohydrate synthesis, nitrogen metabolism, and plant stress tolerance (Rautela et al., n.d.).

Materials and methods

In this research paper, biochar was obtained from orange seeds. The orange seeds were collected and washed with distilled water to remove impurities. They were then left to dry for a week at room temperature. They were then placed in a dryer at a temperature of 85-90 degrees Celsius for three hours. They were then transferred to an evaporating dish. Their weight before burning was 288 grams. They were placed in an electric oven at a temperature of 350 degrees Celsius for five hours. After burning, the seeds were left to cool. Then, the black material was ground and weighed (155 grams). Infrared and ultraviolet tests were conducted on them at the College of Education for Pure Sciences, University of Diyala, and mass spectrometry was performed at the Ministry of Science and Technology, Environmental Research Center. The physical properties, such as solubility and color, were for both biochar and nano zinc oxide.

This experiment was conducted at the nursery of the College of Education for Pure Sciences/University of Diyala, from 20/2/2025 to 25/4/2025, to study the effect of nanomaterial fertilization on some growth characteristics of tomato plants. Three treatments were used, each with three repetitions: the first treatment had no soil fertilization, the second involved fertilizer with nanosized ZnO at a concentration of 150 mg/L, and the third was a mixture of ZnO and the extract from orange seeds, also at 150 mg/L. The complete randomized design (CRD) was employed, using black plastic pots with a diameter of 20 cm, a height of 20 cm, and a soil capacity of 5 kg per pot. The pots were covered with plastic bags until germination. After germination and plant emergence above the soil surface, the previously mentioned nanomaterials were added to the soil. Daily observations of plant changes throughout the study period were recorded. The trial extended over 65–66 days. Note that the growing media is sandy soil.

The growth traits studied included:

Plant height (cm): at the end of the experiment, measured using graduated measuring tape from the soil base up to the top of the plant.

FW (g): Fresh weight of the root system was measured using a sensitive balance after washing clean the roots repeatedly with distilled water.

Dry weight (g): The dry weight of the root system was recorded after drying the roots for 72 hours in air to a constant weight with a sensitive balance.

Total chlorophyll (SPAD) content: The SPAD was used to measure the chlorophyll content of different tomato leaves. Readings were made from five leaves selected at random on plants in each pot, and the average was determined.

Results and Discussion

The biochar compound was characterized by IR spectroscopy with KBr powder. A peak due to the C=O stretch was observed at 1716 cm⁻¹, and the ring resonance shift effect is seen on this band. The C–O stretching at 1288 cm^{-1} and the C=C stretching at 1558 cm^{-1} were observed, which is characteristic of aromatic compounds. Additionally, a peak at 2943 cm^{-1} was detected, attributable to the aliphatic carbon stretch. These spectral features are summarized in the **table. 1** and **Figure 1**)

Regarding the UV-Vis spectrum, the compound was dissolved in benzene, and the UV-Vis

Table 1 shows peaks in the infrared spectrum.

COMPOUND	υ C=O	υ C-O	υC=C	υC-H	υC=C-H
Biochar	1716M	BORD	1558.48 W	2943S	3305M

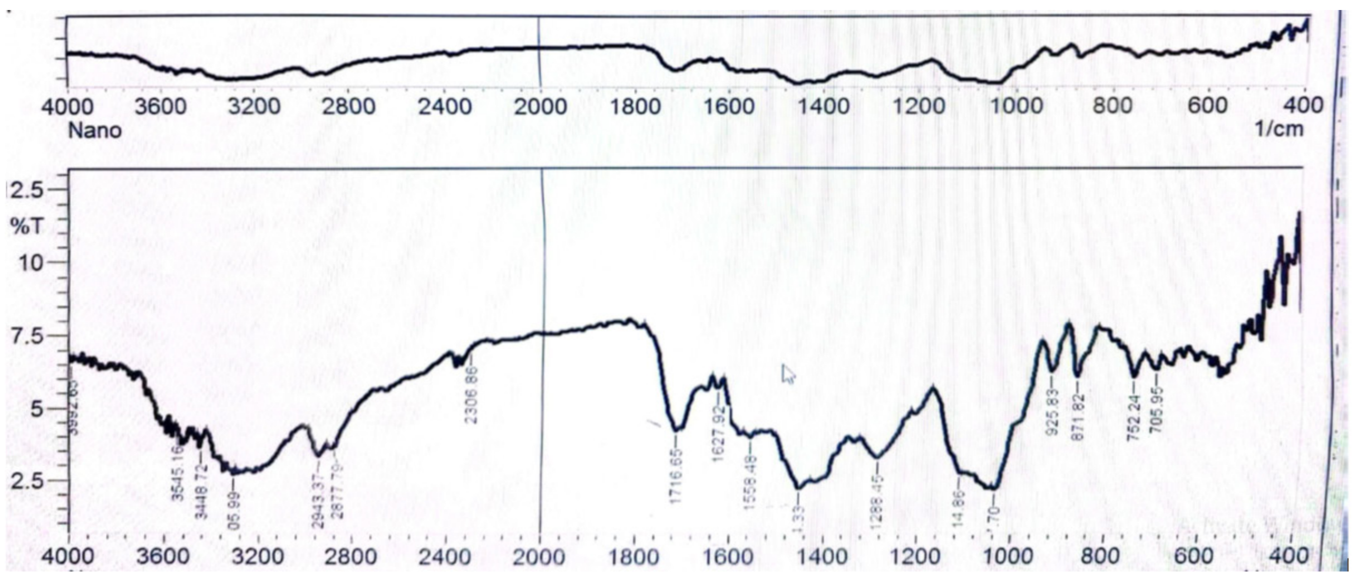

Figure 1 shows peaks in the infrared spectrum.

spectrophotometer was used to direct the radiation. A peak was observed at 300 nm, corresponding to an n→π* transition, and another at 370 nm, associated with a π→ π* transition in the carbonyl and C–O groups. Additionally, a peak at 380 nm was recorded, indicating a π→π* transition in the double bonds (**Table 2** and **Figure 2**)

Table 2 shows transitions in the ultraviolet spectrum.

The compound	Type of transition		Observe value.
Biochar	n	π*	300 nm
	π	π*	370 nm
	π	π*	380 nm

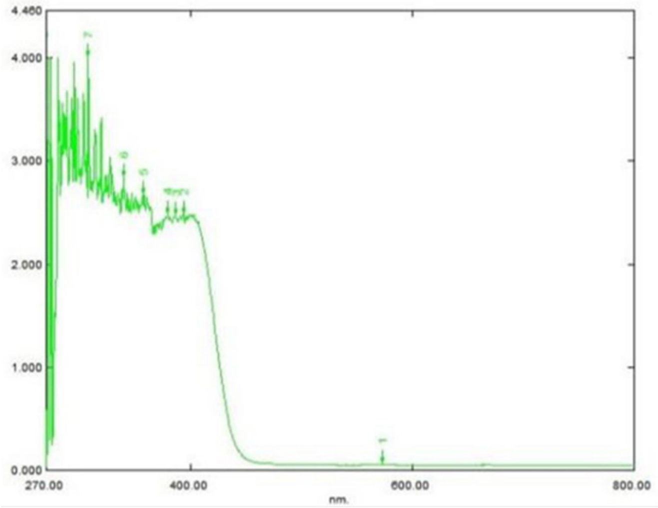

Figure 2 shows the peaks of the compound in the UV spectrum.

To characterize the compound by physical properties, the biochar compound was black in the form of a black powder. Solubility tests were conducted on it in a number of solvents. It was found to be insoluble in polar solvents, such as distilled water. Because biochar is an organic substance, it cannot form apo-bonds. Therefore, it was dissolved in organic compounds, such as acetone, where it was incompletely dissolved, resulting in a black solution. However, it was completely dissolved in benzene, resulting in a light green solution. Solubility tests were conducted on the previously prepared zinc oxide nanoparticle in the form of a white powder. It was insoluble in distilled water, acetone, or benzene due to the small size of the nanoparticles, as shown in **table 3**.

Table 4 shows significant differences in the studied plant traits, as the highest significant difference was observed in the trait of plant height (cm) in the treatment of fertilization with nano zinc oxide (ZnO), where the highest average reached 26.2 cm, followed by fertilization with the nanomaterial of orange seeds

Table 3 shows the solubility of the extracted material and zinc oxide in solvents.

COMP	distilled water	ethanol	Dimethyl sulfoxide	Acetone	benzene	color of the chemical compound
biochar	not dissolve.	not dissolve.	not dissolve.	dissolves	dissolves	black
ZnO	not dissolve.	not dissolve.	not dissolve.	not dissolve.	not dissolve.	white

Table (4): The effect of nano-fertilization on tomato plant characteristics

Plant Transactions	Plant height	Fresh weight	Fresh weight	chlorophyll
Without fertilization	c22.8	b8.967	a5.667	68.267 c
Nano ZnO fertilization 150 mg/L^{-1}	a 26.2	a10.867	6.600a	76.733 a
Fertilization (ZnO + biochar) 150 mg/L^{-1}	b 23.5	b9.933a	5.900a	73.133 b

**Yellow color indicates the highest significant difference.

and nano zinc oxide, where the average reached 23.5 cm, while the lowest average reached 22.8 cm in the treatment without fertilization.

The table also showed the highest significant difference in fresh weight (g) in the nano zinc oxide (ZnO) fertilization treatment, with the highest average reaching 10.867 g, followed by fertilization with the nanomaterial for orange seeds and nano zinc oxide, with the average reaching 9.933 g, while the lowest average reached 8.967 g in the treatment without fertilization.

The table also showed the highest significant difference in dry weight (g) in the nano zinc oxide (ZnO) fertilization treatment, with the highest average reaching 6.600 g, followed by fertilization with the nanomaterial for orange seeds and nano zinc oxide, with the average reaching 5.900 g, while the lowest average reached 5.667 g in the treatment without fertilization.

The table also showed the highest significant difference in chlorophyll (SPAD) in the nano zinc oxide (ZnO) fertilization treatment, with the highest average reaching 5.667 g. 76.733, followed by fertilization with nanomaterial for orange seeds and nano zinc oxide, as the average reached 73.133, while the lowest average reached 68.267 in the treatment without fertilization.

Conclusions

Biochar was obtained from sweet orange seeds. This means the compound contains a wide range of organic compounds. Fertilization results showed that commercial nano-zinc oxide was more effective in fertilizing tomato plants than biochar. Therefore, we advise farmers not to use it in tomato cultivation.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.