



Evaluation of biochar and *Agaricus bisporus* spent compost on some physiological, production characteristics of tomato *Solanum lycopersicum* L.

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ABSTRACT

This study was conducted for the period 2024-2026 in the laboratories and fields of the College of Agriculture, Tikrit University, aimed to evaluation of biochar prepared from various plant sources and Spent mushroom compost (SMC) for enhanced growth and productivity parameters in *Barcelona cultivar* tomato plants, for the photosynthetic Rate SMC at 5% concentration achieved the highest rate of 123.7 mg cm⁻² day⁻¹, surpassing Sesban biochar at 5% (101.3 mg cm⁻² day⁻¹) and the control (61.32 mg cm⁻² day⁻¹). All treatments improved photosynthesis, with efficacy increasing at higher doses. SMC at 5% yielded superior dry vegetative weight (101.73 g plant⁻¹) and root dry weight (14.18 g plant⁻¹), compared to the control (9.36 g plant⁻¹ root weight). Sesban biochar followed closely at 98.88 g plant⁻¹ (vegetative) and 13.75 g plant⁻¹ (root), while palm biochar recorded 96.01 g plant⁻¹ (vegetative) and 13.07 g plant⁻¹ (root). SMC at 5% maximized root activity at 138.44 mg g⁻¹ h⁻¹ versus the control's 52.54 mg g⁻¹ h⁻¹. Sesban biochar at 5% reached 127.48 mg g⁻¹ h⁻¹, highlighting the influence of feedstock on root dynamics. Peroxidase activity peaked with SMC at 5% (1.78 units mL⁻¹) over the control (1.03 units mL⁻¹); Sesban biochar hit 1.63 units mL⁻¹. Catalase activity was highest in SMC at 5% (403.78 units g⁻¹ FW), exceeding Sesban (397.49 units g⁻¹ FW) and the control (281.11 units g⁻¹ FW). SMC at 5% produced the top yield of 661.23 g plant⁻¹, followed by Sesban biochar (641.04 g plant⁻¹) and palm biochar (612.93 g plant⁻¹), against the control's 448.55 g plant⁻¹. Higher concentrations consistently drove greater improvements across all metrics.

تقييم الفحم الحيوي والكومبوست المستنفذ من فطر *Agaricus bisporus* على بعض الخصائص الفسيولوجية والإنتاجية للطماطة *Solanum lycopersicum* L.

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الخلاصة

أجريت الدراسة خلال الفترة 2024-2026 في مختبرات وحقول كلية الزراعة بجامعة تكريت، بهدف تقييم تأثير الفحم الحيوي المُحضّر من خمس مخلفات نباتية (السيسبان ،النخيل ،اليوكالبتوس ، الحور، السدر) ، فضلاً عن كومبوست الفطر *Agaricus bisporus* المُستنفذ (SMC) في معايير النمو والإنتاجية لمحصول الطماطة صنف برشلونة. من خلال قياس معدل التمثيل الضوئي، محتوى الكلوروفيل، وزيادة فعالية الجذور ،والوزن الجاف للمجموعين الخضري والجذري ،فضلاً عن قياس الفعالية الانزيمية لانزيمي البيروكسيداز والكتاليز ، سجل كومبوست الفطر المُستنفذ SMC بتركيز 5% أعلى فرقاً معنوياً بلغ 123.7 ملغم سم-2 يوم-1، متفوقاً على جميع أنواع الفحم الحيوي المدروسة. تلاه الفحم الحيوي للسيسبان بتركيز 5% (101.3 ملغم سم-2 يوم-1) والسيطرة (61.32 ملغم سم-2 يوم-1). حفزت جميع المعاملات عملية التمثيل الضوئي، بزيادة طردية مع زيادة التركيز. تفوق SMC بتركيز 5% معنوياً في تسجيله أعلى وزن خضري جاف بلغ 101.73 غم نبات-1 وأعلى وزن جاف للجذور بلغ 14.18 غم نبات-1، مقارنةً بالسيطرة التي سجلت 78.64 و 9.36 غم نبات-1 ووزن جاف للمجموعين الخضري والجذري على التوالي. تلاه الفحم الحيوي للسيسبان الذي سجل وزن جاف للمجموع الخضري بلغ 98.88 غم نبات-1 و 13.75 غم نبات-1 للمجموع الجذري ،بينما سجل الفحم الحيوي للنخيل وزن جاف للمجموع الخضري بلغ 96.01 غم نبات-1 و 13.07 غم نبات-1 للمجموع الجذري. مع تفوق معنوي لـ SMC بتركيز 5% في زيادة نشاط الجذور اذ بلغ 138.44 ملغم غم-1 ساعة-1، مقارنةً بـ 52.54 ملغم غم-1 ساعة-1 للسيطرة. تلاه الفحم الحيوي للسيسبان بتركيز 5% الذي سجل زيادة فعالية الجذور بلغت 127.48 ملغم غم-1 ساعة-1. وهذا انعكس إيجابياً على النشاط الانزيمي ، اذا ارتفعت الفعالية الانزيمية عند استخدام SMC بتركيز 5% الذي سجل تفوق معنوي على جميع المعاملات في الفعالية لانزيم البيروكسيداز بلغت 1.78 وحدة غم-1 وزن طري، مقارنةً بالسيطرة 1.03 وحدة غم-1 وزن طري ، تلاه الفحم الحيوي للسيسبان الذي اعطى فعالية انزيمية للبيروكسيداز بلغت 1.63 وحدة غم-1، فضلاً عن تسجيل SMC أعلى فعالية انزيمية لانزيم الكتاليز بلغت 403.78 وحدة غم-1 وزن طري ،مقارنةً بالسيطرة التي أعطت 281.11 وحدة غم-1 وزن طري ،تلاه الفحم الحيوي للسيسبان والنخيل اللذان سجلا فعالية انزيمية للكتاليز بلغت 397.49 و 380.76 وحدة غم-1 وزن طري على التوالي. حقق SMC بتركيز 5% أعلى إنتاجية بلغت 661.23 غم نبات-1 بتفوق معنوي على كل المعاملات ، يليه الفحم الحيوي للسيسبان الذي سجل 641.04 غم نبات-1 ، و الفحم الحيوي للنخيل الذي سجل 612.93 غم نبات-1، مقارنةً بـ 448.55 غم نبات-1 في معاملة السيطرة ،مع تسجيل زيادة طردية مع زيادة التركيز لجميع المعاملات وفي جميع المعايير.

الكلمات الافتتاحية: الكومبوست المستنفذ للفطر *Agaricus bisporus* ، الفحم الحيوي، المخلفات النباتية ، محصول الطماطة، الخصائص الفيزيولوجية والإنتاجية.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), belonging to the Solanaceae family, ranks among the most widely consumed vegetable crops globally. The cultivated area spans approximately five billion hectares worldwide (Gatah, 2020). Global tomato production saw a significant increase between 2016 and 2020, rising from 177.3 million metric tons in 2016 to 186.8 million metric tons in 2020. However, recent years have witnessed a 12% decline in global production due to climate change - particularly rising temperatures, especially in South Asia - coupled with soil fertility degradation and water scarcity (Food and Agriculture Organization of the United Nations, 2024). Iraq holds the sixth position among Arab countries in tomato production, with a total output of 700,000 tons in 2023, and Basrah Governorate is the largest producing region (FAO, 2023). Given its economic importance as a food source rich in carotenoids, phenolic compounds, vitamin C, essential amino acids, and minerals, tomato serves as a primary raw material in the food industry (Chaudhary *et al.*, 2018).

Tomatoes exhibit high adaptability to diverse environmental conditions and are cultivated either in plastic greenhouses or open fields (Smith and Lee, 2021; Wang *et al.*, 2020; Rehman *et al.*, 2021). Negative impacts of climate change, water scarcity, and increasing soil salinity—among the most critical factors threatening over 8 billion hectares of arable land worldwide, combined with excessive use of chemical fertilizers, have led to numerous environmental challenges. These include

soil degradation through acidification, nutrient leaching, disruption of soil structure, decline in beneficial microbial communities, and elevated greenhouse gas emissions (Hartmann and Six, 2023). Consequently, there is an urgent need for eco-friendly alternatives that first preserve soil quality and second ensure water resource sustainability. Key strategies involve organic soil amendments such as compost, animal manure, crop residues, and biochar as environmentally benign substitutes for chemical fertilizers to mitigate soil degradation and salinity effects (Din *et al.*, 2023; Wang *et al.*, 2024; Tian *et al.*, 2024; Zhang *et al.*, 2024).

In recent years, scientific interest has shifted toward biochar, defined as a carbon-rich solid material produced via pyrolysis under limited oxygen conditions from diverse biomass sources (e.g., agricultural residues). It has emerged as a sustainable soil amendment due to its capacity to enhance soil properties and promote beneficial microbial activity (Ren *et al.*, 2022; Wu *et al.*, 2023; Qian *et al.*, 2025). Thanks to its high carbon content, porous structure, negatively charged surface, and alkaline properties, biochar markedly alters soil physicochemical characteristics, including reduced bulk density, increased pH, improved nutrient retention, enhanced water-holding capacity, cation exchange capacity, and microbial community stability Sardar *et al.* 2025, Hassan *et al.*, 2024; Kang *et al.*, 2022). Biochar application efficacy depends on feedstock type, pyrolysis conditions, application rate, soil type, and climate (Kuok *et al.*, 2024; Liu *et al.*, 2024). Simiele *et al.* (2022) and reported that applying biochar at specific ratios with irrigation water improved quality indicators such as individual fruit weight, edible portion ratio, fruit juice content, soluble solids, vitamin C, organic acids, and the soluble solids-to-acids ratio. Similarly, Adebajo *et al.* (2022); Fawibe *et al.* (2025) and Zhang *et al.* (2020) demonstrated that biochar enhances soil nutrient supply and root system development in tomato plants, thereby improving overall plant growth and nutrient uptake. This stimulates vegetative growth through increased plant height, stem diameter, leaf area, and flower number, ultimately boosting productivity and fruit quality—particularly in arid, semi-arid continental, temperate climates in northwest China; semi-humid continental monsoon climates in central and western China; and Mediterranean climates. Recent studies have shown that irrigation with varying biochar levels significantly influences the native microbial flora in the tomato rhizosphere (Obadi, *et al.*, 2024; Liu *et al.*, 2025; Shi *et al.*, 2024; Elad, 2022).

The present study aims to evaluate different types of biochar prepared from five agricultural residues (Christ's thorn (*Ziziphus spina-christi*), Euphrates poplar (*Populus euphratica*), date palm (*Phoenix dactylifera*), river red gum (*Eucalyptus camaldulensis*), and sesbania (*Sesbania sesban*)), alongside spent compost from edible mushroom (*Agaricus bisporus*) cultivation as a natural, eco-friendly organic fertilizer alternative to chemical fertilizers in tomato production, and to elucidate its effects on the physiological traits and productivity of tomato crops.

MATERIALS AND METHODS

The study was conducted in the laboratories and fields of the College of Agriculture - Tikrit University. The field study was carried out in pots containing 10 kg of gypsiferous soil, with 3 plants (Barcelona tomato cultivar) planted per pot. The experiment included six treatments for

different types of biochar, ,in addition to SMC. with five pots for each treatment and three concentrations (1,3 and 5%) for each treatment, in addition to a control treatment.

Biochar Preparation

Biochar was prepared through pyrolysis of stems and branches from five tree species, including Christ's thorn (*Ziziphus spina-christi*), Euphrates poplar (*Populus euphratica*), date palm (*Phoenix dactylifera*), river red gum (*Eucalyptus camaldulensis*), and sesbania (*Sesbania sesban*). Plant parts were cut into 5-10 cm segments for each species (5 kg of each type), followed by pyrolysis in a pyrolysis reactor at 400-600°C under oxygen-limited conditions for 6 hr., as described by Ahmed and Hassan (2024). This method ensures consistent biochar production suitable for soil amendment studies in tomato cultivation.

Spent Compost

Spent compost derived from *Agaricus bisporus* cultivation was obtained from the mushroom production farm at the College of Agriculture, Tikrit University. This substrate represents nutrient-rich post-harvest material commonly used as a soil amendment in agricultural studies (Mohammad *et al.*, 2020).

Total Chlorophyll Content

Total chlorophyll content was analyzed according to Wellburn (1994). Fresh leaf samples (1 g) ,at flowering time, were homogenized with 20 mL of 80% acetone (v/v). Absorbance was measured at 663 nm (OD 663) and 645 nm (OD645) using a spectrophotometer (Shimadzu UV-16A, Shimadzu, Japan).

Total chlorophyll (mg/L) was calculated as: $20.20 \times (\text{OD}645) + 8.02 \times (\text{OD}663)$.

Net Assimilation Rate (NAR)(mg cm⁻² day⁻¹)

Five plants were used for NAR determination, NAR was expressed as the increase in photosynthetic output per unit leaf area over a time period, according to Hunt (1978).

$$\text{NAR} = (\text{W}_2 - \text{W}_1) (\text{LnA}_2 - \text{LnA}_1) / (\text{T}_2 - \text{T}_1) (\text{A}_2 - \text{A}_1)$$

Where:

W1: Dry weight of the plant at the start of the period (T1)

W2: Dry weight of the plant at the end of the period (T2)

lnA1: Natural logarithm of leaf area at the start (T1)

lnA2: Natural logarithm of leaf area at the end (T2)

T1: Start of the period (first weight measurement post-germination)

T2: End of the period (second weight measurement after cultivation interval)

Root Activity

Root activity was analyzed using the triphenyltetrazolium chloride (TTC) method, expressed as deoxidization ability, according to Zhang *et al.* (2013). This assay measures root metabolic activity through TTC reduction to red formazan, indicating dehydrogenase enzyme function and root viable. Root activity was calculated as:

$$\text{Root Activity} = \text{TTC reduction amount } (\mu\text{g}) / \text{Fresh root weight (g)} \times \text{Time (h)}$$

Crude Enzyme Extraction from Tomato

Crude enzymes were extracted from 5 g fresh tomato leaves crushed in 10 mL extraction buffer (0.1 M acetate buffer, pH 5.6; 1:2 w/v ratio). The homogenate was filtered through three layers of cheesecloth and centrifuged at 12000 rpm for 30 min Luhove *et al.*(2003). The supernatant, representing crude enzyme extract, was collected via syringe (discarding pellet) and stored at 4°C.

Peroxidase Enzyme Assay

Peroxidase activity was determined by adding 0.1 mL crude enzyme extract to 2.5 mL acetate buffer, measuring absorbance at 470 nm using a UV spectrophotometer. One enzyme unit was defined as a 0.01 change in absorbance per minute.

Peroxidase activity (units/mL) = $\Delta A_{470\text{nm}} / 0.01$

Specific activity (units/g fresh weight) = [enzyme units / (sample weight ÷ extraction volume)] × reaction mixture volume (Mahadevan and Sridhar, 1986).

Catalase Enzyme Assay

Catalase activity was assayed per using a reaction mixture of 2 mL acetate buffer (pH 5.6), 0.3 mL 3% H₂O₂ and 0.2 ml crude enzyme, incubated 5 min at room temperature. Reaction was stopped with 1 mL 32.4 mM ammonium molybdate; absorbance read at 405 nm.

Catalase activity = [(sample – blank 1) / (blank 2 – blank 3)] × 271

Where:

- Blank 1: 1 mL substrate (H₂O₂+ buffer) + 1 mL molybdate + 0.2 mL sample
- Blank 2: 1 mL substrate + 1 mL molybdate + 0.2 mL buffer
- Blank 3: 1 mL buffer + 1 mL molybdate
- 271: enzyme constant

Specific activity calculated as units/g fresh weight, as above. Aebi (1984)

Dry Vegetative and Root Weights

Two plants per treatment were randomly sampled at flowering initiation. Roots were separated from shoots, washed to remove soil, and both parts oven-dried at 70°C until constant weight. Average dry weights (g) were recorded for vegetative and root biomass.

Productivity Standard(g plant⁻¹)

Fruit yield per plant was calculated from the product of three harvests for a week between harvests from three plants per experimental unit per treatment.

Statistical analysis

The experiments of this study were carried out in a completely randomized design (CRD). The measurements involved using 5 replicates of each treatment.

An analysis of variance was carried out according to the SPSS program (version 30, 2024), and the averages were compared according to the Duncan's Multiple Range Test (DMRT) at a probability level of 0.05 (Al-Rawi and Khalaf Allah 1980)

RESULTS AND DISCUSSION

Figure 1 illustrates the effect of various biochar types and spent compost from *Agaricus bisporus* on the photosynthetic rate of *Barcelona cultivar* tomato plants. Results showed that all treatments significantly enhanced photosynthetic rates compared to the control, with the highest value recorded for spent compost at 5% concentration ($123.7 \text{ mg cm}^{-2} \text{ day}^{-1}$). This was followed by Sesban biochar at 5% concentration ($101.37 \text{ mg cm}^{-2} \text{ day}^{-1}$), while the control exhibited a notably lower rate of $61.327 \text{ mg cm}^{-2} \text{ day}^{-1}$.

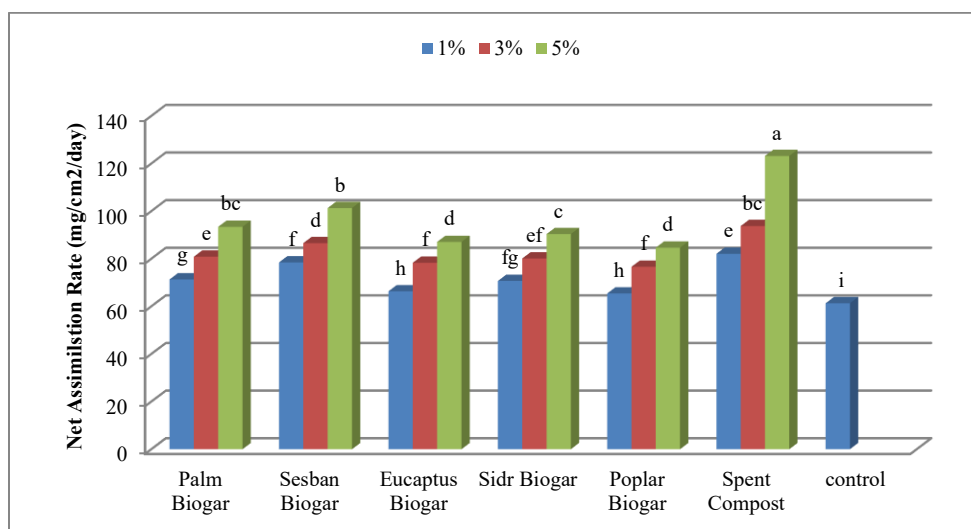


Figure (1) Effect of biochar types and spent compost of the edible mushroom *Agaricus bisporus* on the Net Assimilation Rate of tomato (*Barcelona cultivar*)

Figure (2) illustrates the effect of different types of biochar and spent compost from *Agaricus bisporus* on total chlorophyll content in *Barcelona* tomato plants. The results revealed a significant superiority of all applied treatments compared to the control, which recorded the lowest value of 0.78 mg g^{-1} leaf FW. The spent compost treatment achieved the highest values across its concentrations of 1, 3, and 5%, reaching 1.06 , 1.41 , and 1.86 mg g^{-1} leaf FW, respectively. Additionally, the Sesban biochar recorded the highest value among all biochar types tested, at three concentration levels (1.01 , 1.23 , and 1.77 mg g^{-1} leaf FW). This was followed by the palm biochar at 5%, which reached 1.64 mg g^{-1} leaf FW.

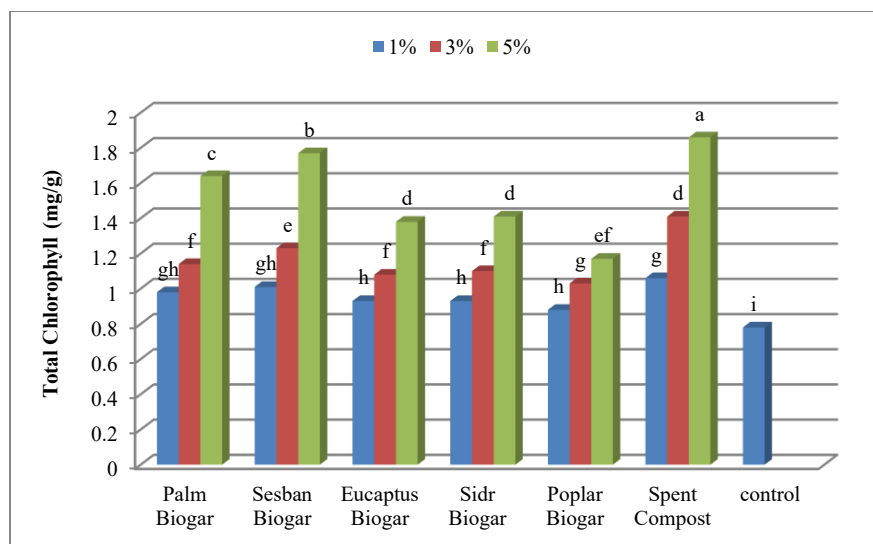


Figure (2) Effect of biochar types and spent compost of the edible mushroom *Agaricus bisporus* on the Total chlorophyll of tomato (*Barcelona cultivar*)

Figure 3 results indicate that spent compost at 5% concentration yielded the highest root activity value of $138.44 \text{ Mg g}^{-1} \text{ h}^{-1}$, compared to the lowest value in the control treatment at $52.54 \text{ Mg g}^{-1} \text{ h}^{-1}$. All treatments increased root activity in *Barcelona cultivar* tomato plants across concentrations from 1% to 5%, with notable enhancements at higher doses. The plant material type used in biochar production influences its efficacy and root growth activity. Among biochar types tested, Sesban Biochar at 5% concentration recorded high activity at $127.48 \text{ Mg g}^{-1} \text{ h}^{-1}$, followed by Palm Biochar in promoting root growth dynamics

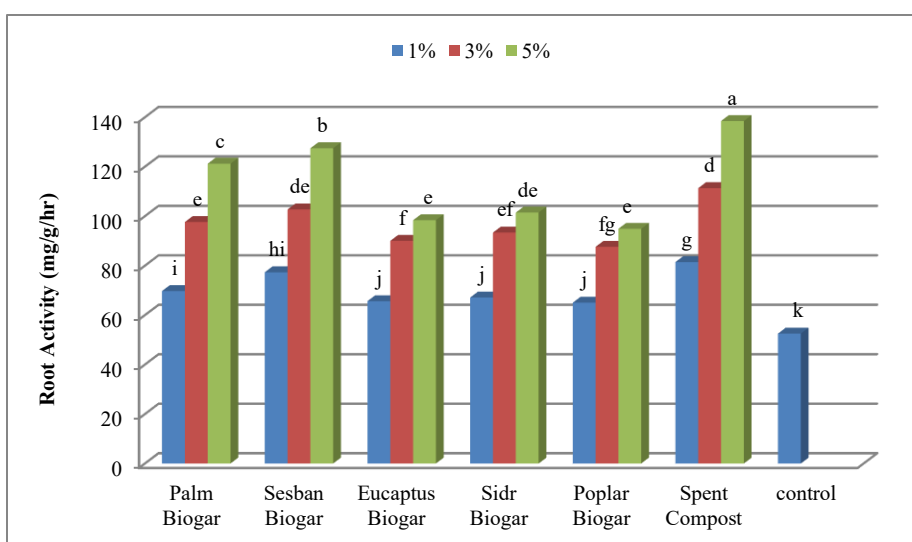


Figure (3) Effect of biochar types and spent compost of the edible mushroom *Agaricus bisporus* on the Root activity of tomato (*Barcelona cultivar*)

Figure 4 demonstrates significant superiority of the spent compost treatment on the dry vegetative weight of *Barcelona cultivar* tomato plants, recording the highest value of 101.73 g plant⁻¹ at 5% concentration. This was followed by Sesban biochar at 98.88 g plant⁻¹ 5% concentration, then Palm biochar at 96.01 g plant⁻¹ at the same concentration. Eucalyptus biochar and Poplar biochar treatments at 1% concentration exhibited the lowest impact on the dry weight of the total vegetative biomass.

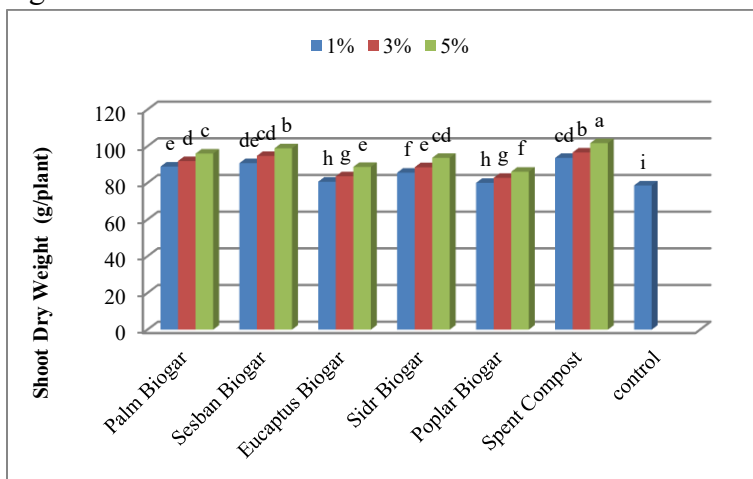


Figure (4) Effect of biochar types and spent compost of the edible mushroom *Agaricus bisporus* on the Shoot dry weight of tomato (*Barcelona cultivar*)

Figure 5 illustrates the effect of biochar and spent compost from *Agaricus bisporus* on the dry root weight of *Barcelona cultivar* tomato plants. Results revealed significant superiority in root dry weight across all treatments compared to the control 9.36 g/plant, with spent compost recording the highest value of 14.18 g plant⁻¹ at 5% concentration. This enhanced efficacy likely stems from abundant nutrient availability promoting root growth. Among biochar types, Sesban Biochar demonstrated significant superiority over others, achieving the highest value of 13.75 g plant⁻¹ at 5% concentration, followed by Palm Biochar at 13.07 g plant⁻¹ at the same concentration. Remaining biochar types yielded lower increases in root dry weight

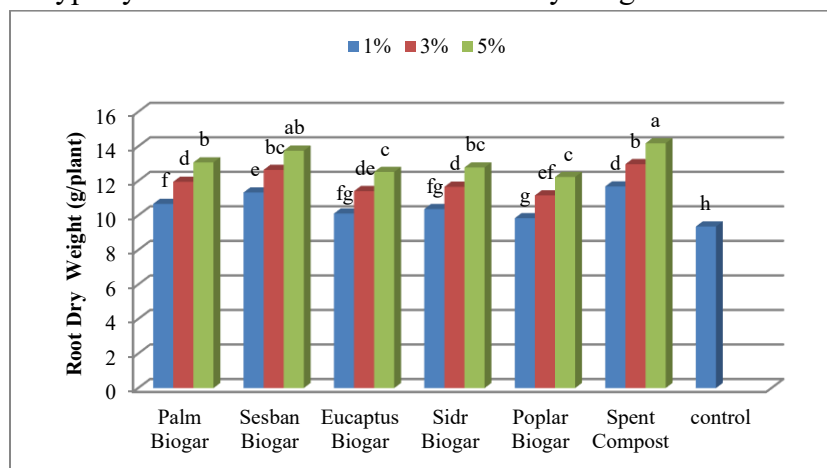


Figure (5) Effect of biochar types and spent compost of the edible mushroom *Agaricus bisporus* on the Root dry weight of tomato (*Barcelona cultivar*)

Figure 6 indicates the effect of adding various biochar types and spent compost from *Agaricus bisporus* on peroxidase enzyme activity in *Barcelona cultivar* tomato plants. Spent compost treatment demonstrated significant superiority across its three concentrations, recording values of 1.55, 1.66, and 1.78 units ml^{-1} , respectively, compared to the control's lowest value of 1.03 units ml^{-1} . Among biochar types, Sesban Biochar achieved the highest results relative to other types tested, with values of 1.46, 1.55, and 1.63 units ml^{-1} across its three concentrations.

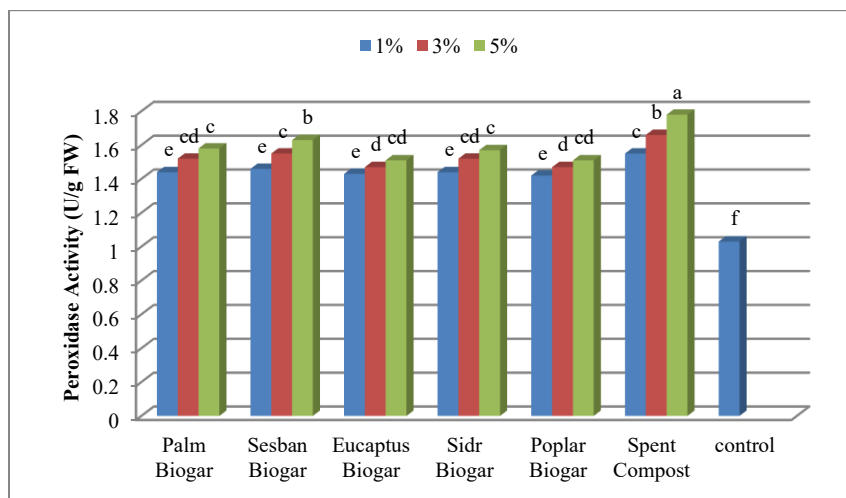


Figure (6) Effect of biochar types and spent compost of the edible mushroom *Agaricus bisporus* on the Peroxidase activity of tomato (*Barcelona cultivar*)

Figure 7 illustrates the effect of various biochar types and spent compost from *Agaricus bisporus* on catalase enzyme activity in tomato plants. All treatments enhanced this enzyme activity across concentrations compared to the control, which recorded the lowest value of 281.11 units g^{-1} FW. Spent compost achieved the highest values, with 403.78 units/g FW at 5% concentration, 382.71 units g^{-1} FW at 3%, and 354.54 units g^{-1} FW at 1%, demonstrating significant superiority over other treatments. Among biochar types, Sesban biochar (5%) recorded the highest at 397.49 units g^{-1} FW, followed by Palm Biochar (5%) at 380.76 units g^{-1} FW.

Figure 8 illustrates the effect of various biochar types and spent compost on the productivity of *Barcelona cultivar* tomato plants. The highest productivity was observed with spent compost at 5% concentration, reaching 661.23 g plant^{-1} , followed by Sesban Biochar biochar at the same concentration (641.04 g plant^{-1}), and then Palm Biochar at 5% (612.93 g plant^{-1}). The control treatment recorded the lowest tomato yield at 448.55 g plant^{-1} . These results underscore the substantial yield enhancements from organic amendments, particularly at higher concentrations

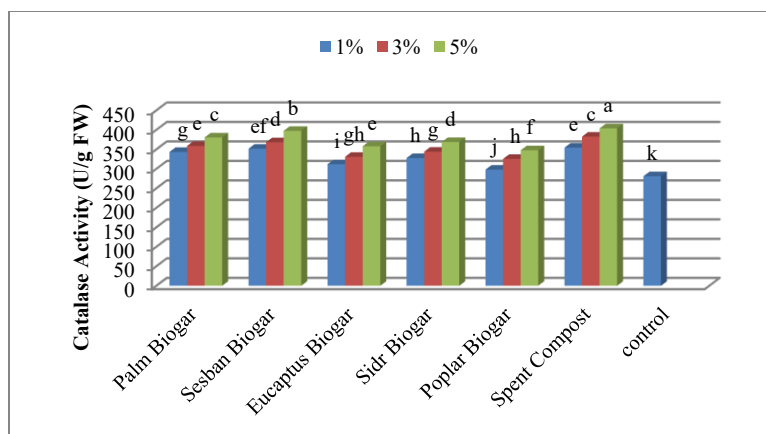


Figure (7) Effect of biochar types and spent compost of the edible mushroom *Agaricus bisporus* on the Catalase activity of tomato (*Barcelona cultivar*)

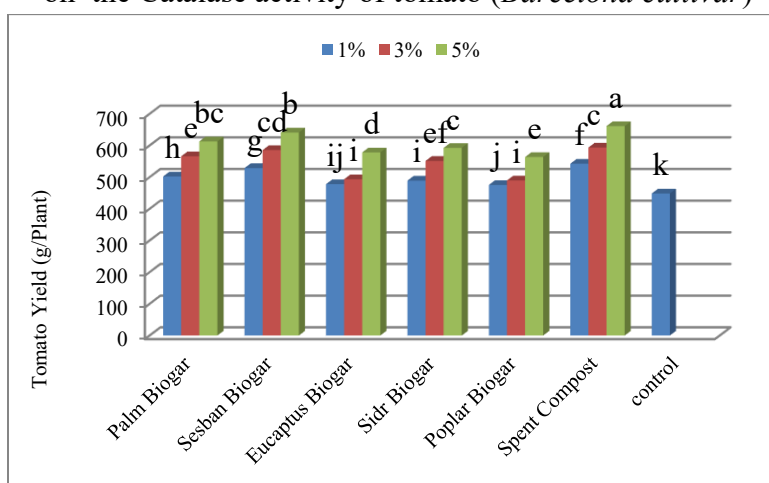


Figure (8) Effect of biochar types and spent compost of the edible mushroom *Agaricus bisporus* on the Yield (first Two harvests) of tomato (*Barcelona cultivar*)..

The results demonstrated a significant superiority of the biochar prepared from spent mushroom compost (SMC) derived from white button mushroom (*Agaricus bisporus*) cultivation at a 5% concentration over all other studied biochars and across all tested indicators in this study. It recorded the highest photosynthetic rate (Fig.1), along with the highest percentages for total chlorophyll (Fig.2), root efficiency (Fig.3), and dry weights of shoots and roots (Fig.4,5). Additionally, it exhibited the highest percentages for peroxidase and catalase enzymes (Fig.6,7). This superiority is attributed to the unique physical properties of SMC, including high porosity, large surface area, and its role in ameliorating acidic soils, as well as its high cation exchange capacity (CEC). These properties were confirmed by Baptista *et al.* (2023) and Aiduang *et al.* (2025), who demonstrated the efficacy of SMC due to its rich macronutrient content: N (0.44–2.77%), P (0.03–3.80%), and K (0.08–1.39%). It also contains substantial micronutrients, such as Ca (0.40–9.69%) and Mg (0.05–1.70%), along with trace elements including Fe (1500–24,000 mg kg⁻¹), Mn (10–1200 mg kg⁻¹), Zn (84–1000 mg kg⁻¹), Cu (10 mg kg⁻¹), and Na (290–1100 mg kg⁻¹). These compositions vary depending on the edible mushroom species grown on the compost used as the

raw material for biochar production, ultimately promoting plant growth, productivity, and soil microbial community stimulation. Our findings align with those of Sardar *et al.* (2025) and Liu *et al.* (2024), who tested the effect of SMC on tomato plant growth and yield, reporting significant increases with rising SMC ratios; the 4% SMC treatment yielded the highest plant growth and yield, alongside significant elevations in chlorophyll *a* (Chl *a*: 64.3%), Chl *b* (77.4%), total chlorophyll (67.4%), carotenoids (120%), vitamin C (101.1%), and peroxidase and catalase enzyme activities compared to the control. The remaining biochar types ranked in descending order of efficacy as follows: Sesbania biochar > date palm biochar > Sidr biochar > eucalyptus biochar > poplar tree biochar.

Sesbania residues biochar recorded the highest significant values for photosynthetic rate, chlorophyll percentage, root efficiency, shoot and root dry weights, and peroxidase and catalase enzyme percentages. This is due to Sesbania's nitrogen-fixing ability as a legume, coupled with its abundance of bioactive compounds, particularly secondary metabolites such as flavonoid glycosides, flavonoids, and terpenoids, which exhibit diverse bioactivities; flavonoid glycosides are among the most potent antioxidants. Our results corroborate those of Thissera *et al.* (2020), Hiep *et al.* (2022), and Shaker and fenjan (2023), who characterized Sesbania-derived biochar with key physical properties like high porosity and surface area ($561.8 \text{ m}^2 \text{ g}^{-1}$), enhancing mineral adsorption. It is also rich in macronutrients (N, P, K) and bioactive compounds, which boost soil productivity via increased organic matter, nutrient mobility, and microbial habitat enhancement. Furthermore, its alkalinity (pH ranging from 6.9 to 9.3) and enrichment with stable carbon, which increases with rising pyrolysis temperature contribute to these benefits (Abdelghany *et al.*, 2023),

Date palm tree biochar exhibited notable significant differences in photosynthetic rate, chlorophyll percentage, root efficiency, and dry weights of shoots and roots, along with the highest percentages for peroxidase and catalase enzymes. This may be attributed to its content of aromatic lignin compounds, which enhance surface area and porosity, rendering it a high-adsorption agent for elements. Similarly, Som *et al.* (2012) reported substantial mineral element content in biochar prepared from date palm tree wastes. Our study results indicate that SMC and all biochars prepared from various agricultural wastes, significantly outperformed the untreated control across vegetative and yield quantity indicators, as well as peroxidase and catalase activities. This aligns with Zhang *et al.* (2025), Ahmed (2020), Alharby *et al.*, (2023), Liang *et al.*, (2022) and Liu *et al.*, (2024) who confirmed that biochar-water treatments significantly improved soil nutrients, stimulated tomato growth, enhanced fruit yield and quality, and optimized water use efficiency. Plant height and stem diameter increased by 14.87% and 5.47%, respectively, compared to the control; nitrate nitrogen rose 2.92-fold with biochar-water treatment, while tomato yield, lycopene content, and soluble solids increased by 27.99, 19.50, and 128.4%, respectively, in hot, dry southwestern China regions. Our findings also agree with Frimpong *et al.* (2025) and Anyebe *et al.*, (2025), whose results showed marked soil property improvements with increasing biochar rates: soil pH rose from 5.45 (control) to 6.16 at 7.5 t ha^{-1} , while 10 t ha^{-1} increased soil organic carbon by 24.3%, total nitrogen by 60%, and available phosphorus by 80%. Plant water-holding capacity improved notably, with 7.5 t ha^{-1} achieving an 11.7% increase versus 10.8% in the control; this rate

also yielded the highest leaf number, stem girth, and significant yield gains. Finally, our results concur with Lei *et al.* (2024), who demonstrated that biochar application significantly boosted tomato yield by 29.55%, total soluble solids by 4.28%, and vitamin C by 6.77% compared to the control, particularly at higher rates. However, benefits may diminish over time due to biochar aging in soil, necessitating periodic reapplication. Stimulating the production of catalase and peroxidase by both spent compost and various types of biochar has positively impacted plant health and increased productivity. Khan 's study indicated that these enzymes resisting environmental stress and promoting overall physiological health (Khan *et al.*, 2024;El-Kader,2023)

CONCLUSION

In conclusion, spent mushroom compost of *Agaricus bisporus* proved superior to plant-derived biochars and the control in boosting photosynthesis, vegetative and root growth, root activity, antioxidant enzyme levels, and overall tomato yield in the *Barcelona cultivar*. Optimal effects emerged at higher application rates, with feedstock type playing a pivotal role in performance—spent mushroom compost consistently outperforming others. These results highlight spent mushroom and biochar's potential as a sustainable soil amendment for enhanced plant productivity.

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