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تأثير الفحم الحيوي وسماد الدجاج على نمو وإنتاجية البازلاء في الترب الرملية

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The effects of biochar and chicken manure on the growth and yield of pea in sandy soil

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الملخص:
البازلاء (*Pisum sativum* L) نبات عشبي سنوي من الفصيلة البقولية، تم زراعته على مدى آلاف السنين كمحصول غذائي حيوي في جميع أنحاء العالم. ومع ذلك، فإن تأثير الفحم الحيوي على إنتاج البازلاء في ظل ظروف الزراعة العضوية لا يزال غير مدروس بشكل جيد. ونهدف بهذه الدراسة لمعرفة تأثير الفحم الحيوي وسماد الدجاج على نمو وإنتاجية نبات البازلاء. تم استخدام تصميم القطاعات العشوائية الكاملة (CRBD) بثلاث مكررات للتجربة، وتشمل على أربع معاملات وهي: معاملة الشاهد، و10 طن / هكتار من سماد الدجاج، و2 ٪ من الفحم الحيوي مع 10 طن / هكتار من سماد الدجاج، و5 ٪ من الفحم الحيوي مع 10 طن / هكتار من سماد الدجاج. نفذت التجربة بفصل الشتاء 2023، أوضحت النتائج أن اضافة الفحم الحيوي مع سماد الدجاج له تأثير معنوي على نمو وحاصل البازلاء. والجدير بالذكر أن معاملة 5 ٪ من الفحم الحيوي مع 10 طن / هكتار من سماد الدجاج سجلت أعلى زيادة في الحاصل وكانت بنسبة 70 ٪ مقارنة بمعاملة الشاهد. تدل هذه النتائج على إمكانية استخدام الفحم الحيوي في الزراعة العضوية وخاصة في ظروف الترب الفقيرة مثل الترب الرملية. نوصي من خلال هذه الدراسة بمزيد من الأبحاث حول التأثيرات طويلة المدى للفحم الحيوي على خصائص التربة وإنتاجية البازلاء لتحسين الممارسات الزراعية المستدامة.

الكلمات المفتاحية: البازلاء (*Pisum sativum* L.)، الفحم الحيوي، سماد الدجاج، مؤشرات الحصاد، مؤشرات النمو.

ABSTRACT:
Pea (*Pisum sativum* L.) is an herbaceous annual plant in the Fabaceae family, known for its cultivation over millennia as a vital food crop worldwide. However, the influence of biochar on its production under organic farming conditions remains inadequately explored. This study investigates the synergistic effects of biochar and chicken manure on the growth and yield of pea plants. The experiment employed a completely randomized block design (CRBD) with three replicates, encompassing four treatments: a control, 10 t/ha chicken manure, 2 % biochar combined with 10 t/ha chicken manure, and 5 % biochar combined with 10 t/ha chicken manure. The experiment was conducted in the winter of 2023. The results revealed that the biochar-chicken manure combination significantly enhanced pea growth and yield. Notably, the 5 % biochar plus 10 t/ha chicken manure treatment achieved the highest increase, boosting yield by 70 % compared to the control. These findings highlight the potential of biochar as a potent amendment in organic farming, especially in challenging soil conditions like sandy soils. Future

research should delve deeper into the long-term impacts of biochar on soil health and pea productivity to refine sustainable agricultural practices.

Key words: Pea (*Pisum sativum* L)، Biochar, Chicken Manure, Yield Parameters, Growth Parameters.

INTRODUCTION

Pea (*Pisum sativum* L.) is an herbaceous annual plant in the Fabaceae family, known for its cultivation over millennia as a vital food crop. Typically grown for their edible seeds, which can be consumed fresh, frozen, or dried, peas thrive in cool seasons with mild temperatures and well-drained soil. Additionally, peas are renowned for their nitrogen-fixing ability, which enriches the soil by converting atmospheric nitrogen into a usable form for plants, making them a valuable crop in sustainable farming practices (Gollner *et al.,* 2019).

Biochar is formed through the pyrolysis of organic materials in an oxygen-deprived environment, resulting in stable, carbon-rich products (Sakhiya *et al.,* 2020). Due to its desirable properties, such as porosity and high surface area, biochar has been used as a soil amendment to improve soil health. It enhances nutrient retention (Nanda *et al.,* 2024; Park *et al.,* 2023) and improves soil structure (Bo *et al.,* 2023). Additionally, biochar increases water-holding capacity (Zhao *et al.,* 2023; Al-Madani and Daryak, 2023), promotes microbial activity (Ren *et al.,* 2020), and reduces soil acidity (Hachib *et al.,* 2023). Furthermore, it helps in reducing greenhouse gas emissions (Kalu *et al.,* 2022).

Chicken manure is a valuable organic fertilizer rich in essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), which are crucial for plant growth and soil health (Tawfik *et al.,* 2023 and Fadl and alkut, 2023). It is produced from the excrement of chickens and often mixed with bedding materials like straw and sawdust. The high nutrient content and organic matter in chicken manure make it an excellent amendment for improving soil fertility and structure (Agbede *et al.,* 2020). Combining biochar with organic manure may further enhance soil properties and plant productivity. For instance, Cai *et al.,* (2022) discovered that combining biochar with poultry manure enhanced soil aggregate stability and micropore volume, resulting in a 71.1 % increase in crop yield. Similarly, Agbede *et al.,* (2020) found that this combination significantly improved soil properties and crop yield in degraded tropical sandy soils. Fareed *et al.,* (2024) reported that biochar notably enhanced pea plant growth under salinity stress, improving nutrient uptake and increasing antioxidant activities, which led to a 20-30 % yield increase compared to the control group. A meta-analysis by Singh *et al.,* (2022) further highlights the broad benefits of biochar on various crops, including wheat, maize, rice, and soybeans. Additionally, Mikajlo *et al.,* (2024) observed that adding biochar positively affected soil properties and plant growth. These studies provide valuable insights that can be applied to pea cultivation.

Since the effects of biochar depend on soil type, biochar type, and climate, this study aims to evaluate the role of biochar combined with chicken manure on the growth and yield of peas. We hypothesize that the positive effects of chicken manure and biochar on soil properties, such as reducing bulk density, increasing porosity, and enhancing nutrient availability, will lead to improvements in pea growth and yield.

MATERIAL AND METHODS

Location and soil

The experiment was conducted in the winter of 2023 at the Agriculture Facility farm of Sebha University, Libya (Latitude 26°58'21.58"N, Longitude 14°26'23.85"E). The region experiences a desert climate, characterized by arid conditions and minimal rainfall, with no recorded rainfall during the study period. It features an average annual temperature of 30°C and typically receives 22 mm of precipitation annually (World Weather Online, https://www.worldweatheronline.com/). The experimental site had previously been cultivated with peanut (Arachis hypogaea) crops and is characterized by sandy soil, consisting of 92 % sand, 6.4 % silt, and 3.2 % clay (American Soil Taxonomy), with a pH of 7.2 and an organic matter content of 0.44 %. The soil exhibits good drainage and has a bulk density of 1.81 g/cm³. Soil samples were collected from the top 30 cm of the experimental site for analysis. Additional physical and chemical analyses are presented in Table 1.

Table 1. Chemical and physical properties of soil site.

Sand	Salt	Clay	Texture	pH	EC	O.M	N	P	K
%					dS m^{-1}	%	ppm		
93.65	3,64	2.8	Sandy	7.2	0.48	1.32	0.09	300	80

Adapted from Rasem & Elzobair 2023

Experimental design and treatments

The study was initiated in the winter of 2023. A randomized complete block design (RCBD) with three replicates was employed to assess the effects of biochar and chicken manure on pea growth. The treatments included control, 10 t/ha chicken manure, 2 % biochar (w/w) plus 10 t/ha chicken manure, and 5 % biochar (w/w) plus 10 t/ha chicken manure. Biochar was produced in a small-scale pit, then crushed into a fine powder with particle sizes less than 0.5 mm, and stored in a sealed plastic bag until use. Biochar was applied to the soil surface and incorporated to a depth of 15 cm. Chicken manure was sourced from a private farm and composted under optimal air and moisture conditions for six months. Pea seeds (Utrillo Variety) were sown at a depth of 2 cm and spaced 30 cm apart in rows 40 cm apart. Planting occurred on December 8 / 2023. Irrigation was provided as necessary to maintain soil moisture at field capacity. No additional fertilizers were applied, and weeds were controlled manually.

Statistical analysis

A one-way ANOVA was conducted to compare the effects of biochar and chicken manure treatments on pea yield and Bacteria population, Treatment means were then compared for differences using LSD at $\alpha = 0.05$. Al data were analysed using SAS version 9.4.

RESULTS AND DISSECTION

Effect of biochar on pea growth parameters

The study revealed that pea plants treated with biochar and chicken manure exhibited a significant increase in height compared to the control. The combination of 5 % biochar plus 10 t/ha chicken manure resulted in the tallest plants, with an average height of 82 cm, compared to 55.33 cm in the control group, accounting for a 48 % increase. Chicken manure alone increased plant height by 17 %. The application of biochar and chicken manure significantly affected the growth parameters of peas in our study. These findings align with research conducted on red ginger, which demonstrated that the combined use of biochar and chicken manure significantly improved plant height and yield. The highest growth in red ginger was observed with the application of 10 t/ha chicken manure plus 15 t/ha biochar (Mardiansyah *et al.,* 2020). Similarly, a study on cowpea showed that different biochar application methods significantly improved plant height, biomass, and nutrient uptake compared to the control (Yeboah *et al.,* 2020). Our results suggest that biochar and chicken manure synergistically enhance soil properties and nutrient availability, leading to better growth parameters. The number of branches per plant also varied significantly across different treatments. The highest average number of branches was observed in the 5 % biochar plus 10 t/ha chicken manure treatment, while the lowest was in the control, showing about a 50 % increase. The positive impact of biochar and chicken manure on pea growth in our study aligns with the study by Yasser *et al.* (2024), which demonstrated that biochar combined with organic fertilizer improved plant growth parameters, especially the number of branches and overall plant health.

Germination rates were monitored as a key growth parameter. Our study found no significant effect on seed germination rates, suggesting that while these amendments enhance post-germination growth processes, they do not significantly influence the initial germination stage. The effects of biochar on seed germination can be variable and dependent on factors such as biochar type, concentration, and the specific crop being studied. For instance, Liaqat *et al*, (2021) found that biochar had variable effects on seed germination, with some types and concentrations showing no effects or even negative effects on the germination rates of basil, lettuce, and tomato seeds. Conversely, Carril *et al.,* (2023) reported positive effects of biochar on maize seed germination percentage, and research on rice by Nguyen *et al.,* (2022) demonstrated improvements in germination rates with biochar application. These species-specific responses emphasize the need for further research to fully understand these dynamics.

Table 2. Effect of biochar and chicken manure on growth parameters of pea

Treatment	Germination rates	Plant height (cm)	Number of branches/plants	Total of Bacteria ($\times 10^4$ CFU/g))
Control	96.30	55.33^{d}	2.66^{b}	2.4×10^{5d}
10 t ha^{-1} CHM	92.60	64.66^{c}	3.33^{ab}	4.3×10^{5c}
2 % B + 10 t ha^{-1} CHM	88.90	70.00^{b}	3.66^{a}	10.5×10^{5a}
5 % B + 10 t ha^{-1} CHM	88.90	82.00^{a}	4.00^{a}	6.1×10^{5b}
F-test	NS	S	S	S
CV %	9.685	2.462	10.90	4.987
CD (P = 0.05)	N	3.345	0.745	5.835

Effects of biochar on bacteria population

The results, illustrated in Figure 1, indicate that the application of biochar led to a significant increase in the bacterial population. In the 2 % biochar treatment, the bacterial population showed a four-fold increase compared to the control. However, in the 5 % biochar treatment, the bacterial population exhibited a two-fold increase compared to the control, but this represented a 50 % reduction in bacteria population compared to the 2 % biochar treatment. This trend deviates from the results observed by Elzobair and Rassem (unpublished data, 2023) and Xiang *et al.,* (2023) who reported a steady and significant increase in the bacterial population with rising biochar rates. The decline in the bacterial population at higher biochar concentrations suggests that elevated levels of biochar may exert a detrimental effect on bacterial communities in the long term. Biochar can negatively affect bacterial populations through several mechanisms. Nutrient sequestration by biochar reduces nutrient availability for microbes (Lehmann *et al.,* 2011). The presence of potentially toxic substances formed during the pyrolysis process can adversely affect microbial communities (Palansooriya *et al.,* 2019). Additionally, biochar can alter soil pH, creating less favourable conditions for some bacteria (Yuan *et al.,* 2011), and its porous structure can disrupt microbial habitats, leading to reduced microbial activity (Warnock *et al.,* 2007).

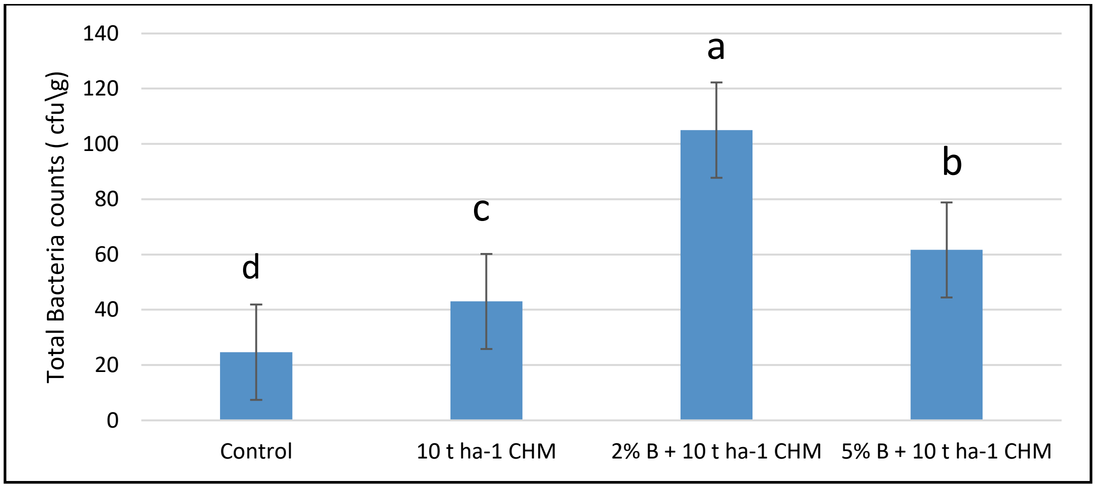

Figure 1. The effects of biochar on bacterial population

Effect of biochar on the yield parameters

The application of biochar and chicken manure had a significant impact on pod numbers, pod length, and seed number (Table 3). Compared to the control, treated plots with biochar and chicken manure exhibited higher pod numbers, longer pods, and increased total seed weight for pea plants. Specifically, there was a 64 % increase in yield with 5 % biochar plus 10 t/ha chicken manure and a 62 % increase with 2 % biochar plus 10 t/ha chicken manure. Seed numbers per pod increased by 42 % and 31 % compared to the control. The application of biochar enhanced the efficiency of chicken manure, with biochar-chicken manure treatments significantly varying from chicken manure alone across all yield parameters. These findings are supported by previous research. For example, Adekiya *et al.,* (2020) found that combining biochar with poultry manure improved soil properties and significantly increased ginger yield. Additionally, a study by Sayed *et al.,* (2024) demonstrated that biochar derived from poultry manure increased nutrient availability and promoted plant growth, leading to higher yields in black cumin plants. These studies suggest that the synergistic effects of biochar and chicken manure can enhance soil fertility and crop productivity, aligning with our results. The synergy between biochar's soil conditioning properties and the nutrient-rich composition of chicken manure likely contributed to these positive outcomes.

Table 3. Effect of biochar and chicken manure on yield parameters

Treatment	Number of pods /plants	Length of pods	Seed number/ Pods	Dry weight of 100 seeds (g)
Control	25.33^{c}	7.66^{c}	6.33^{c}	30.02
10 t ha^{-1} CHM	34.00^{b}	9.33^{b}	7.66^{b}	32.69
2 % B + 10 t ha^{-1} CHM	39.00^{a}	9.66^{ab}	8.33^{ab}	31.76
5 % B + 10 t ha^{-1} CHM	41.66^{a}	10.66^{a}	9.00^{a}	35.25
F-test	S	S	S	NS
CV %	5.196	6.188	4.755	5.875
CD (P = 0.05)	3.635	1.155	0.745	N

Table 4 illustrates the effects of different treatments on seed and straw yield. The results indicate a significant increase in seed yield with the application of biochar. Specifically, seed yield increased by 70 % with 5 % biochar plus 10 t/ha chicken manure, and by 48 % with 2 % biochar plus 10 t/ha chicken manure. In comparison, the increment was 28 % with chicken manure alone, highlighting the enhanced effect of biochar when combined with organic manure. A similar trend was observed in straw yield, where the combined treatments with biochar and chicken manure surpassed the results of chicken manure alone. The 5 % biochar plus 10 t/ha chicken manure treatment not only improved seed yield but also significantly boosted straw yield, demonstrating the comprehensive benefits of this combination. These findings align with those of Adekiya *et al,* (2020), who reported improved soil properties and increased ginger yield with biochar and poultry manure. Similarly, Sayed *et al.,* (2024) found that biochar derived from poultry manure increased nutrient availability and crop yields, further supporting our results. Additionally, Cai *et al.,* (2022) discovered that biochar mixed with poultry manure had synergistic effects on soil aggregate stability and micropore volume, leading to an enhanced crop yield by 71.1 %.

Table 4. Effect of biochar and chicken manure on yield attribute

Treatment	Weight of pods t\h	Straw yield t/h	Biological yield	Harvest index
Control	0.924^{d}	7.462^{d}	8.384^{d}	11.02
10 t ha^{-1} CHM	1.184^{c}	8.904^{c}	10.097^{c}	11.76
2 % B + 10 t ha^{-1} CHM	1.368^{b}	9.855^{b}	11.224^{b}	12.19
5 % B + 10 t ha^{-1} CHM	1.572^{a}	13.381^{a}	14.953^{a}	10.50
F-test	S	S	S	NS
CV %	4.909	1.918	1.536	5.562
CD (P = 0.05)	0.126	0.372	0.344	N

CONCLUSION

In conclusion, the combined application of biochar and chicken manure significantly improved pea growth and yield compared to the control. The treatment with 5 % biochar plus 10 t/ha chicken manure demonstrated the most effective enhancement of growth and yield parameters. The substantial improvement in yield observed in this study underscores the potential of biochar as a valuable amendment in organic farming systems, especially in challenging soil conditions such as sandy soils. Future research should further investigate the optimal application rates and combinations of biochar with various organic fertilizers to maximize agricultural benefits.

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