Ministry of Education
General Directorate of Education
in the Governorate of North Al Batinah
Al-Wafaa Basic Education School

A Research Study Entitled

Soil Rehabilitation Using Biochar from Nut Waste

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Index

Abstract

Since the discovery of biochar in the 1980s by soil scientists in the Amazon, research has increasingly focused on its role in improving soil quality and rehabilitating degraded soils. Biochar has emerged as a sustainable and effective option for enhancing soil health, increasing agricultural productivity, improving water quality, and reducing carbon emissions. Based on this background, the idea of our research study arose to produce biochar from nut waste and to investigate its effect on soil improvement and plant growth.

The main objective of this research is to study the effect of biochar produced from nut waste on improving soil properties and plant growth. Several sub-objectives fall under this main goal, including:

- Recycling nut waste to produce biochar.
- Promoting sustainable soil and water management in the Sultanate of Oman.
- Rehabilitating soil using biochar derived from nut waste.
- Providing a greener and more sustainable future.
- Reducing the use of chemical fertilizers and replacing them with biochar.
- Reducing carbon emissions.
- Contributing to increased plant growth to achieve good food security.
- Increasing agricultural productivity effectively.

Based on these objectives, the research questions were formulated. The main research question is:

- How can biochar produced from nut waste contribute to soil rehabilitation?

This main question is further divided into the following sub-questions:

- How does biochar contribute to healthy plant growth?
- How does biochar improve soil properties?

To answer these questions, an experimental approach was applied. The experiment was conducted on six (6) eggplant seedlings. Biochar derived from nut waste was added to the soil of one sample containing three eggplant seedlings, while the other sample, which also contained three seedlings, did not receive biochar and was irrigated with water only. Standard protocols related to water, air, and soil were applied, and plant growth was monitored. Soil and water samples were analyzed in the soil and water laboratories at Sultan Qaboos University to ensure the validity of the conclusions.

The results showed that the soil amended with nut-waste biochar was more fertile than the soil irrigated with water only. This was evident from plant growth observations, as the plants treated with biochar exhibited increased height, a greater number of leaves and roots, and a larger leaf surface area. Laboratory analyses at the university confirmed these findings through nutrient content analysis. In addition, the biochar-amended soil retained water for a longer period and showed greater structural stability compared to soil containing water only, which was confirmed by moisture tests conducted at Sultan Qaboos University. Furthermore, the carbon content in the biochar-treated soil increased, as indicated by measurements of the carbon rate.

Based on these findings, several recommendations were proposed, including:

- Rehabilitating agricultural soils by adding biochar to improve growth conditions and productivity.
- Using nut-waste biochar to improve soil structure and enhance water-holding capacity.

Keywords:

Biochar:
A carbon-rich product obtained through the pyrolysis of biomass under oxygen-limited or oxygen-free conditions at high temperatures (Haider, 2022).

Soil Fertility:
The ability of soil to supply plants with essential or necessary nutrients in balanced quantities that meet plant requirements (Al-Ani, 1980).

Soil:
The thin, fragmented layer that covers the Earth’s surface (Mawloud, 2021).

Macronutrients:
Nutrients that plants require in relatively large quantities (Salloum, 2020).

Research Questions

Main Research Question:

- How does biochar derived from nut waste affect soil and plants?

Sub-questions:

- How did biochar contribute to healthy plant growth?
- Does biochar affect soil fertility?

Work Plan

Students	Time Period	Task
Aya	October	Formulating the problem and identifying tools
&	October	Data collection and analysis
Shatha	March	Drawing conclusions, writing the report, and presenting it

Research Method:
The experimental method was used in this study.

Research Tools:
Experimentation, observation, interviews, and the application of water, air, and soil protocols from the GLOBE Program.

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Introduction and Literature Review

Ensuring food security for the rapidly growing global population is one of the most significant challenges facing humanity in the near future. It is expected that the world's population will exceed 9 billion by 2050, which will substantially increase the demand for food. This situation necessitates exploring new approaches to meet diverse food requirements, particularly in light of the decreasing availability of arable land. Consequently, it has become essential to develop innovative methods that enhance the efficiency of agricultural land use for food production by improving soil fertility indicators, such as organic matter, which plays a crucial role in the physical and chemical properties of soil and its fertility. A decline in soil organic matter poses a major threat to soil fertility and crop productivity (Shaheen, 2023).

For Omanis, the importance of natural resources and their conservation has long been recognized, as these resources form the foundation of life and sustainability in the country. Among the most vital natural resources are soil and water, which constitute two essential pillars of life in Oman. Agricultural soils in the Sultanate are generally sandy-loamy, highly permeable, poor in nutrients and organic matter, and have a low capacity for water retention. One promising solution to these challenges is the use of biochar, which offers significant potential for improving soil fertility—defined as the soil's ability to supply plants with essential nutrients in balanced amounts that meet their needs (Al-Ani, 1980)—as well as increasing productivity and enhancing soil water and nutrient retention.

The use of biochar has gained global importance, with increasing interest worldwide, and it is often produced from organic waste materials. Accordingly, this research study aims to achieve soil sustainability, productivity enhancement, and soil rehabilitation through recycling nut waste to produce biochar that can be utilized in agricultural applications. The study examines the impact of this biochar on soil and plant performance by monitoring the growth of eggplant plants and applying soil protocols to assess its effectiveness in addressing soil-related problems such as soil fertility, soil structure, and plant chlorosis. Based on the excellent results obtained from this experiment, we hope that this research represents an innovative approach to addressing challenges related to soil and water management and agricultural productivity in the Sultanate of Oman and globally.

Research Methods

Materials Used

Safety equipment	GPS device	Water protocol tools	Nut waste	Vinegar	Eggplant seedlings	Biochar production furnace	pH meter	Measuring cups and graduated cylinders	Temperature measuring devices	**Materials Used**

Location of the Study

Sultanate of Oman	North Al Batinah Governorate	Wilayat of Al–Suwaiq,	Al–Wafaa School

Data Collection

-1Collecting nut waste and producing biochar using a specialized furnace

Image of the furnace and nut waste during the first stage of combustion.

Biochar after complete pyrolysis and grinding

معلومات الموقع

معرف الموقع	309748
اسم	مدرسة الوفاء
خط العرض	23.825179°
خط الطول	57.415459°
ارتفاع	12.2 م
مصدر الموقع	نظام تحديد المواقع

Site Information

* **Site ID:** 309748
* **Name:** Al-Wafa School
* **Latitude:** 23.825179°
* **Longitude:** 57.415459°
* **Elevation:** 12.2 m
* **Location Source:** GPS System

2- Purchasing young eggplant seedlings from the nursery

3- Applying the atmospheric protocol at the experiment site and entering data into the program.

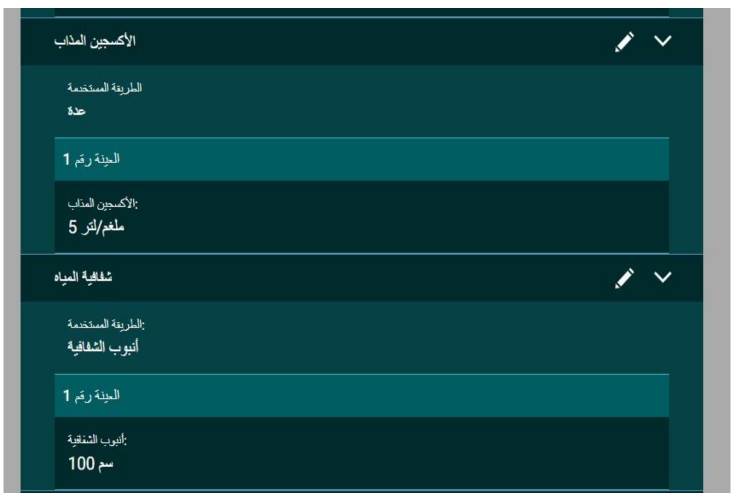
Images of data entry on the program site

Air Temperature (°C) min	Air Temperature (°C) max	Soil Moisture min	SoilMoisture max	
31.1	31.5	%23	%32	1
31.1	32.2	%24	%30	2
33.7	31.8	%25	%31	3
32.1	31.83	%24	%31	Average

4- The first sample, containing three eggplant seedlings, was irrigated with water only, without adding biochar to the soil. The water protocol was applied, data were entered into the program, and plant growth was monitored by measuring lengths daily.

Salinity (mS/cm	Electrical Conductivity (EC)mS/cm)	pH	Densityg/cm³	Dissolved Oxygen (mg/L)	Water Transparency (cm)	Air Temperature (°C	Property Measurements
359	1398	7.26	991	6	100	24	1
357	1400	7.29	999	6	100	25	2
358	1398	7.23	997	5	100	24	3
358	1398	7.26	995	5	100	24.3	Average

Table 2: Water Protocol Measurements with Images of Data Entry



5- The second sample contained three eggplant seedlings. Biochar made from nut waste was added to the soil, and the plants were irrigated with the same quantity and type of water as the first sample. Plant growth was monitored for one week, and measurements were recorded in a table.

6- Applying the soil protocol to both soil samples—one with biochar and one without—and recording the results.

Soil Type	**Temperature (°C)**	**pH**	**Turbidity**	**Adhesion**	**Surface Temperature (°C)**	**Color**	**Root Quantity**	
clay	22	6.4	**Low Root Quantity**	**Not Adhesive**	**20.3**	7.5**YR2.5/2**	**Moderate Quantity**	**1**

Table 3: Results of the Soil Protocol for Samples Irrigated with Water Only

Soil Type	Temperature (°C)	pH	Turbidity	Adhesion	Surface Temperature (°C	Color	Root Quantity	
clay	22	6.8	**Moderate Turbidity**	**Adhesive**	**22.6**	7.5**YR2.5/1**	**High Root Quantity**	**1**

Table 4: Results of the Soil Protocol for Samples with Added Biochar

-7 Results of Stem Length and Firmness, Number of Leaves, Leaf Surface Area, and Leaf Color in Both Cases



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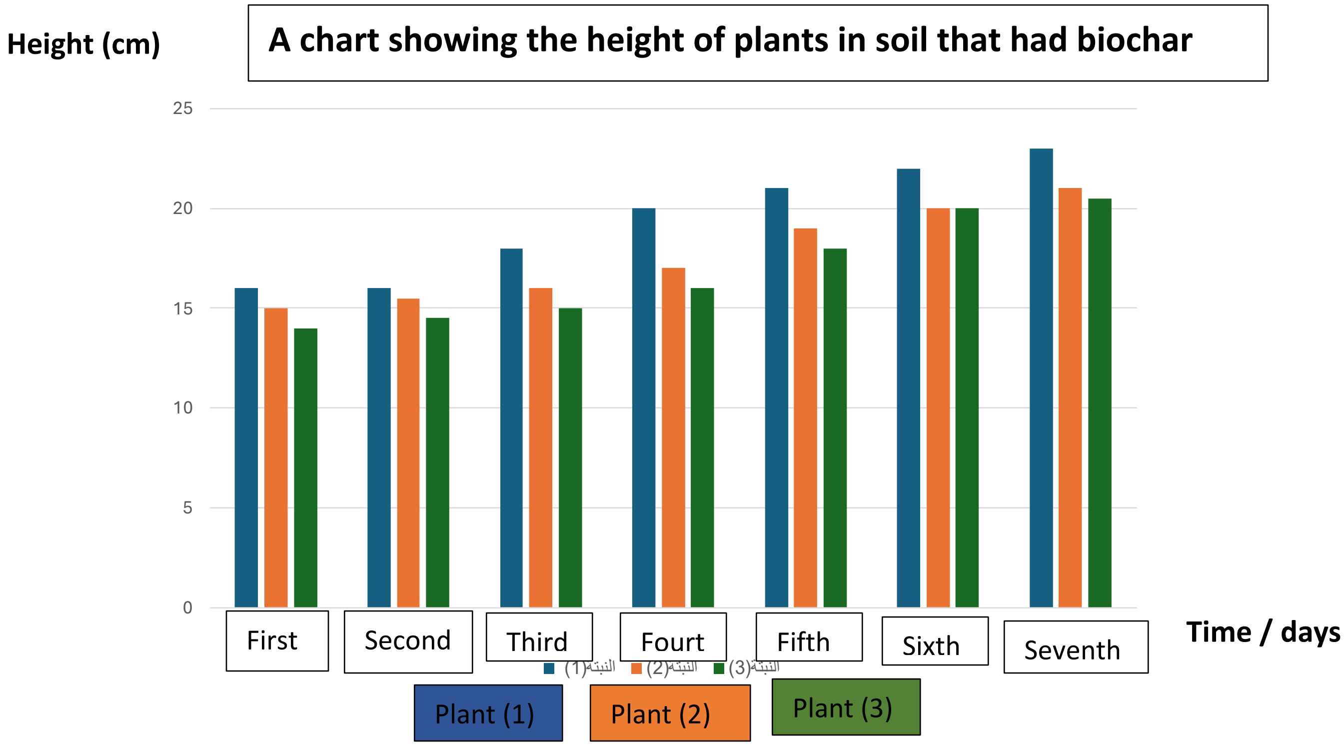
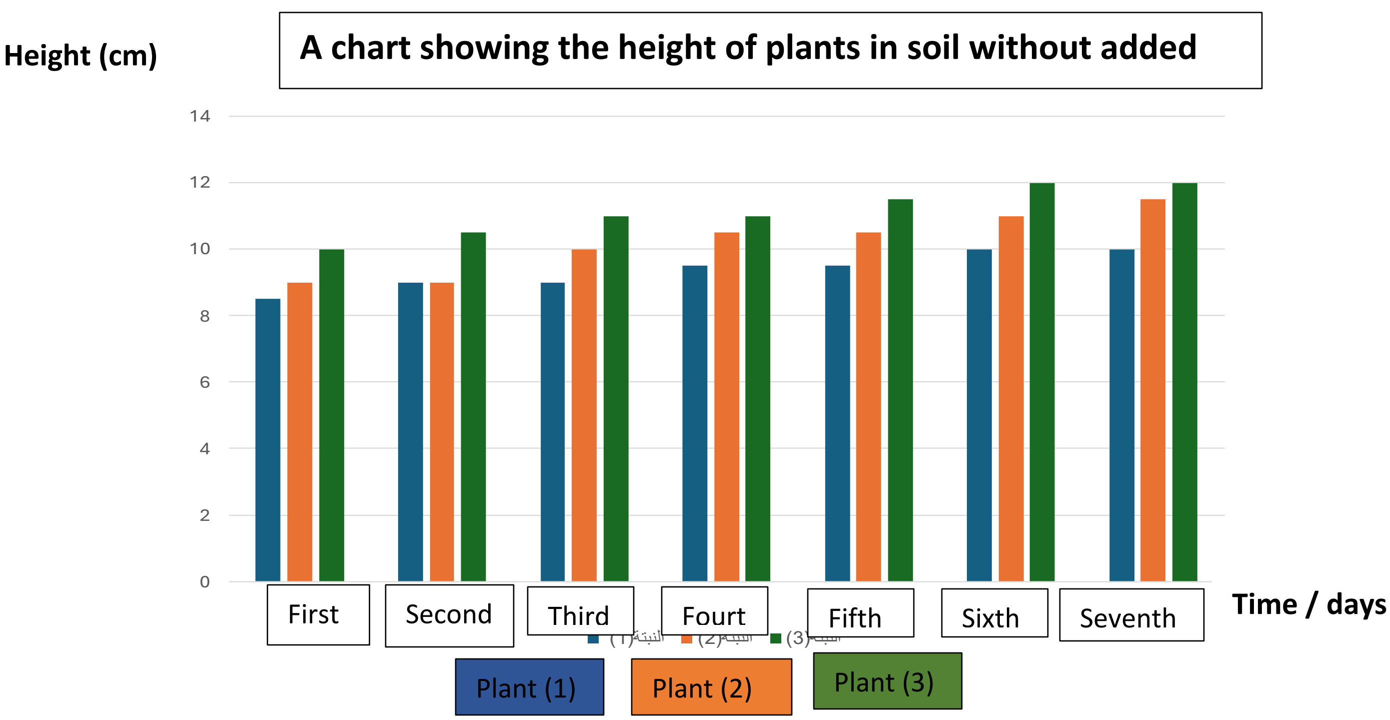
observations from the results indicate that plants grown in biochar-amended soil exhibited greater height, higher leaf count, and stronger, firmer stems compared to plants irrigated with water alone. Furthermore, leaf color and surface area measurements revealed that the biochar-treated plants had greener leaves with increased leaf surface area.

Days	Lengths of Plants Grown in Soil Without Biochar (cm)			Lengths of Plants Grown in Soil Amended with Biochar (cm)		
	(1) Plant	(2) Plant	(3) Plant	(1) Plant	(2) Plant	(3) Plant
First	8.5	9	10	16	15	14
Second	9	9	10.5	16	15.5	14.5
Third	9	10	11	18	16	15
Fourt	9.5	10.5	11	20	17	16
Fifth	9.5	10.5	11.5	21	19	18
Sixth	10	11	12	22	20	20
Seventh	10	11.5	12	23	21	20.5
Average	9.357143	10.21429	11.14286	19.428571	17.642857	16.857143

Table 5: Plant Length Measurements during the First Week of the Experiment


Height (cm)
A chart showing the height of plants in soil that had biochar
25
20
15
10
5
0
First
Second
Third
Fourt
Fifth
Sixth
Seventh
Time / days
Plant (1)
Plant (2)
Plant (3)


Height (cm)
A chart showing the height of plants in soil without added
14
12
10
8
6
4
2
0
First
Second
Third
Fourt
Fifth
Sixth
Seventh
Time / days
Plant (1)
Plant (2)
Plant (3)

Days	Number of Leaves for Plants in Soil Without Biochar			Number of Leaves for Plants in Biochar–Amended Soil		
	Plant (1)	Plant(2)	Plant(3)	Plant(1)	Plant(2)	Plant(3)
First	2	3	4	1	2	3
Second	3	3	4	2	3	4
Third	3	4	4	3	4	5
Fourth	4	4	5	3	5	6
Fifth	4	4	5	4	5	6
Sixth	4	5	5	4	6	7
Seventh	4	5	5	5	6	8
Average	3.428571	4	4.666667	3.1428	4.4285	5.5714

Number of Leaves of the Plants in the First Week of the Experiment

Chart showing the number of plant leaves in soil with biochar"

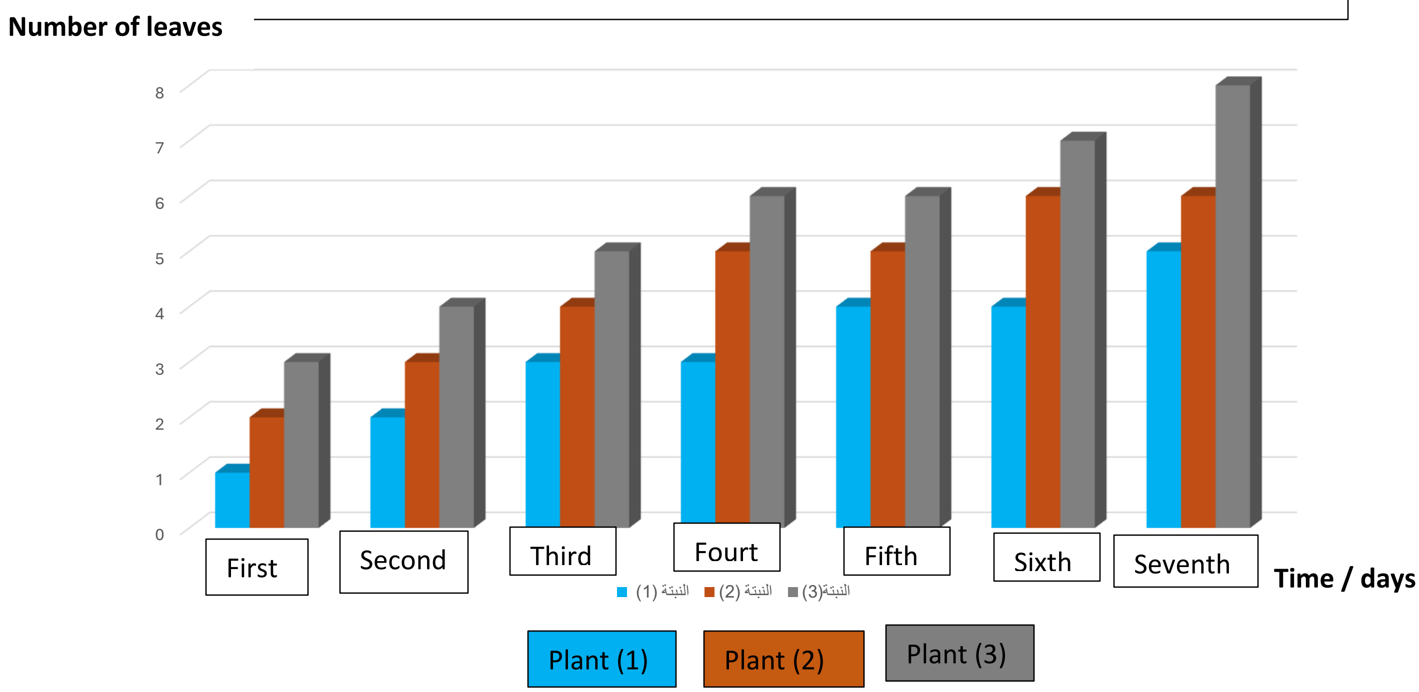
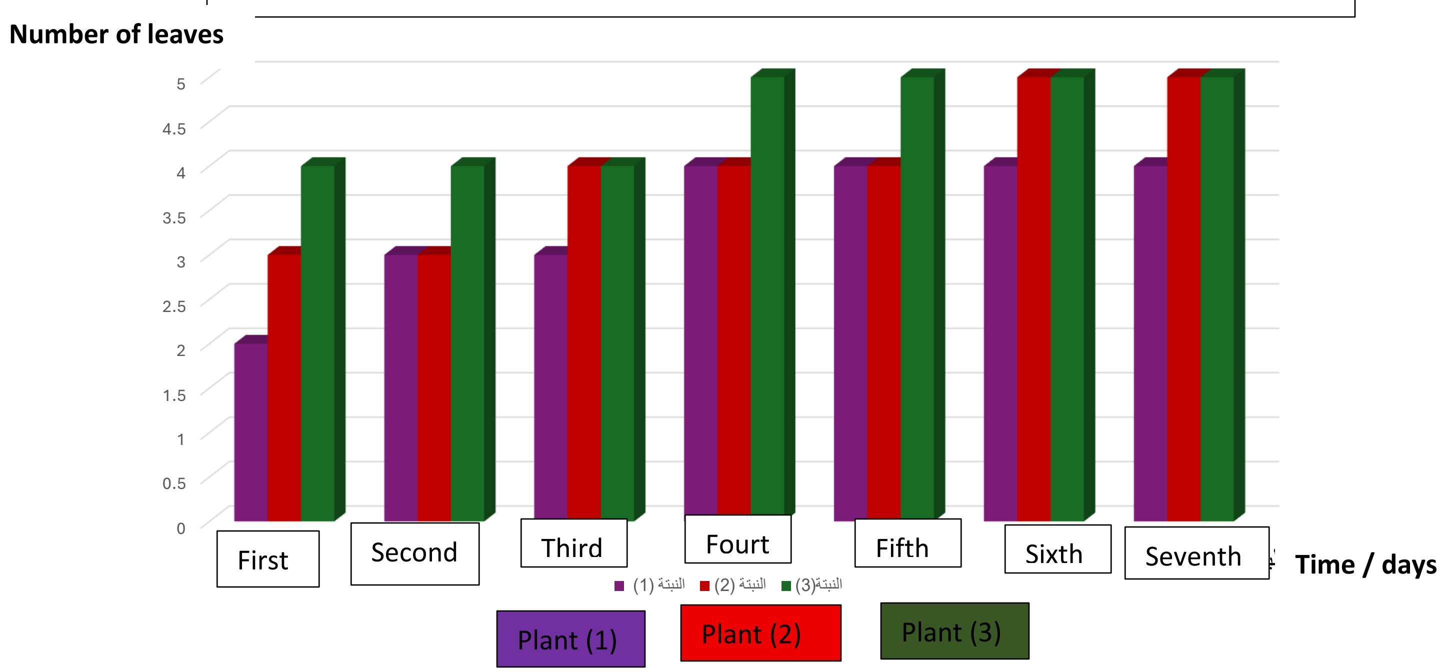


Chart showing the number of plant leaves in soil Without biochar"



8. To ensure the validity of the results, two soil samples were analyzed in the Soil and Water Laboratories affiliated with the College of Agriculture.

Sample-A — **Soil amended with biochar**

Elements	Results in mg/kg
K	1550
Ca	25300
Ba	21.4
Sr	13
Cr	16
Mn	51.8
Fe	3490
Ni	111
Cu	22.5
Zn	12.4
P	668
S	6180
Al	5160
Ti	96.2
Zr	2.33
Mo	2.27
Si	12700

Sample-B — **Soil without biochar**

Elements	Results in mg/kg
K	976
Ca	18500
Ba	20.6
Sr	6.9
Cr	14.7
Mn	40.4
Fe	2470
Ni	95.4
Cu	19.9
Zn	10.4
P	423
S	3870
Al	3440
Ti	ND
Zr	3.31
Mo	5.21
Si	7620

Sample id	Moisture Content %
A	71.5
B	37.8

Sample id	EC in mS/cm	pH
A	2.41	6.8
B	2.08	6.5

Based on the above results, it is evident that the sample amended with biochar is richer in essential macronutrients important for plant growth, such as potassium, phosphorus, calcium, and sulfur, and exhibits a higher moisture content compared to the other sample. These findings confirm the effectiveness of biochar and validate the results of our experiment

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Second: Experimental Results

After several days of observation and continuous monitoring of plant growth, and after recording the measurements in the tables presented above, a number of conclusions were drawn:

- An increase in plant height accompanied by greater stem strength and rigidity in the biochar-treated sample.
- An increase in the number of leaves, along with a larger leaf surface area, improved leaf firmness, and enhanced greenness.
- An increase in the number of roots in plants grown in soil amended with biochar.

The interpretation of all the aforementioned observations in the biochar-treated sample indicates improved soil fertility and enhanced availability of water and essential nutrients to the plants. This improvement can be attributed to the role of biochar in supplying readily absorbable nutrients within the soil. This was confirmed by Ahmed Al-Rubaie, who explained that biochar functions as a nutrient reservoir by retaining essential nutrients and releasing them slowly over time. In addition, biochar enhances microbial activity, creates a favorable environment for beneficial microorganisms, improves soil health, and promotes plant growth. Moreover, biochar remains in the soil for decades, continuously contributing to soil quality improvement .

These findings are further supported by a study entitled *"The Effect of Biochar on Some Chemical Properties and Soil Fertility"*, which concluded that the application of biochar at a rate of 10 t/ha outperformed the application of cattle manure at a rate of 30 t/ha in terms of increasing the availability of phosphorus and potassium in the soil (Shaheen, 2023). It is well known that phosphorus and potassium are major macronutrients required by plants in relatively large quantities (Saloum, 2020). Phosphorus is considered a primary nutrient that plays a crucial role in plant growth and development, as it directly supports root development by promoting the formation of strong and deep root systems. This, in turn, enhances the plant's ability to absorb water and nutrients efficiently. Deficiency of phosphorus and potassium leads to stunted plant growth, weak stems, and increased susceptibility to lodging.

2. Soil Properties after Applying the Soil Protocol to Biochar-Amended Samples

Following the application of the soil protocol to samples treated with biochar, the following results were obtained:

- The soil exhibited improved moisture retention and became more cohesive, indicating its potential to mitigate issues related to high permeability and excessive water leaching commonly observed in agricultural soils of the Sultanate, which are typically sandy–loamy with high permeability. The increased surface area and porosity of biochar particles added to the soil contribute to enhancing its water-holding capacity (Haider, 2022). Consequently, water management in such soils can be improved. This was also confirmed by Ahmed Al-Rubaie, who stated that one of the well-known benefits of biochar is its ability to absorb and retain water, thereby reducing irrigation requirements (Appendix 1).

- The soil became slightly more effervescent, which indicates a reaction between acids, carbon, and various mineral elements present in the soil. This behavior is attributed to the ability of biochar to increase carbon storage in the soil, making it an important soil amendment. This finding aligns with the study entitled *"The Effect of Adding Different Levels of Biochar on the Physical Properties of Soil"*, which demonstrated that biochar plays a significant role in carbon sequestration and stabilization in soil, as well as in improving soil physical properties (Haider, 2022).
- An increase in soil pH was observed. This can be explained by the alkaline nature of biochar, which, when added to the soil, slightly increased the pH value.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

- Rehabilitating agricultural soils through the application of biochar.
- Implementing integrated management of water, soil, and crops to achieve maximum productivity with minimal environmental impact.
- Reducing the use of chemical fertilizers and replacing them with biochar as a sustainable alternative.
- Recommending the addition of biochar to soil to improve growth conditions and enhance crop productivity.
- Utilizing biochar derived from nut waste to improve soil structure and increase its water-holding capacity.
- Expanding research on the effects of biochar produced from other types of organic waste on soil–plant systems.

Challenges

1. Producing biochar from nut waste using a specialized furnace.
2. Identifying laboratories capable of conducting soil analyses to validate the conclusions reached.

Conclusion

The results of this study were obtained through an experimental scientific approach using biochar produced from nut waste. The study identified key issues related to plant growth and soil properties. It was found that agricultural soils in the Sultanate are predominantly sandy–loamy with high permeability, resulting in poor water retention and contributing to excessive water depletion. In addition, areas such as Wilayat Al-Suwaiq and the Al-Batinah coast suffer from soil salinization due to low rainfall, as well as deficiencies in essential nutrients. These factors have led to reduced agricultural productivity and the abandonment of many farms by local farmers.

Following the implementation of soil protocols, continuous monitoring of plant growth, systematic recording of observations, soil analysis, interviews with experts and specialists, and consultation of scientific references, several important conclusions were reached. Among the most significant is that effective soil and water management is crucial for achieving sustainable agricultural development and ensuring food security. Furthermore, replacing chemical fertilizers with biochar derived from nut waste contributes to reducing environmental pollution while effectively addressing soil-related problems such as low fertility and high permeability. This, in turn, reduces water loss through leaching to groundwater and improves plant water uptake, ultimately leading to increased crop productivity.

In summary, **biochar produced from nut waste represents a vital tool for sustainable agriculture and environmental protection**. Future work will focus on applying this approach to other types of organic waste, testing it on different soil types and crop species, and extending the experimental period to assess long-term effects.

Acknowledgements

We extend our sincere thanks and appreciation to the father of the GLOBE team member, Rahaf Al-Maimani, for his assistance in constructing a specialized furnace for biochar production. We also express our gratitude to Mr. Hamad Al-Busaidi from the College of Agriculture at Sultan Qaboos University for his cooperation in analyzing soil samples at the Soil and Water Laboratories. Our special thanks are extended to Dr. Ahmed Al-Rubaie, an expert and consultant at Neutrality Solutions Company in the field of biochar, for his valuable contributions in explaining and interpreting the results, as well as to the Technical Manager at Mawrid Environmental Solutions Company.

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