Sultanate of Oman
General Directorate of Education in Al Wusta Governorate
Haj School for Basic Education (Grades 5–12)

**A Study on the Effect of Bio-Crushing of Green Mussels on Plant Growth,

Enhancing Soil Fertility, and Reducing Soil Salinity in the Haj Area, Wilayat Mahout**

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1.Abstract

Modern agricultural practices face increasing environmental challenges, most notably the excessive reliance on inorganic chemical fertilizers, which leads to soil fertility degradation and a long-term rise in soil salinity levels. In an attempt to mitigate these effects, farmers often resort to traditional organic fertilizers such as animal manure; however, this alternative is not without negative environmental impacts, particularly the emission of greenhouse gases such as methane and carbon dioxide.

In this context, the Sultanate of Oman possesses a rich marine biodiversity that includes various types of marine shells and mollusks, among them the green mussel. These resources are often limited to ornamental and decorative uses, while their underlying biochemical potential and possible applications in sustainable agriculture remain largely overlooked.

This study aimed to investigate the effect of using marine shell powder (green mussel shells) as a bio-organic alternative to improve plant growth, enhance soil fertility, and reduce soil salinity. The effectiveness of this alternative was evaluated through comparison with three types of fertilizers: inorganic chemical fertilizers, organic fertilizer derived from cattle manure, and a marine-based organic product extracted from shells and mollusks.

The study relied on the collection and analysis of data related to germination rates, growth performance, plant health, and the impact of each fertilizer type on soil properties. The results indicated that chemical fertilizers, despite their rapid effectiveness in promoting germination, contribute to soil depletion and increased salinity when misused. Although animal-based organic fertilizers improved the physical properties of the soil, they were associated with environmentally harmful gaseous emissions.

In contrast, the organic product derived from green mussel shells demonstrated promising results, including enrichment of the soil with calcium and essential minerals, replacement of sodium ions with calcium—thereby contributing to salinity reduction—improved root stabilization and fruit set, as well as reduced negative environmental impacts and sustainable utilization of marine resources.

The study concluded that the use of marine shells represents an effective and sustainable agricultural option for addressing soil salinity issues and enhancing plant productivity, while promoting the utilization of local marine resources in the Sultanate of Oman. Furthermore, an innovative formulation was developed by combining marine shell powder with decomposed leaf residues, which yielded notable improvements in reducing soil salinity and enhancing the growth of fruit-bearing plants. These findings highlight the potential for practical application of this approach within sustainable agricultural systems.

2.Introduction

Soil is a fundamental component of the agricultural system, as the sustainability and quality of plant production largely depend on it. However, the extensive use of inorganic chemical fertilizers over recent decades has led to multiple environmental and agricultural challenges, most notably soil fertility degradation and increased soil salinity levels. These issues negatively affect plant growth and productivity and pose a long-term threat to the sustainability of agricultural resources.

In an effort to mitigate these impacts, agricultural practices have increasingly turned to traditional organic fertilizers, such as animal manure, due to their role in improving soil physical structure and increasing organic matter content. Nevertheless, this option presents its own environmental concerns, particularly the emission of greenhouse gases resulting from the decomposition of animal waste, which necessitates the search for safer and more sustainable organic alternatives.

On the other hand, the Sultanate of Oman is characterized by rich environmental and marine biodiversity, encompassing natural resources that remain underutilized, including marine shells and mollusks such as the green mussel. Despite their abundance, these resources are largely confined to ornamental and decorative uses, without fully exploiting their biochemical value, which is rich in calcium and minerals that can be utilized to improve agricultural soil properties.

In response to the need for innovative and sustainable agricultural solutions, this study aims to highlight the potential use of bio-crushed green mussel shells as an alternative organic fertilizer that contributes to improving plant growth, enhancing soil fertility, and reducing soil salinity, particularly in salt-affected areas such as Haj in Wilayat Mahout.

This study seeks to present an applied model that promotes the concept of sustainable agriculture by integrating the utilization of local marine resources with the protection of the agricultural environment, in alignment with contemporary environmental approaches and the sustainable development goals of the Sultanate of Oman.

3.Research Questions

This study sought to address the following main research questions:

1. Does the use of marine shell and mollusk powder contribute to reducing soil salinity in agricultural soils?
2. To what extent can marine shells be considered an effective and distinctive alternative to inorganic chemical fertilizers in improving soil properties?
3. Is it possible to replace animal-based organic fertilizers, such as cattle manure, with an organic fertilizer derived from the marine environment without compromising plant growth efficiency?
4. What is the effect of using marine shell and mollusk powder on the growth of arugula (rocket) plants and other crops cultivated in Haj, Wilayat Mahout?

4.Literature Review

The Sultanate of Oman possesses a rich marine wealth and remarkable marine biodiversity, reflected in the abundance and diversity of marine shells and mollusks distributed along its coastlines. Among the commonly documented species in Omani waters are the green mussel, echinoderm shells, clam shells, and pearl oysters. Traditionally, these shells have been utilized in various fields such as ornamentation and decoration, construction activities, poultry feed supplements, and water purification. However, their application in agriculture—particularly as a means of soil treatment and improvement—remains limited and has not received sufficient research attention.

Recent scientific studies have highlighted the high biochemical value of marine shells and mollusks. Wang et al. (2018) reported that mussel shells contain very high levels of calcium carbonate, ranging between 95% and 98%, in addition to trace elements of agricultural significance such as magnesium, manganese, zinc, and iron. These elements play a crucial role in improving soil properties and supporting vital plant physiological processes.

In a complementary study, Hassan et al. (2019) found that marine shells also contain varying proportions of phosphorus and potassium, which are essential nutrients for promoting vegetative growth, enhancing flowering and fruit set, and ensuring overall plant health and productivity. This balanced chemical composition underscores the strong potential of marine shells as a promising source of sustainable organic fertilization.

Within the context of the growing global emphasis on sustainable agricultural practices, the use of marine shells and mollusks has emerged as an innovative solution capable of delivering

multiple environmental and agricultural benefits. These include reducing dependence on inorganic chemical fertilizers and the associated decline in soil fertility and increased salinity, lowering greenhouse gas emissions compared to traditional organic fertilizers such as animal manure, optimizing the utilization of local marine resources in the Sultanate of Oman, and enhancing the carbon cycle through the recycling of calcium carbonate present in marine shells.

The utilization of this renewable marine resource in organic soil treatment represents a practical model that supports the principles of the circular economy and environmental sustainability. Moreover, it contributes simultaneously to food security and environmental protection. Consequently, this field is expected to receive increasing attention in future agricultural research, particularly in environments affected by soil salinity and fertility degradation.

5.Research Methodology

This study adopted both the descriptive-analytical approach and the experimental method in order to examine the effect of using marine shell powder on soil properties and plant growth. The research was conducted according to the following steps:

1. **Collection of Theoretical Information:**

   Data and information related to the research topic were collected from multiple sources, including scientific books available at the Learning Resource Center, peer-reviewed scientific articles, and international online resources. This process aimed to establish a comprehensive scientific framework to support the study.

2. **Development of the Research Plan:**

   A clear research plan was developed, outlining the research problem, objectives, research questions, and methodology, ensuring an organized and systematic research process.

3. **Preparation of the Timeline:**

   A detailed timeline was designed to illustrate the stages of implementing the research plan and the distribution of tasks within the specified time frame, ensuring adherence to the research schedule and timely achievement of the study objectives.

4. **Preparation of Laboratory Samples:**

   Samples of marine shell powder (green mussel shells and marine mollusks) were collected and prepared following appropriate scientific procedures. The samples were then sent to Duqm Laboratories Center for the required chemical analyses and testing.

5. **Conducting Interviews:**

   Interviews were conducted with a number of specialists and stakeholders in the agricultural and environmental fields in order to benefit from their scientific and practical expertise and to support the field findings of the study.

6. **Identification of Soil Properties Under Study:**

   The essential physical and chemical properties of the soil were identified, including salinity level, pH value, and nutrient content, to assess the extent to which these properties were affected by the application of marine shell powder.

7. **Identification of Research Tools:**

   The tools and materials required to carry out the agricultural experiments were identified, including planting containers, measurement instruments, organic materials, and data recording sheets.

8. **Data Analysis and Graphical Representation:**

   The collected data were analyzed using appropriate statistical methods, and the results were presented in the form of tables and graphs to illustrate differences and effects among the various fertilizer types.

9. **Derivation of Results and Recommendations:**

   Based on the analysis results, the main conclusions of the study were drawn, and a set of scientific and practical recommendations was formulated to support the use of marine shells as a sustainable

6.Concepts and Terminology

Bio-crushing

Bio-crushing refers to a biological process that relies on the activity of microorganisms associated with marine shells and mollusks. Through the secretion of specialized enzymes and proteins, these microorganisms decompose organic and inorganic materials into simpler compounds that can be easily absorbed and utilized by the soil. This process contributes to improving the chemical properties of the soil and enhancing the availability of essential nutrients required for plant growth.

Marine Shells

Marine shells are the hard external structures of marine mollusks that serve to protect and support their bodies. Shells are primarily composed of calcium carbonate, in addition to varying amounts of minerals and trace elements. Marine shells are considered a natural, calcium-rich resource that can be utilized to improve agricultural soil properties and reduce soil salinity.

Humus

Humus is fully decomposed organic matter present in soil, resulting from the biological decomposition of dead plant and animal residues by microorganisms such as bacteria and fungi. Humus plays a fundamental role in improving soil fertility, increasing its capacity to retain water and nutrients, and enhancing its physical structure.

Green Mussel

The green mussel is a common species of marine mussel found in coastal environments, characterized by its green coloration and high content of calcium carbonate and minerals. In this study, green mussel shells were processed and converted into bio-powder to investigate their effect on reducing soil salinity and

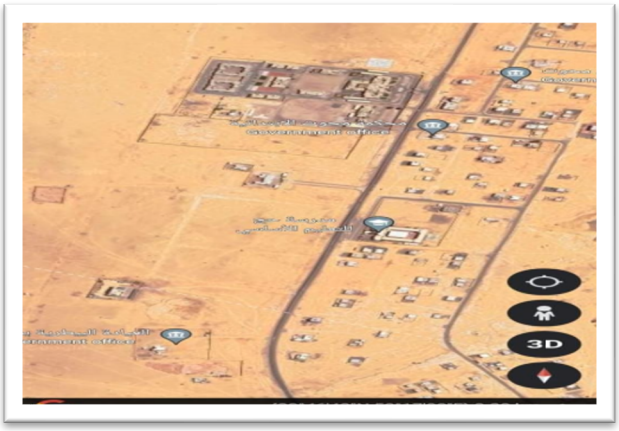
7.Research Implementation Timeline

The following table illustrates the chronological phases of implementing the research plan, the tasks completed at each stage, and the names of the participating students, under the supervision of Ms. Amani Al-Amri:

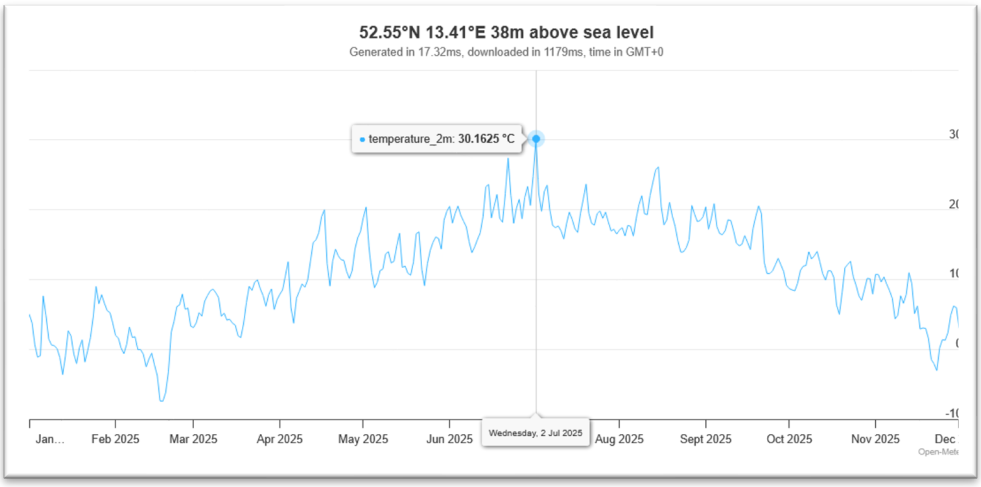
Student(s) / Participants	Date	Task
Maryam Al-Hakamani Thuraya Al-Ghafili	20–30 / 9 / 2024	Collection of information related to the research topic from various scientific sources
Thuraya Al-Ghafili	20 / 10 / 2024	Measurement of the properties of water used in the experiment
Maryam Al-Hakamani	25 / 11 / 2024	Identification of sources of marine mussels and shells used in the research
Maryam Al-Hakamani Thuraya Al-Ghafili Under the supervision of Ms. Amani Al-Amri	23–26 / 2 / 2025	Preparation of soil samples using different types of fertilizers and conducting preliminary soil investigations
Thuraya Al-Ghafili Maryam Al-Wuhaibi	22 / 3 / 2025	Conducting interviews with specialists in the agricultural and environmental fields
Mr. Saeed Al-Hashmi (Director of Mahout Municipality)	26–29 / 3 / 2025	Sending soil samples to the research center for laboratory analysis
Thuraya Al-Ghafili Maryam Al-Hakamani	3–5 / 4 / 2025	Observation of final results, data analysis, and preparation of the research report
In collaboration with Haj School students	1 / 8 / 2025 – 1 / 1 / 2026	Field implementation of the project and conducting investigations on other types of trees and plants

8.Study Area

This study was conducted in the Sultanate of Oman, specifically in Al Wusta Governorate – Wilayat Mahout – Haj area, during the period extending from October 2024 to the end of 2025. The selection of this study area is of particular significance due to its climatic and environmental characteristics, which provide a suitable setting for examining the impact of organic alternatives on improving soil properties and plant growth.



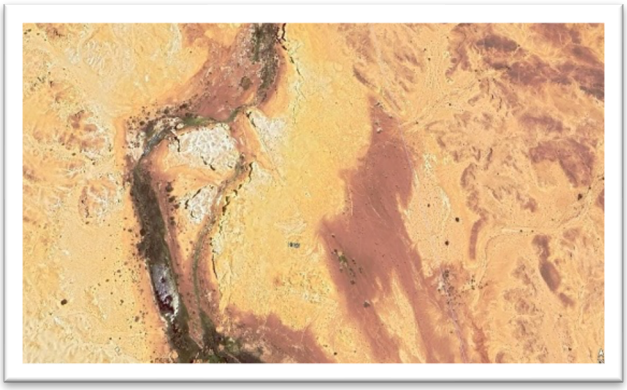
The Haj area is characterized by a relatively moderate climate, with temperatures during the study period ranging between **30 and 36°C**. The region experiences high humidity levels during the early morning and nighttime hours, ranging from **85% to 95%**, accompanied by noticeable fog formation. In contrast, humidity levels decrease during the afternoon and early evening periods, ranging between **28% and 34%**.



Based on the climatic monitoring data available through the GLOBE weather monitoring platform used at the school, a review of the climatic records from previous months revealed a noticeable increase in humidity levels, along with a gradual rise in temperatures. These climatic changes are considered direct influencing factors on soil properties, such as increased salinity and reduced fertility, which negatively affect plant growth and productivity.

Measured Date:	2025-12-17
Organization Name:	Hig School
Site ID:	330732
Site Name:	Alhij school in Mahout
Country Name:	Oman
Country Code:	OMN
Latitude:	20.62665
Longitude:	58.1951
Elevation:	8.1m
Measured At:	2025-12-17T03:53:00
Solar Measured At:	2025-12-17T07:49:00
Solar Noon At:	2025-12-17T08:03:00
Relative Humidity:	71 %
Dewpoint:	17.6 °C

Through the use of **Google Maps**, extensive desert areas were observed within the study region, along with limited utilization of lands located near water resources, despite the ability of certain wild plant species to adapt to harsh climatic conditions. This observation indicates the presence of significant potential for soil rehabilitation and treatment, enabling the cultivation of flowering and fruit-bearing plants rather than limiting vegetation to wild species alone.



Field observations and a review of content shared on social media platforms revealed the circulation of images documenting the flow of wadis in Wilayat Mahout during 2023, which was accompanied by the growth of natural vegetation in certain areas. However, this vegetation growth

remains temporary and limited unless soil treatment and salinity reduction measures are implemented to enable fruit-bearing and perennial plants to establish and thrive.

Accordingly, this study seeks to contribute to addressing the challenges of rising temperatures and the expansion of desert areas by enhancing vegetation cover and improving soil properties. Increasing vegetation cover helps reduce surface and ambient air temperatures through the processes of evapotranspiration and carbon sequestration, while also improving air quality and increasing the potential for rainfall. In addition, soil treatment enhances soil fertility and its capacity to retain water, thereby creating a more favorable environment for improved plant growth.

Therefore, the study aims to encourage local communities to adopt sustainable agricultural solutions based on soil improvement and increased vegetation cover. Such practices contribute to combating desertification, enhancing local food security, and achieving a sustainable environmental balance in the Haj area of Wilayat Mahout.

8. Data Collection and Analysis

To address the research questions, a scientific protocol was adopted to measure soil properties, water characteristics, and climatic conditions, with the aim of examining the effect of using a marine-based organic product extracted from shells and mollusks on soil properties and plant growth.

First: Water and Climatic Conditions Protocol

The physical and chemical properties of the irrigation water were measured, including:

- **pH level**
- **Salinity (ppm)**
- **Water transparency**
- **Dissolved oxygen content**
- **Water temperature**

In addition, **ambient air temperature and relative humidity** in the Haj area of Wilayat Mahout were recorded on a daily basis throughout the experimental period.

Average Properties of Irrigation Water

Property	Average Value
pH level	7.3
Salinity	140 ppm
Transparency	110
Dissolved oxygen	5
Temperature	25 °C

Collaboration with Relevant Authorities

The research team was keen to communicate and collaborate with relevant institutions in order to benefit from their scientific and practical expertise, as outlined below:

- Visiting **Mahout Municipality / Haj** and conducting an interview with **Mr. Saeed Al-Hashmi**, Director of Mahout Municipality, to discuss vegetation cover, the impact of desertification, and the potential use of marine resources in soil treatment.
- Visiting the **Department of Agricultural and Fisheries Wealth and Water Resources** and conducting an interview with **Mr. Saeed Al-Hakamani** to discuss agricultural soil characteristics in the region.
- Coordinating with the **Duqm Laboratories Center** to conduct laboratory analyses on soil samples.
- Communicating with **Wimpy Laboratories** to perform more precise analyses and benefit from their research expertise.
- Cooperating with the **Chamber of Commerce and Industry in Wilayat Duqm**.
- Coordinating with the **Small and Medium Enterprises Authority**, in collaboration with **Mr. Salem Al-Shahri**, to explore the feasibility of establishing a future student-led company based on the marine organic product.

Data and Sample Size

The number of samples subjected to investigation exceeded **32 samples**. The following procedures were carried out:

- Uniform soil samples were collected from the school courtyard.
- Soil properties were measured in accordance with the soil protocol.
- Properties of the irrigation water were measured.
- Ambient air temperature and relative humidity data were recorded daily.

First Experiment: School Courtyard Soil Samples

Average Soil Properties (First Experiment)

Property	Value
pH level	7.4
Salinity	1150 ppm
Soil type	Clayey soil with very low water permeability
Carbonate content	Low
Rock content	Moderate
Texture	Granular

Results of the First Experiment

No germination was observed in any of the pots. This outcome is attributed to:

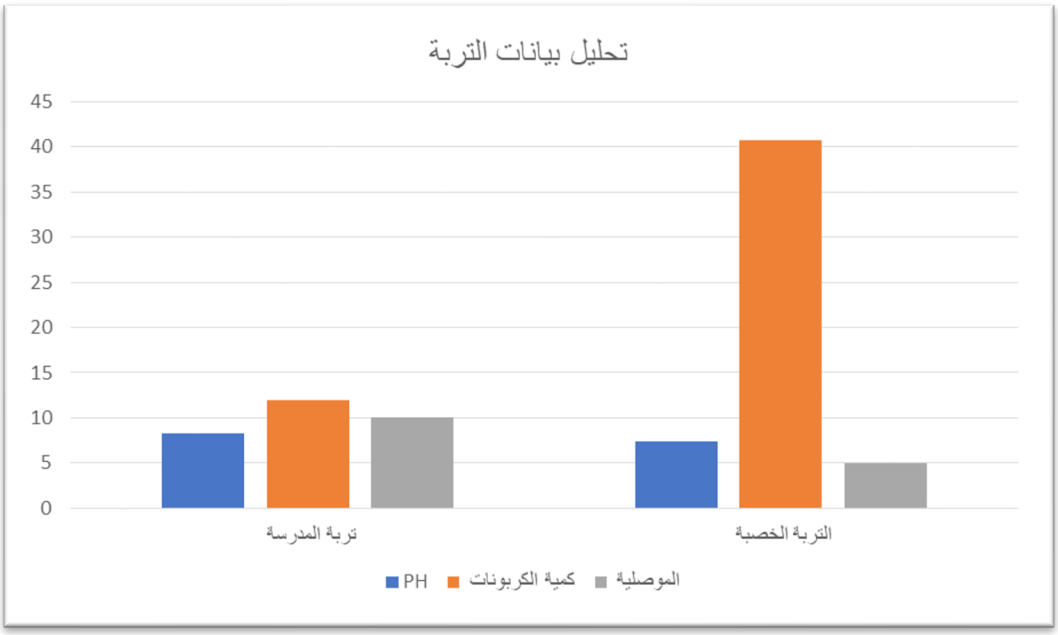
- The high salinity level of the soil.
- Poor water permeability resulting from the clayey nature of the soil.


Accordingly, the soil was replaced with another type containing decomposed grass residues (**humus**) characterized by **moderate water permeability** and **salinity levels suitable for cultivation**.

Second Experiment: Improved Soil (32 Pots)

Average Soil Properties (Second Experiment)

Property	Value
pH level	7.2
Salinity	700 ppm
Soil type	Fertile clay soil with moderate water permeability and good porosity
Carbonate content	High
Soil structure	Semi-cohesive
Rock particles	Very fine
Texture	Granular



Analysis of Arugula (Rocket) Plant Growth Results (After Two Months)

The effects of four different treatments on soil properties after cultivating arugula plants were compared, as presented in the following table:

Comparison of Soil Properties After Arugula Cultivation

Treatment	Average pH	Average Salinity	Soil Characteristics	Carbonate Content
No fertilizer	7.2	730 ppm	Light brown soil with moderate permeability	Moderate
Animal fertilizer	7.5	697 ppm	Light brown soil with increased permeability	High
Marine organic product	7.9	Before decomposition: 730 ppm After decomposition: 657 ppm	Light brown soil with moderate permeability	High
Chemical fertilizer	8.7	790 ppm	Light brown soil with moderate permeability	Low

Preliminary Discussion of Results

The results indicated that:

- **Chemical fertilizer** led to increased soil salinity and pH levels, which may negatively affect soil quality over the long term.
- **Animal-based fertilizer** contributed to improved soil permeability; however, it did not result in a significant reduction in soil salinity.
- **The marine-based organic product** achieved the most favorable results, demonstrating a noticeable reduction in soil salinity after decomposition, along with increased carbonate content. This combination enhances soil fertility and improves the root-zone environment.

10. Discussion of Results

The results of the study, conducted in collaboration with agricultural nurseries and involving more than 200 plant seedlings, revealed clear variations in the effects of different fertilizer types on seed germination, plant growth, and the physical and chemical properties of the soil. The findings are discussed below according to the type of fertilizer used:

First: Pots Treated with Inorganic Fertilizers

Inorganic fertilizers demonstrated a high capacity to achieve rapid and successful seed germination during the early growth stages. However, subsequent observations revealed negative effects on soil properties, particularly when these fertilizers were used excessively or without proper calibration. These effects included:

- Depletion of essential nutrients from the soil over the long term.
- Increased soil salinity, especially when application rates were not adjusted according to soil characteristics.

These findings highlight the importance of conducting prior soil analysis and determining appropriate fertilizer application rates to minimize negative impacts and ensure the sustainability of agricultural soils.

Second: Pots Treated with Cattle Manure Fertilizer

Cattle manure fertilizer exhibited notable effectiveness in supporting plant growth and improving soil properties. Observations indicated:

- Improved soil structure due to increased porosity.
- Enhanced soil water retention capacity, providing a favorable environment for root development.

However, this type of fertilizer is associated with the emission of greenhouse gases, such as methane and carbon dioxide, during the decomposition process. This represents a negative environmental impact that must be considered when evaluating its overall environmental sustainability.

Third: Pots Treated with the Marine-Based Organic Product Derived from Shells and Mollusks

The marine-based organic product demonstrated superior performance without exhibiting the negative effects associated with other fertilizer types. The key outcomes included:

1. An increase in soil organic content due to the high carbonate content, which raised soil pH levels and stimulated the activity of microorganisms responsible for organic matter decomposition.
2. Enrichment of the soil with essential minerals such as calcium, magnesium, phosphorus, and zinc, along with the replacement of harmful sodium ions with calcium, thereby contributing to reduced soil salinity.
3. Improved root growth and enhanced fruit set.
4. Improved soil structure and increased water-holding capacity.
5. Gradual and sustainable release of nutrients for plant uptake.

To achieve a fully integrated organic product, humus was added to the marine shell powder. This addition increased microbial populations in the soil and accelerated the biodecomposition of shells, further enhancing the effectiveness of the marine-based organic fertilizer.

Comparison of Germination Results

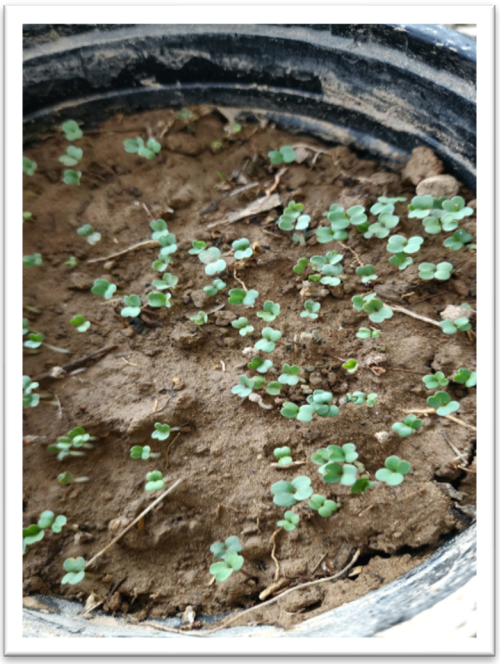
The germination results demonstrated a clear ranking in growth efficiency as follows:

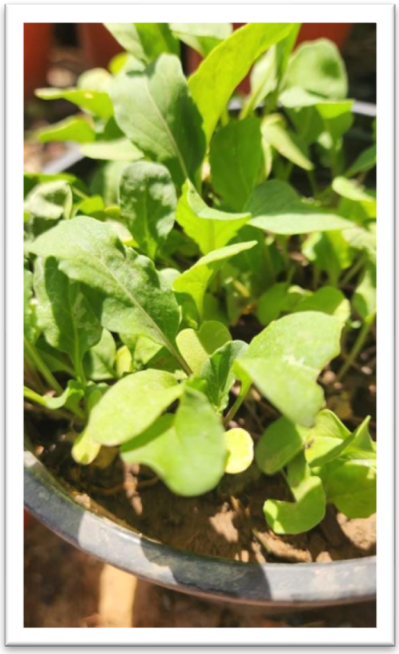
1. Pots treated with cattle manure fertilizer ranked first in terms of growth rate.
2. This was followed by pots treated with the marine-based organic product derived from shells.
3. Pots treated with inorganic fertilizers ranked last.



Although cattle manure fertilizer exhibited faster growth during the early stages, the marine-based organic product was distinguished by the sustainability of its effects and its long-term improvement of soil properties, while simultaneously reducing negative environmental impacts.

Humus sample combined with the marine-based product:





Comparison of Soil and Plant Conditions Before and After the Application of the Marine-Based Organic Product

Before the application of the organic product in the school courtyard and its expansion to other fruit-bearing and flowering plants:

After the application of the marine-based organic product extracted from shells:



Field observations revealed clear differences in soil and plant conditions before and after the application of the organic product derived from marine shells. A noticeable improvement in soil fertility was observed, along with a reduction in soil salinity and an increase in vegetation density and growth activity, both within the school courtyard and following the expansion of the experiment to fruit-bearing and flowering plants.

Summary of the Discussion

The findings of the study indicate that the use of the marine-based organic product derived from mussels and shells—particularly when combined with humus—represents a sustainable agricultural solution that integrates effective germination, improved soil properties, and reduced negative environmental impacts when compared to conventional chemical and traditional organic fertilizers.

11. Conclusion

This study reached significant scientific and practical findings that confirm the successful use of the organic product derived from marine shells and green mussels in reducing soil salinity, rehabilitating soil, and improving soil fertility in the Haj area of Wilayat Mahout. The results demonstrated that this product increases the soil content of calcium and carbonate compounds, which contribute to the replacement of harmful sodium ions. This process improves the chemical structure of the soil, enhances its organic matter content, and supplies plants with essential mineral nutrients required for healthy growth.

The study also demonstrated the feasibility of producing an integrated organic fertilizer by combining marine shell and mollusk powder with humus. This mixture enhanced soil efficiency, stimulated microbial activity, and accelerated biodegradation processes, thereby supporting plant growth and limiting the accumulation of excess sodium in the soil.

Furthermore, the findings highlighted the potential use of cattle manure for the production of cooking gas (biogas) as an alternative to its direct application as fertilizer. This approach contributes to reducing greenhouse gas emissions, mitigating the effects of global warming, and maximizing the sustainable utilization of animal resources.



These research efforts were further recognized by the project's achievement of **second place in the Science and Mathematics Innovations category for the year 2025**, in addition to receiving honorable recognition from **Her Excellency Nawal bint Talal bin Tariq Al Said** in appreciation of the research team's efforts during her visit to the school. The study also relied on the measurement of soil and water properties and the utilization of the **GLOBE Program** to investigate the impact of bio-crushing of marine mussels and shells on plant growth in the Haj area. The experiment initially focused on arugula plants and was subsequently expanded to include various flowering and fruit-bearing plants.

12. Recommendations

In light of the findings of this study, the research team recommends the following:

- Expanding the use of the organic product derived from marine shells and mollusks as a sustainable alternative to chemical fertilizers, particularly in areas affected by soil salinity.
- Encouraging relevant authorities to support projects focused on recycling marine resources and converting them into organic agricultural products with environmental and economic value.
- Utilizing livestock manure for the production of biogas to achieve energy self-sufficiency and reduce carbon emissions, instead of its random or direct use as fertilizer.
- Expanding the application of the experiment to a broader range of fruit-bearing and flowering crops, and investigating its long-term effects on soil properties.
- Strengthening the role of educational institutions in promoting environmental awareness through the implementation of applied programs, such as school twinning initiatives, similar to the experience conducted with Al-Shumoukh School under the supervision of **Ms. Nashla Al-Jadaili**, to enable students to apply environmental solutions in real-world contexts.
- Recommending that the **General Directorate of Regional Municipalities and Water Resources in Al Wusta Governorate** organize a specialized awareness conference on combating desertification, in partnership with schools, volunteer groups, and the local community, to promote environmental sustainability and the optimal utilization of marine and animal resources.
- Supporting student-led entrepreneurial initiatives aimed at establishing student companies in the field of sustainable organic products, thereby contributing to both environmental and economic development.

13. Future Vision

This research initiative seeks to move beyond the experimental scientific framework toward **practical entrepreneurial application** by working toward the establishment of a **student-led company** specialized in producing a mineral-rich marine-based organic product derived from marine shells and mollusks. The initiative aims to provide this product in appropriate quantities as a sustainable alternative to inorganic chemical fertilizers and traditional animal-based fertilizers. In addition, it seeks to design and produce **organic planting pots** made from this product, thereby supporting home, school, and community-based agriculture.

The project's future vision aspires to create a lasting scientific and environmental impact by contributing to **applied scientific research** focused on environmental protection, expanding green spaces, achieving food security, and reducing pollution. This is to be achieved through the adoption of agricultural waste recycling practices and the reuse of marine shells within the framework of the **circular economy and environmental sustainability**.

Furthermore, the future vision includes expanding collaboration with industrial sectors—particularly **oil and gas companies**—in partnership with the local community, through the collection and utilization of animal manure (livestock waste) for **biogas production**. This approach contributes to achieving self-sufficiency in clean energy derived from environmental resources, reducing carbon emissions, and maximizing resource efficiency through recycling.

This vision underscores the project's commitment to **environmental innovation** and to strengthening the role of students in developing practical solutions to environmental and economic challenges, in alignment with the principles of sustainable development and the objectives of **Oman's future vision**.

14. Acknowledgments

The research team extends its sincere gratitude and deep appreciation to **Ms. Amani Al-Amri** and **Ms. Maryam Al-Amriya**, Principal of Haj School for Basic Education, for their continuous support, scientific guidance, and fruitful cooperation that significantly contributed to the successful completion of this research and the achievement of its objectives.

The team also expresses its heartfelt thanks and appreciation to the specialists at the **Regional Municipalities** and the **Department of Agricultural and Animal Wealth**, particularly **Mr. Saeed Al-Hashmi** and **Mr. Saeed Al-Hakamani**, for their valuable efforts in supporting the research, assisting with soil and fertilizer sample analyses, and providing essential information and data related to soil characteristics, vegetation cover, and regional environmental statistics.

The research team is also pleased to extend its gratitude to the **Nama Department**, represented by **Engineer Saeed Hamada**, as well as to the officials of **Wimpy Laboratories in Wilayat Duqm**, for their scientific cooperation and for providing technical and laboratory support that enhanced the accuracy of the results and the overall quality of the research.

Finally, the team sincerely appreciates all those who contributed directly or indirectly to the success of this research and wishes them continued success and prosperity.

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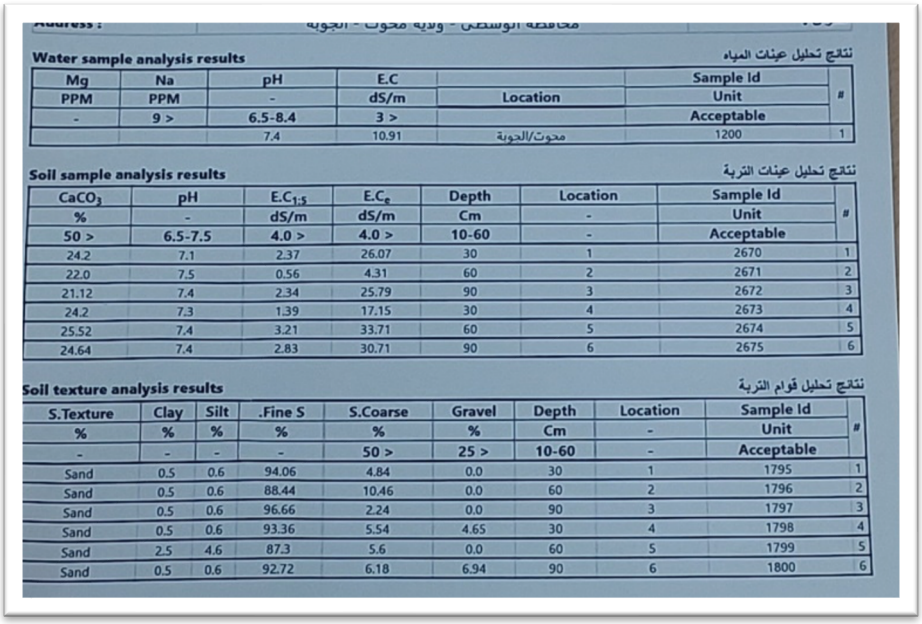
Appendices


VINTAGE


دائرة الثروة الزراعية والسمكية ومصادر المياه
وزارة الثروة الزراعية والسمكية ومصادر المياه

- **Results of the Analysis of Carbonate Content in Marine Shells**
- **Results of Soil Sample Analysis and Mineral Deficiencies**



Water sample analysis results — نتائج تحليل عينات المياه

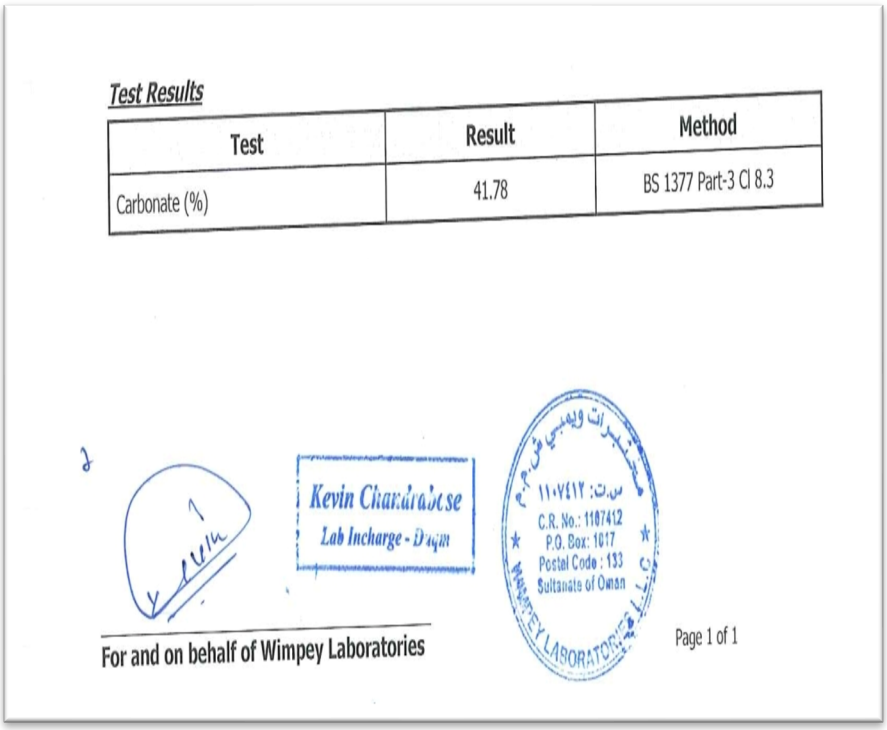
Mg	Na	pH	E.C		Sample Id	#
PPM	PPM	-	dS/m	Location	Unit	
-	9 >	6.5-8.4	3 >		Acceptable	
		7.4	10.91	محوت/الجوبة	1200	1

Soil sample analysis results — نتائج تحليل عينات التربة

$CaCO_3$	pH	$E.C_{1:5}$	$E.C_e$	Depth	Location	Sample Id	#
%	-	dS/m	dS/m	Cm	-	Unit	
50 >	6.5-7.5	4.0 >	4.0 >	10-60	-	Acceptable	
24.2	7.1	2.37	26.07	30	1	2670	1
22.0	7.5	0.56	4.31	60	2	2671	2
21.12	7.4	2.34	25.79	90	3	2672	3
24.2	7.3	1.39	17.15	30	4	2673	4
25.52	7.4	3.21	33.71	60	5	2674	5
24.64	7.4	2.83	30.71	90	6	2675	6

Soil texture analysis results — نتائج تحليل قوام التربة

S.Texture	Clay	Silt	.Fine S	S.Coarse	Gravel	Depth	Location	Sample Id	#
%	%	%	%	%	%	Cm	-	Unit	
-	-	-	-	50 >	25 >	10-60	-	Acceptable	
Sand	0.5	0.6	94.06	4.84	0.0	30	1	1795	1
Sand	0.5	0.6	88.44	10.46	0.0	60	2	1796	2
Sand	0.5	0.6	96.66	2.24	0.0	90	3	1797	3
Sand	0.5	0.6	93.36	5.54	4.65	30	4	1798	4
Sand	2.5	4.6	87.3	5.6	0.0	60	5	1799	5
Sand	0.5	0.6	92.72	6.18	6.94	90	6	1800	6



Test Results

Test	Result	Method
Carbonate (%)	41.78	BS 1377 Part-3 Cl 8.3

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For and on behalf of Wimpey Laboratories

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