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# Effect of MIRA Solution on Grape Cultivation

## Case Study: Jordan Valley / Jeftlik

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Effect of MIRA Solution on Grape Cultivation

Case Study: Jordan Valley / Jeftlik

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# Dedication

To the soul of my father and my beloved mother, whose love, sacrifices, and unwavering support have shaped the person I am today.

To my wife and family, whose encouragement and belief in me have been my greatest source of strength.

To My Uncle Dr. Saeid Yameen for his inspiring support and guidance.

A heartfelt thank you to my supervisor, Prof. Amer Marei, for his invaluable guidance, continuous support, and insightful feedback throughout this journey. His expertise and encouragement have been instrumental in the completion of this work.

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Additionally, I extend my sincere appreciation to my external examiner, Dr. Subhi Samhan, for taking the time to review and assess my work, providing invaluable insights and critical perspectives.

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With deep gratitude and respect,

**Younes Yameen**

## Declaration

I Certify that this thesis submitted for the degree of Master of Science in environmental studies is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for higher degree to any other university or institution.

Younes Yameen

Signature: ……………………

Date: 16/03/2025

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Additionally, I extend my sincere appreciation to my external examiner, Dr. Subhi Samhan, for taking the time to review and assess my work, providing invaluable insights and critical perspectives.

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## Abstract

This research examines the effects of MIRA solution made from digested date palm waste as a bio-fertilizer on grapevine growth, productivity, and fruit quality in the Jordan Valley/Jeftlik. This study evaluates MIRA solution as an organic fertilizer replacement to analyse its performance enhancement effects on plants while supporting sustainable farming methods.

The study employs an experimental design with three treatment groups: The study includes three groups for comparison which consist of group A receiving MIRA solution fertilizer, group B using chemical fertilizers and a control group that receives no additional fertigation. Key growth parameters under examination include leaf area together with chlorophyll content and leaf texture while assessments of yield-related factors focus on cluster weight, total yield per tree, and fruit quality parameters including Brix levels, color and sensory attributes.

MIRA solution application shows substantial improvement in both grapevine growth and productivity. Treated vines show greater leaf areas of 237 $cm^2$ and higher chlorophyll content at 43.8 SPAD units along with better leaf texture when compared to other groups. The vines treated with MIRA generated an average cluster weight of 320 grams and produced 6.7 kg per tree revealing superior yields compared to both chemical fertilized vines and control groups. Fruit quality stands out due to its 19.6% Brix level as well as improved sensory characteristics including sweetness and texture and flavour.

The MIRA solution enhances soil quality while improving fertility and microbial activity which helps to establish circular economy principles and sustainable agriculture through recycling organic waste. The study demonstrates that MIRA solution serves as an environmentally sustainable fertilizer substitute in arid and semi-arid areas including the Jordan Valley. These findings suggest the need to expand MIRA production while simultaneously initiating long-term trials and incorporating this organic fertigation method into wider sustainable farming practices.

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## List of Abbreviations

| | |
|---|---|
| ANOVA | Analysis of Variance |
| CEC | Cation Exchange Capacity |
| CGD | Cluster Grape Dropping |
| DPW | Digested Date palm Wastes |
| FAOSTAT | Food and Agriculture Organization Corporate Statistical Database |
| HSD | Tukey's HSD (Honestly Significant Difference) test |
| IPM | Integrated Pest Management |
| K | Potassium |
| MIRA Solution | The name of the solution that resulted as an output of the digested date palm fruits via the used bio digester in this study. |
| N | Nitrogen |
| NPK | Common abbreviation for fertilizer components (Nitrogen, Phosphorus, Potassium) |
| P | Phosphorous |
| RCBD | Randomized Complete Block Design |
| SPAD | Soil Plant Analysis Development meter |
| SPS | A grapevine variety used in the study |
| SPSS | Statistical software used for analysis |

# Chapter One

# Introduction

## 1.1 Background

Grapes are the second most cultivated fruit, after olives, in Palestinian agriculture. They cover almost 29,000 dunums of agricultural land. Their numbers are quite high in Hebron (almost 5,500 dunums) and a little less than 3,000 dunums in the Jordan Valley, where early seedless varieties are popular. More than 50 varieties of grapes are cultivated to make juice, for raisins, molasses and jam (Basheer-Salimia *et al.*, 2014; Ighbareyeh & Carmona, 2018). This diversity is necessary to meet consumer demand and boost the agricultural economy.

Moreover, delivery of high-yield and high-quality grape varieties is another essential point, where Early Sweet variety produces 2000 kg to 3000 kg per dunum, and just the seedless sort in protected systems generate more than $15,000 for yearly profit per dunum (Basheer-Salimia et al., 2014; Ighbareyeh & Carmona, 2018), and grape production under the protected greenhouses still make a valid gross profit in 2024. This economic trend Validates the importance of advanced agricultural practices, e.g., conversion waste generated from Dates to be utilized as organic fertilizer and its positive role in enhancing the quality of table grapes via improvement of physical properties like firmness, color, and taste (Zhang *et al.*, 2024; Zhao *et al.*, 2020). Additionally, research underlined drawing attention to fruit quality-related factors that can be significantly affected by proper irrigation and fertilization technique for the duration of the growing stage. In fact, grape growers have adopted different irrigation and fertilization methods at specific timeframe to maintain the plant needs (Hou *et al.*, 2019; Tangolar *et al.*, 2015).

Additionally, irrigation too is of vital importance in the growth of the grape, irrigation has a high positive correlation with the effective yield of vines in irrigated areas, especially in arid and semi-arid environments such as those in Palestine (Myburgh & Howell, 2006; Tangolar et al., 2015). An extension of this enables further understanding to the intersection of water and fertilizer application with the yield and quality of grapes (Hou *et al.*, 2019; Li *et al.*, 2020).

For instance, the conjunction of controlled irrigation along with the application of organic fertilizers indicates to increase the overall quality of the grapes, including parameters such as color, flavor, etc. that significantly contribute to its marketability (Mirás-Avalos *et al.*, 2016; Zhang et al., 2024; Zhao et al., 2020). Beside of grape cultivation, and according to the PALM farmers association, there are no less than 19 large Date palm companies in Palestine, and around 800 Date farms. Palestine has produced an average of 15,131 ton/year (FAOSTAT, 2023) during ten years from 2013-2023.

Figure 1.1: Vineyard Conditions. (Left) Grapevines in a covered structure are shown, (Middle) with healthy foliage and clusters of green grapes, (Right) but also significant leaf damage indicating areas needing attention.

Date fruits are rich in essential nutrient like carbohydrates, salts and minerals, dietary fiber, vitamins, fatty acids, amino acids and protein (Chandrasekaran & Bahkali, 2013). The palm fruit is a good nutritive source because of its high sugar content, and they are also mostly good materials for microbial growth and it has a very high fermentative potential for bioenergy production (Gupta & Kushwaha, 2011).

In the Palestinian market, large amounts of unused date palm waste are available, and it can be used in different way with the benefit role of cow manure to produce bio-fertilizers. Bio-fertilizers produced from mixing rich sources of micro and macro nutrients and microorganisms such as Date waste and cow manure could be a very good, less cost, and safer alternative of chemical fertilizers for grape fertigation.

In this study we will call the produced bio fertilizer from a home biogas system using a formula of date palm fruit waste and cow manure as MIRA Solution, this solution could have a suitable composition for using alternative, cheaper, and ecological friendly chemical fertilizers.

## 1.2 Problem Statement

The agricultural sector in the Jordan Valley struggles with date palm waste accumulation each year because most of it goes unused which causes environmental problems and management inefficiencies. The grape cultivation industry in this area now relies heavily on expensive chemical fertilizers which threaten soil vitality and water purity and create economic challenges for agriculturalists. Synthetic fertilizer dependency raises production expenses and creates lasting soil damage while decreasing microbial activity and generating greenhouse gases. The global push toward sustainable agriculture demands immediate research into new fertilization techniques that decrease chemical use while improving soil health and crop yields. The widespread availability of organic waste materials like date palm residues allows for their conversion into biofertilizers which offer sustainable grape fertigation alternatives.

Utilizing processed date palm residues as biofertilizers represents a sustainable solution that corresponds with circular economic standards and agricultural sustainability objectives. Scientific research remains insufficient in determining how this method impacts grape yield, fruit quality, and soil health within the arid and semi-arid climates of regions such as the Jordan Valley. Scientific inquiry must explore how to apply biofertilizers from date palm residues most effectively and discover their ideal nutrient composition along with their long-term benefits. Smallholder farmers need affordable solutions that can grow with their systems and enhance their current agricultural operations while maintaining productivity. By addressing these gaps we can improve grape farming's economic sustainability and reduce environmental pollution through agricultural waste repurposing which will strengthen regional farming system resilience.

## 1.3 Study Justification

Excessive use of chemical fertilizers in the Jordan Valley creates soil degradation and environmental pollution while driving up production costs despite its status as a critical agricultural area. The region produces substantial amounts of date palm waste that continues to be underexploited and poorly managed leading to environmental harm and economic inefficiency. The circular economy model provides an environmentally friendly solution by converting organic waste into valuable biofertilizer which links waste production with agricultural input requirements.

This research shows how converting digested date palm waste into biofertilizers enforces circular economy concepts by turning farm waste into soil enrichment products which support crop production while cutting down synthetic fertilizer usage. The approach achieves ecological benefits through organic residue recycling while providing farmers with reduced input expenses which supports sustainable grape farming economic viability. The use of biofertilizers in grape cultivation creates a self-sustaining agricultural system through soil regeneration and enhanced water retention while promoting microbial diversity. The research seeks to prove that a circular economy model increases agricultural efficiency and supports environmental sustainability specifically in the Jordan Valley / Jeftlik.

## 1.4 Study Objectives

- To test the ability of the study to produce suitable bio fertilizer from Date waste (MIRA Solution).
- To assess the quantity and quality of the produced biogas from Date waste.
- To test the effect of Date palm residues on grape yields.
- To assess the impact the bio fertilizer on leaf size, softness, shine, chlorophyll content, fruit weight, cluster size, color, maturity period, Brix and taste.

## 1.5 Study Period

This study is performed during the season of pruning, pollinating and harvesting grapes.

- **Oct – 2023:** Date palm fruit (waste) collection after the Date harvesting process.
- **Oct/2023 – Jan/2024:** Production and storage of liquid fertilizer produced from a bio-digester system.
- **Jan – 2024:** Grape Trimming and pollination.
- **Jan/2024 – May/2024:** Fertigation with the targeted Liquid fertilizer.
- **Apr/May – 2024:** Harvesting of Fruits, measuring and analysis.

## 1.6 Study Location

All practical experiments of the study were carried out at the site of Younes vineyard which is located in Al-Jeftlik region - Jordan Valley.

## 1.7 Study Questions

Study questions were divided into two evaluation approaches (Qualitative and Quantitative), where for each of them the best fit global standards.

1. **How fertigation with digested Date palm wastes affects the growth characteristics of grapevines namely leaf size, softness and shine.**
   This question serves as an assessment of the impact of digested Date palm biofertilizer (MIRA solution) on grapevine leaf size, softness, and shine.

   To apply this objective, an experimental design will be conducted with three groups: Group A: MIRA Solution (biofertilizer), Group B: Chemical fertilizers, and Group C: Control (no additional fertigation).

2. **In what ways does the productivity of grapevines (fruit yield per plant) fluctuate with the application of Date palm wastes that have been energetically transformed (digested)?**
   This question serves as an evaluation of the effect of digested Date palm biofertilizer on grapevine yield and fruit productivity through the measurement of yield parameters.
3. **What are the effects on clusters' size and their weight when using digested Date palm wastes compared with conventional fertilizers?**
   This question is to determine the influence of biofertilizers on grape cluster size and weight through measurement of Cluster Size and Weight.
4. **What are the effects of fertigation with digested Date palm wastes on the color, maturity period and Brix (sugar concentration) level of grape cluster?**
   This question is to analyze the impact of biofertilizer on grape color, maturity period, and sugar concentration (Brix level) through measuring maturity period, color analysis, and brix level.
5. **How does the taste of digested Date palm wastes-fertilized grapes compare with a conventional fertilizer counterpart?**
   This question is to assess the sensory quality and marketability of grapes grown with biofertilizers through Sensory Evaluation Panel.

# Chapter Two

## Literature Review and Previous Studies

### 2.1 Introduction

Due to exponential growth, an increase in global population means limited resources are being threatened and a rising amount of waste is being produced. Sources around the world including Agricultural municipal and industrial, produce millions of tonnes of solid waste each year (Weber *et al.*, 2020).

The global population increase is leading to an accumulation in pressure on finite the resources, there is now an increasing amount of waste being produced which includes Agricultural municipal and industrial waste, together totalling billions of tonnes of solid waste is produced every year, which underlines the need for sustainable waste management practices (Papargyropoulou *et al.*, 2014). The need for novel solutions is urgent here, particularly in the agricultural sector where organic waste can be used in recycling to increase soil fertility and crop productivity.

In the study area (Jeftlik), there is a noticeable growth and an annual increase in the date palm waste amongst other organic leftovers with limited utilization so far.

#### 2.1.1 Sustainable agricultural practices

Sustainable agriculture combines agricultural practices that maintain ecological balance (its link with the environment and bio agriculture) and organize production to feed the growing needs of the population. Practices for sustainable agriculture can include crop rotation, cover cropping and the inclusion of organic fertilizers, to encourage soil health and lower inputs of agrochemicals (Diacono *et al.*, 2019).

An integral association of managing organic waste is being studied to facilitate these practices, increasing sustainability. For example, applying compost from agricultural waste can improve soil structure, increase nutrient availability and stimulate beneficial microbiota activity

(Jakubus, 2020). Moreover, sustainable practices strive to avert disposal risks associated with land use and activities of conventional farming practices, which include soil degradation and water pollution (Yang *et al.*, 2021).

Given that many initiatives tried to tackle the sustainability in agriculture in Palestine, yet limited penetration has occurred so far may be the absence factor was needed to create commercial solutions as the main instrument of sustainability.

### 2.1.2 Importance of organic waste recycling in agriculture

The recycling of organic waste through agriculture is vital, for multiple reasons. Firstly, it contributes to the reduction, if not eradication, of waste from the environment, increasing agricultural sustainability. Recycling of organic waste allows, for instance, to produce biofertilizer from manure, which is a great input to make soils fertile and optimise crops production (Diacono et al., 2019). Nitrogen, phosphorus and potassium, key nutrients for proper plant growth and production, can increase substantially after the use of digested organic wastes such as those from Date palm wastes (Duque-Acevedo *et al.*, 2020). Additionally, the 'product' of waste recycling is a fertile soil filled with living organisms, thus representing an asset for the farmer. It is aligned with the perspective of the 'circular economy' (Kamar Zaman & Yaacob, 2022). This is not only 'carbon-friendly' because waste is eliminated, but also 'economy-friendly' since it creates new added-value markets for organic fertilizers and soil amendments (Kaur, 2020). Worth highlighting the opportunity of creating new products that replaces essential chemical fertilizers.

### 2.1.3 Role of digested organic waste in enhancing soil fertility and characteristics of yield

As a product of the anaerobic digestion, digestate represents a valuable solid fertilizer for improving soil fertility and crop yield. According to recent research, the addition of digestates can lead to significant increases in soil nutrient profiles, which are crucial in determining the overall plant growth (Diacono et al., 2019). For instance, the solid fraction of digestate could represent up to 80 per cent of the original organic matter of which the destined organic waste is constituted, as well as a not negligible amount of the nitrogen and phosphorous content of the ex-feedstock material (Diacono et al., 2019).

Furthermore, it has been demonstrated, by several research studies, that compared with other organic amendments, the application of by-products generated within the vinification process can indeed boost the growth of plants with a greater bioavailability of nutrients, while also improving the biological activity, especially of the soil microbiome, which is an integral part of the sustainable agricultural production (Teixeira *et al.*, 2014) The benefit of using such organic materials, in addition to a greater total crop yield, could then translate into a long-term benefit for the health of agroecosystems by fostering soil carbon sequestration and attenuating the use of synthetic fertilizer (Du *et al.*, 2022).

## 2.2 Date palm Wastes as a Valuable Agricultural Resource

### 2.2.1 Composition and properties of Date palm wastes

Date palm wastes mainly consist of the stems of the Date palm tree (*Phoenix dactylifera*) and thus have high contents in holocellulose, which alone can contribute about 60-75% to the overall quantity of the fuels (Belgacem *et al.*, 2021a). Moreover, waste from Date palm contains nutrients for optimal plant growth such as nitrogen, phosphorus and potassium (NPK) (Abid *et al.*, 2020). Date palm fibre structural properties with high cellulose/lignin ratio and are, therefore, a promising renewable resource towards more sustainable agriculture (Belgacem *et al.*, 2021b). As proven recently, the nanoscale cellulose in Date palm leaves validated their advantageous features for advanced applications, especially for nanocellulose production (Dhahi *et al.*, 2024).

### 2.2.2 Current uses of Date palm wastes in agriculture

Nowadays, several different agricultural applications take advantage of Date palm wastes. One of the most used applications is related to its use as mushroom substrate. For instance, the "*Pleurotus eryngii*" variety mushrooms, which thrive on the organic matter of Date palm waste (Alqaisi *et al.*, 2022), are cultivated on Date palm wastes. Another application concerns composting processes: thanks to its organic nature, Date palm residues are lately used in the production of organic fertilizers, the production of which appears to improve soil quality and, consequently, plant growth (Abid et al., 2020).

Date palm waste is fibrous, and its fibres are easily processed and used as soil amendments that improve soil structure and aeration, increasing its water retention (Aydi *et al.*, 2023). Additionally, Date palm waste is explored as a substrate in the production of bio composite materials, which are increasingly investigated as eco-friendly alternatives for the building and agricultural applications (Gallala *et al.*, 2020).

### 2.2.3 Benefits of using Date palm wastes for soil amendment

Utilisation of Date palm wastes for soil amendment brings numerous advantages. First, the organic matter from the Date palm residues, such as leaves, inflorescences, fronds and stems, can increase the porosity of soils and improve nutrients availability and microbial activity, which are helpful for plant growth (Abid et al., 2020).

Utilisation of Date palm waste in the process of making compost can improve both physical and chemical properties of soils, such as increasing water holding capacity, air permeability and infiltration of water, while decreasing bulk density (Aydi et al., 2023) (Aydi et al, 2023). Furthermore, Date palm waste can be used to alleviate soil erosion and the formation of soil crust (Mahdi *et al.*, 2018). It is therefore useful for sustainable agricultural practices and human management. Utilisation of Date palm waste for the production of biochar can help with carbon sequestration in the soil and mitigate climate change, and benefitting the improvement of soil quality (Sizirici *et al.*, 2021)

## 2.3 Soil Health and Fertility in the Jordan Valley

### 2.3.1 Characteristics of soil in the Jordan Valley

The salinity levels of the soil in the Jordan Valley are quite high: approximately 63 per cent of the sampled soils were classified as salty, and nearly 46 per cent of the soils surveyed were reported as containing moderate to moderately saline characteristics (Massimi, 2021). These conditions are, in part, driven by the climate of the region. The Jordan Valley faces high temperatures and scarce rainfall, which has made the intensification of evaporation and the increasing of salts concentration in the soils a reality (Carr *et al.*, 2010). In addition to salinity, the soil pH in the Jordan Valley is generally alkaline, with most values above 7, which can affect nutrient availability and influence crop growth patterns.

The main soil types in the valley include the soils in loamy sand and clay. Loamy sand is a soil type that has large pore space and facilitates good drainage, but, as demonstrated by some farmers and scientists, it can be unfavorable for nutrient retention (Hamdi *et al.*, 2019). This requires reciprocal expertise between farmers and scientists to implement effective soil management to increase the water availability for crops. Calcium carbonates are a common feature of the Jordan Valley's soil, which can reduce the availability of various nutrients such as phosphate that are crucial for the crop growth and development (Batarseh, 2017).

### 2.3.2 Challenges faced in maintaining soil fertility in arid and semi-arid regions

Preservation of soil fertility in arid and semi-arid environments such as the Jordan Valley poses multiple challenges. These challenges include salinization, nutrient depletion, erosion and others. High soil salinity, resulting in part from the use of saline irrigation water, can cause a decrease in crop yields, reduce plant productivity and growth rates (Carr et al., 2010). Intensive agricultural practices such as mono-cropping, overuse of chemical fertilizers and inadequate use of cover farming can lead to nutrient imbalances, health of the soil and other issues (Abu-Abdoun & Al-balawna, 2021).

Erosion such as wind and water erosion, poor soil management practices, lack of adequate crop residues and cover, among other things, leads to a loss in organic matter. Farmers in the Jordan Valley are familiar with what once growing fields look like, post-erosion. The impact of these factors is a degradation in soil microbial activity and health, and a fall in soil fertility (Benabderrahim *et al.*, 2018). Due in part to erratic rainfall patterns and water scarcity issues, farmers are challenged with irrigating their fields to appropriate moisture levels to enable healthy crop production (Peng *et al.*, 2023).

**2.3.3 Impact of organic amendments on soil health in similar climatic zones**

The use of organic amendments also significantly improves soil health in arid and semi-arid regions, including the Jordan Valley. Studies have shown the use of organic amendments such as composts derived from Date palm waste and other sources have demonstrated high improvements in soil structure, water retention and nutrient availability (Benabderrahim et al., 2018). For instance, applying organic amendments will increase the amount of organic carbon in the soil that serves as basal support for microbial life and improves the overall fertility of the soil (Shaaban *et al.*, 2013).

Likewise, studies have shown that the use of organic amendments reduces the effects of salinity through increased soil aggregation and reduced sodium adsorption ratios, hence improves productivity (Shaaban et al., 2013). Published studies across the Middle East and North Africa have shown that the combined application of organic and inorganic fertilizers results in improved plant growth and crop yields, and improved soil fertility profiles.

Shaaban et al. (2013) in their discussion of these studies concluded that their field trials results in the Jordan Valley shown a great potential for increasing crop yield by combined application of organic and inorganic fertilizers and showing the sustainability of this strategy for the semi-arid marginal lands or Mediterranean climate. Overall, improving soil health and fertility for long-term agricultural productivity in the Jordan Valley will rely heavily on the use of organic modifications.

## 2.4 Grape Cultivation in the Jordan Valley

### 2.4.1 Overview of grape cultivation practices in the Jordan Valley

Grapes grown in Jordan Valley are still generally produced using both classic and modern agronomic practices that are key to sustain this specific and demanding crop in the semi-arid valley. The Jordan Valley has a hot summer and a mild winter, and the specific climate makes it possible to produce both table and wine grapes (Ighbareyeh & Carmona, 2018). To mitigate the scarcity of water, despite the need to ensure a sufficient quantity for the plants, farmers use drip irrigation for optimizing the water use (Kalbouneh, 2011).

Land preparation, which is often done by mechanical means, uses soil to break colds, and, if possible, organic modifications could be incorporated to improve both the fertility and structure of soil. Integrated pest management (IPM), is also being deployed to control pests and diseases in a preventive manner to reduce chemical inputs of pesticides (Scaccini *et al.*, 2021). All these practices are necessary for both the quality and the quantity of the grapes and, therefore, their economic importance and local significance.

### 2.4.2 Factors affecting grape yield and quality

There are a few factors that influence both the quantity, and the quality of grapes produced in the Jordan Valley. The impact of climatic conditions, such as temperature, humidity and the number and intensity of hours of sunlight, is known to influence the ripeness of grapes and their quality (Ighbareyeh & Carmona, 2018). Soil characteristics, including texture and pH, are also important in determining the growth and development of grapes and quality. The choice of grape variety is also a major factor, as different cultivars have different thresholds for tolerance of environmental stressors, as well as different flavor profiles and ripening rates (Faci *et al.*, 2014).

Water management, including timing and method of irrigation, can have a major impact on production. Studies have found that regulated deficit irrigation, for instance, can have a positive impact on grape yield and quality (Faci et al., 2014). Lastly, the management of a vineyard, including pruning and the management of the canopy to increase or reduce exposure to sunlight and air flow, can impact the quality of grapes produced (Ighbareyeh & Carmona, 2018).

### 2.4.3 Historical and economic significance of grape production in the region

The cultivation of grapevines has a long historical background in the Jordan Valley and the broader area of Palestine, whose existence is most evident from archaeological artefacts dating back more than 8,000 years in the region. In the Antiquity, the overall culture and daily life in ancient Canaan and in ancient Egypt (Ighbareyeh & Carmona, 2018) included wine production as a prominent agricultural activity. This is proven by several archaeological and linguistic evidence, usually through artefacts found in archaeological digs being excavated around the area.

Grapevine cultivation and wine production have been preserved throughout various chapters of the history of the area up to the present day. Grapes remain one of the main agricultural producers in the area, playing a major role in the local economy, by supplying a partial agricultural income for local farmers, thanks to home consumption and the export of high-quality table grapes. In 2011, Kalbouneh (2011) showed how 50 per cent of the income of local farmers was supported by the production of table grapes for the exportation to several international markets.

The wine-making industry has undergone a remarkable development in the last five decades with a recent resurgence in local wineries, churning out products of quality, while adding support to the local economy and attracting tourists to the region (Ighbareyeh & Carmona, 2018). Vine growing in the Jordan Valley is not only one of the main sectors of the local economy, guaranteeing thousands of job opportunities in the area, but it is also one of the main pillars of regional sustainability, thanks to its capacity to preserve cultural heritage and local agricultural traditions.

## 2.5 Benefits of using digested Date palm waste on grape cultivation

### 2.5.1 Mechanisms by which digested Date palm wastes improve soil properties

Several mechanisms help improve soil's properties when digested Date palm wastes (DPW) are applied. The addition of the large amount of organic matter in DPW to the soil significantly improves its structure. By adding organic matter, shape and aggregation of soil particles are enhanced, helping increase both aeration and water holding capabilities. Both are important in the semiarid climate of the Jordan Valley  where most vineyards are spread (Alqaisi et al., 2022).

With DPW, the total mass of soil available to the plant increases and the Cation Exchange Capacity (CEC) of the soil in terms of nutrient retention and availability to the plant is improved (Davidson, 2023). When DPW are applied as soil amendments they improve soil characteristics through increased Cation Exchange Capacity. CEC functions as a primary measure of soil fertility because it demonstrates how well the soil can hold onto and deliver vital cations like potassium ($K^+$), calcium ($Ca^{2+}$), and magnesium ($Mg^{2+}$) which plants need to grow. Soils that contain higher amounts of organic matter generally show improved CEC which leads to better nutrient retention and availability.

The use of organic amendments such as DPW provides essential nutrients while also boosting the physical and chemical characteristics of soil including its CEC. The enhancement enables plants to absorb more nutrients while encouraging microbial life and strengthening soil structure leading to maximum plant development and production (Marín-Martínez *et al.*, 2021; Schneider *et al.*, 2023).

Biochar produced from date palm byproducts results in substantial elevation of soil CEC. This improvement enables better nutrient retention and availability which supports sustainable farming methods (Burezq & Davidson, 2023; Rehali *et al.*, 2025). DPW integration enhances soil management by recycling agricultural waste and boosting soil fertility through CEC improvement which results in more sustainable and productive agricultural systems.

DPW stimulates high microbial activity in soil, through decomposition of organic matter to macronutrients. For example, the action of microorganisms helps in the release of mineral nutrients and various elements from applied organic fertilizers to the soil, making elements readily available to grapevines (El Janati *et al.*, 2021). Digested waste products include beneficial micro-organisms that improve soil health by helping in more nutrient cycling and suppressing soilborne diseases (Santos *et al.*, 2021).

### 2.5.2 Expected impact on grapevine growth, yield, and fruit quality

Characterization and field trials showed that the organo-mineral soil amendment with digested Date palm wastes can result in increased vine growth, yield and fruit quality. Many plant nutrition studies have shown that organic amendments can increase vine vigor and fruit set, which are key factors for optimizing yield production (Kontaxakis *et al.*, 2023). Higher nutrient availability because of DPW can lead to increased development of specific flavonoid compounds, including phenolics and antioxidants, among others, which are important for the overall improvement of grape quality and commercial value (Bunea *et al.*, 2012).

Organic amendments have also been shown to increase the sugar content and overall quality characteristics of grapes for both table grapes and wines, and these are of great importance in the production of quality beverages (Meng *et al.*, 2012). The alternate effects of climatic conditions, especially more frequent droughts and heatwaves might be mitigated by the use of soil amendments that have been shown to influence the drought resistance of grapevines (Alqaisi et al., 2022).

### 2.5.3 Comparison with other organic and inorganic fertilizers used in grape cultivation

Because digested Date palm wastes are neither synthetic nor organic fertilizer, they have multiple advantages over other fertilizers used for providing nutrients for grape growth. As stated, synthetic fertilizers such as NPK provide nutrients directly to the soil. However, the presence of leaching in the soil results in nutrient leaching and ultimately reduction of soil health. These synthetic fertilizers also contribute to fertilizer runoff into the waterways, leading to water eutrophication. DPW, on the other hand, is a slow-release source of nutrients which improves soil health over a period (Davidson, 2023).

While organic fertilizers such as compost and manure have several positive benefits on soil structure and microbial activity, they further improve the soil quality, and an improvement in nutrient quality might not be worth supplementing for vineyards (M. Botelho *et al.*, 2021). However, as DPW is not a pure organic fertilizer, but rather a mixture of palm wastes, it might contain a balanced ratio of plant nutrients, of which the lack and imbalance might inhibit the growth and/or reduce the fruit quality of grapevines (Areiqat *et al.*, 2019). This implies that the use of Date palm waste as a deficient can improve grape cultivation in a more sustainable way.

Furthermore, DPW not only helps in recycling agricultural wastes and reducing environmental pollution but also contributes to achieving a circular economy. This reminds the potential of palm wastes in cleaning the environments that are often neglected or insufficiently appreciated (Kontaxakis et al., 2023). In contrast, inorganic fertilizers such as the NPK fertilizer provide nutrients to grapevines that can be detected immediately or after a short period of time. These nutrients are thus available directly for plants, but they require precise adjustments to reduce negative impacts of soil health and the environment, for example the NPK fertilizer uses rock-based sources but includes a very high proportion of rock dust that must be washed out of the soil. This requires precise calculations of the effective period of the fertilizer.

## 2.6 Previous Studies on Organic Waste and Grape Cultivation

Dournes *et al.* (2022) made a comparative analysis between two grape cultivars (Colombard and Gros Manseng) under different cultivation procedures, including control, cultural practices involving increased cluster grape-dropping (CGD) through correspondence between cluster abundance and pruning scars, and a regular management with selective pruning and canopy control. Different letters indicate differences at $P < 0.05$. Variations in grapes must happen due to the impact of the cultivation procedures on wine quality, highlighting the role of agricultural management in determining grape biochemical properties.

R. V. Botelho *et al.* (2016) reported on 'Biodynamic vine water use efficiency: from stomata to the soil' and verified that biodynamic preparations were able to impact the grapevines' physiology, resulting in a decrease of stomatal conductance, the main determinant of water loss (transpiration), and no influence on photosynthetic activity. The conclusion was that biodynamic preparations can improve the grapevines' capacity to endure water shortage. This finding has further implications in arid regions such as the Jordan Valley (Botelho et al, 2015).

El-Waziry *et al.* (2016) Date palm waste components of Date palm waste were extracted using mushroom P. Florida. Following treatment, the nutritive components and digestibility of treated Date palm waste were assessed. The results revealed that treated Date palm waste can be used as a rich organic amendment to enhance the nutritive components, digestibility, which could improve soil quality and crop productivity.

Meng et al. (2012) observed the effect of rain-shelter cultivation on the phenolic profile of 'Vitis vinifera' cv. Cabernet Gernischet and found that grape quality was improved in microclimatic conditions under rain-shelter cultivation because of the promotion of phenolic compounds and reduction of diseases. This study confirms that environmental parameters should be managed in grape growing.

García de Cortázar-Atauri *et al.* (2010) reconstructed climate indicators from Dates of grape harvest. It underlined the relevance of historical agroecological practices and grape varieties as a factor in interpreting traces of climate change over viticulture. Considering that different agricultural practices intervene between grape berry (the fruit) and wine, and even the same performed in distinct periods, numerous factors influence grape quality and weight.

# Chapter Three

## Methodology

### 3.1 Study site description in the Jordan Valley

The land area consists of approximately 16,280 square meters, with a length of about 220 meters and a width of 74 meters, which narrows inward to 60 meters. As shown in Figure 3.1, This land is in the Jordan Valley in the Jeftlik area specifically at the coordinates (32.160368” N, 35.479897” E). The mentioned land also contains an agricultural pond covering an area of one dunum and greenhouses planted with grapes. In general, each dunum had around 220 grape trees, with a maximum productivity of 20 kg/tree.season$^{-1}$.

Figure 3.1: An illustrative image from Google Earth showing the shape and area of the experiment location

### 3.2 Experimental Design

A controlled field experiment evaluated how digested date palm waste (MIRA Solution) influenced grapevine growth and productivity. The research followed a randomized complete block design (RCBD) format with 45 grapevines (Vitis vinifera, variety "SPS") distributed into three experimental groups across three blocks with five trees in each block (Figure 3.2). The treatments included:

- **Group A:** Grapevines fertigated with the biofertilizer (MIRA Solution).
- **Group B:** Grapevines fertigated with conventional chemical fertilizers.
- **Control Group (C):** Grapevines receiving only irrigation, without additional fertigation.

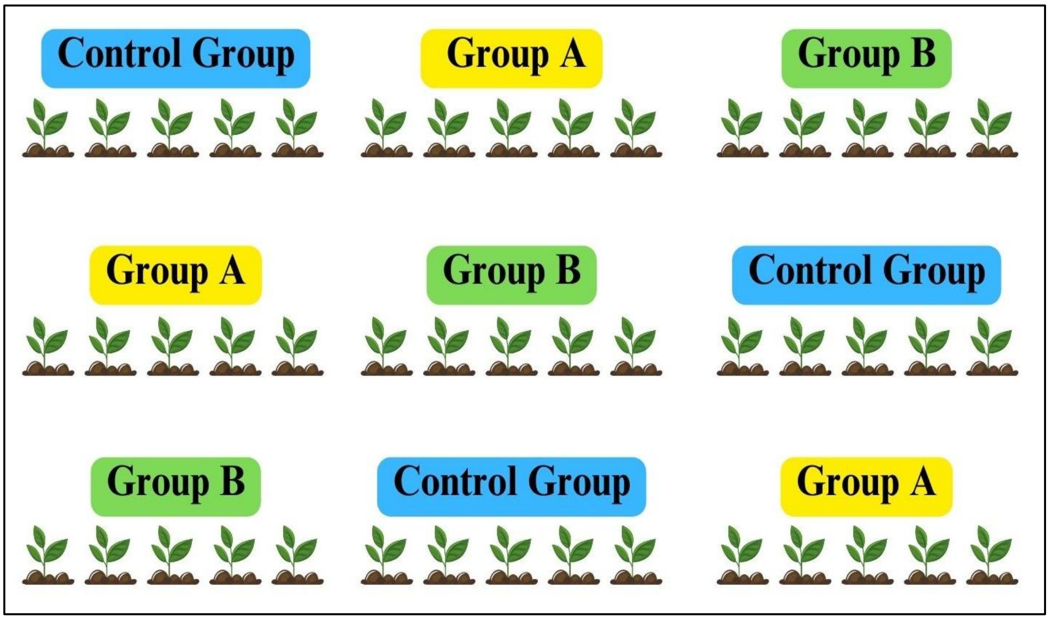


Figure 3.2: Experiment design of the effect of the four groups on grapevine growth

The study goals and land availability determined the selection of 45 grapevines for experimental purposes. The selected number of grapevines allowed researchers to use a Randomized Complete Block Design (RCBD) with three treatments and adequate replication involving 15 trees per treatment group and 5 trees per replicate. The selected sample size provided sufficient statistical power and remained practical regarding land use constraints and resource management. This pilot-scale trial approach established a thorough basis to assess how the MIRA solution impacted grapevine growth and productivity when tested under controlled field conditions.

The experiment proceeded under standardized agronomic circumstances which maintained consistent vineyard management practices across all areas including pruning operations, summer irrigation protocols, dormancy treatments with Dormix, leaf thinning activities, pest control measures, tillage practices, and fertigation scheduling. All groups followed standardized procedures to remove confounding variables and focus on studying how different fertilization treatments influenced results.

MIRA Solution, the organic biofertilizer used in Group A, was formulated from equal proportions (1:1) of cow manure and date fruit waste (Table 3.1). The organic biofertilizer used in Group A contained 1.70% nitrogen, 0.90% phosphorus and 1.70% potassium.

Table 3.1: Nutrient Composition of Organic Fertilizer Sources

| Source | Nitrogen (N) | Phosphorus (P) | Potassium (K) |
|---|---|---|---|
| **Cow Manure** | 1.00% | 0.50% | 1.00% |
| **Date Fruit** | 0.70% | 0.40% | 0.70% |
| **MIRA Solution*** | 1.70% | 0.90% | 1.70% |

*MIRA solution is composed as 1:1 from cow manure and date fruit. Analysis was done in Nablus Central Lab

Table 3.2's soil analysis reveals essential macronutrients including nitrogen (N), phosphorus (P), and potassium (K) exist at low baseline levels. Native soil contains only 0.08% nitrogen, showing that the available nitrogen supply is limited, which is essential for both plant growth and chlorophyll production. The low phosphorus concentration (0.06%) could limit root development and hinder plant energy transfer processes. The potassium level stands at 0.35% which exceeds the levels of other essential nutrients but remains inadequate for optimal plant growth despite its support for water regulation and disease resistance functions.

Table 3.2: Soil composition compared to fertilizers composition per one liter

| Component | Soil Composition (%) | Measurement per 1 L | |
|---|---|---|---|
| | | MIRA Solution (%) | Chemical Fertilizer (%) |
| **Nitrogen (N)** | 0.08% | 1.70% | 5.00% |
| **Phosphorus (P)** | 0.06% | 0.90% | 3.00% |
| **Potassium (K)** | 0.35% | 1.70% | 8.00% |

*Analysis was done in Nablus Central Lab

The natural fertility of soil presents lower levels of all three macronutrients when evaluated against the nutrient composition of MIRA Solution and conventional chemical fertilizers. MIRA Solution delivers 1.70% nitrogen availability from its organic composition of date palm waste and cow manure which exceeds natural soil nitrogen levels but falls below the 5.00% nitrogen concentration found in chemical fertilizers. The phosphorus concentration in MIRA Solution stands at 0.90% which surpasses natural soil levels yet falls short compared to 3.00% found in chemical fertilizers. MIRA Solution boosts potassium to 1.70% for better fruit quality and plant resilience but chemical fertilizers contain a higher potassium concentration of 8.00%.

Although natural soil lacks sufficient nutrients organic amendments like MIRA Solution serve as sustainable alternatives because they enhance soil fertility over time while preserving microbial activity and soil structure. Despite their nutrient density chemical fertilizers can cause fast nutrient loss through leaching which highlights the need for proper fertilization practices to maintain soil health and boost agricultural output over time.

The volume of irrigation water provided remained consistent throughout the growing season. Standard vineyard irrigation practices were applied to the control group (C) without any extra fertilization. The experimental part of this study started on January 15, 2023, where Group A (MIRA Solution) received biofertilizer at 0.636 L per tree per fertigation cycle throughout the season following the schedule presented in Table 3.3. During grape cultivation Group B used standard commercial practices while maintaining the same fertigation volume and schedule listed in Table 3.4.

A progressive drip irrigation system was established throughout all treatment plots to achieve optimal vine growth and uniform water distribution. The system synchronized water supply with the grapevine phenological stages of post-harvest recovery, flowering, berry set, and ripening to ensure productive growth and superior fruit quality. The irrigation volumes were adjusted to maintain optimal hydration during high water demand periods like berry expansion while water application reduced during final fruit ripening stages to improve sugar concentration and flavor development.

Through precise water management the uniform irrigation strategy ensured consistent grape development across plots which supported synchronized ripening and better harvest planning. This water-efficient method reduced resource wastage while supporting sustainable agricultural practices.

One-way analysis of variance (ANOVA) helped evaluate fertilization treatment effects by comparing key growth and productivity parameter means among three experimental groups. The Tukey's HSD post-hoc test analyzed the treatment means to identify significant differences where p-values were below 0.05. The SPSS 26.0 software performed statistical analyses which enabled a thorough evaluation of treatment effects on grapevine performance.

Table 3.3: Monthly Fertilization using Mira Solution and Irrigation Schedule for Grape Tree Growth Stages

| Month | Growth Stage | Fertilizer Type* | Fertilizer Application Frequency | Fertilizer per Session (L/tree) | Total Fertilizer Volume per Month (L/tree) | Irrigation Volume per Session (L/tree) | Total Monthly Irrigation Volume (L/tree) |
|---|---|---|---|---|---|---|---|
| January | Early vegetative growth | None | - | - | - | 10.3 | 51.5 |
| February | Flowering | Mira Solution | Twice (start and mid) | 0.034 | 0.068 | 17 | 85 |
| March | Fruit set and thinning | Mira Solution | Four times (weekly) | 0.144 (0.036 of each) | 0.144 | 35 | 175 |
| April | High water demand during berry ripening | Mira Solution | Four times (weekly) | 0.144 (0.036 of each) | 0.144 | 55 | 275 |
| May | Harvest preparation (stop fertilizer) | None | - | 0 (no fertilization) | - | 45.0 (until May 20) | 225 |
| **Post-Harvest** | Summer pruning and field capacity irrigation | None | (May 20) | - | - | Field flooding to capacity | - |
| June | Early canopy and root recovery | Mira Solution | Twice (start and mid) | 0.035 | 0.07 | Gradual increase from 12.5 to 20 | 101 (average) |
| July | Canopy growth | Mira Solution | Twice (start and mid) | 0.035 | 0.07 | 24 | 120 |
| August | Continued canopy growth | Mira Solution | Twice (start and mid) | 0.035 | 0.07 | 25 | 125 |
| September | Root development | Mira Solution | Twice (start and mid) | 0.035 | 0.07 | 22 | 110 |
| October | Dormancy preparation | None | - | - | - | 20 | 100 |
| November | Minimal irrigation for dormancy | None | - | - | - | 20 | 100 |
| December | Field preparation, apply manure | Animal manure | Once, December 20 | Rich in nitrogen | - | Field flooding to capacity | - |
| **Total** | - | - | **19 sessions** | **Varies by Session** | **0.636 L/tree** | - | **1467.5 L/tree** |

*Mira Solution is composed of 1.7 : 0.9 : 1.7 as NPK.

Table 3.4: Monthly Fertilization using Chemical Fertilizer and Irrigation Schedule for Grape Tree Growth Stages

| Month | Growth Stage | Fertilizer Type* | Fertilizer Application Frequency | Fertilizer per Session (L/tree) | Total Fertilizer Volume per Month (L/tree) | Irrigation Volume per Session (L/tree) | Total Monthly Irrigation Volume (L/tree) |
|---|---|---|---|---|---|---|---|
| January | Early vegetative growth | None | - | - | - | 10.3 | 51.5 |
| February | Flowering | 05:03:08 | Twice (start and mid) | 0.034 | 0.068 | 17 | 85 |
| March | Fruit set and thinning | 05:03:08 | Four times (weekly) | 0.144 (0.036 of each) | 0.144 | 35 | 175 |
| April | High water demand during berry ripening | 5:3:8 + 0:0:14 | Four times (weekly) | 0.144 (0.036 of each) | 0.144 | 55 | 275 |
| May | Harvest preparation (stop fertilizer) | None | - | 0 (no fertilization) | - | 45.0 (until May 20) | 225 |
| **Post-Harvest** | Summer pruning and field capacity irrigation | None | (May 20) | - | - | Field flooding to capacity | - |
| June | Early canopy and root recovery | 05:03:08 | Twice (start and mid) | 0.035 | 0.07 | Gradual increase from 12.5 to 20 | 101 (average) |
| July | Canopy growth | 05:03:08 | Twice (start and mid) | 0.035 | 0.07 | 24 | 120 |
| August | Continued canopy growth | 05:03:08 | Twice (start and mid) | 0.035 | 0.07 | 25 | 125 |
| September | Root development | 05:03:08 | Twice (start and mid) | 0.035 | 0.07 | 22 | 110 |
| October | Dormancy preparation | None | - | - | - | 20 | 100 |
| November | Minimal irrigation for dormancy | None | - | - | - | 20 | 100 |
| December | Field preparation, apply manure | Animal manure | Once, December 20 | Rich in nitrogen | - | Field flooding to capacity | - |
| **Total** | - | - | **19 sessions** | **Varies by Session** | **0.636 L/tree** | - | **1467.5 L/tree** |

*Chemical Fertilizer as NPK = 05 : 03 : 08 and 00 : 00 : 14

## 3.3 Date palm Sample Collection

500 kg of Date fruit waste (Figure 3.3) and 500 kg of cow manure were collected from Al-Jeftlik area Date farmers; therefore, samples were kept in a clean and dry place until the beginning of the experiment.

Figure 3.3: Date palm waste. (Left) Transportation process, (Right) Checking weight and quality.

## 3.4 Biogas and Bio Fertilizer System: Principle of Work

A home biogas unit was established on the farm and tested after purchasing it from Home Biogas company. In general, the principle of work for the unit described in Figure (3.4) begins by mixing cow manure with water and adding it through the inlet (Point 1) toward the lower part of the system (Point 2), where the added anaerobic bacteria with the types that found in cow manure will digest, decompose, and ferment the added substrate that will out from the outlet (Point 4) as liquid fertilizer.

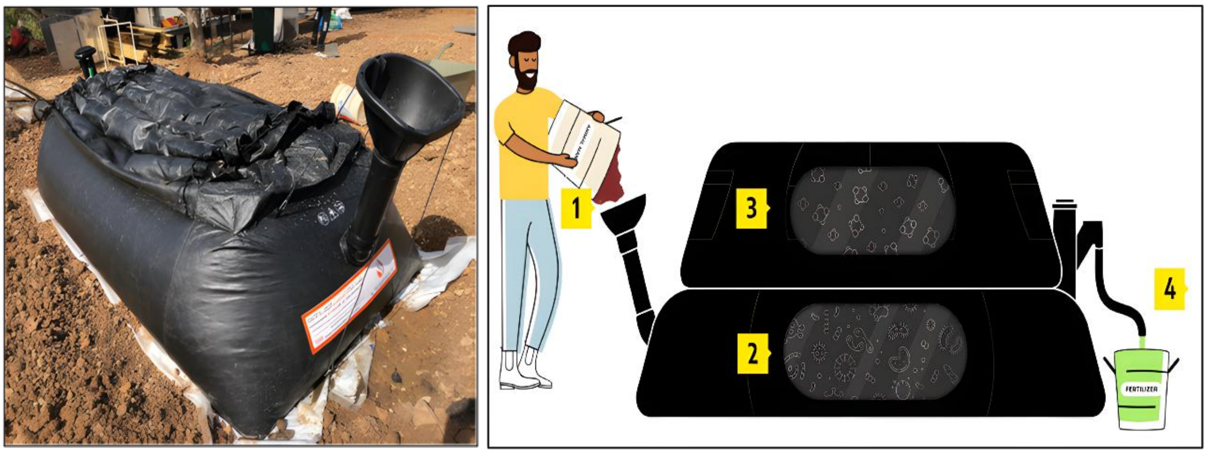


Figure 3.4: (Left) Home biogas system, (Right) Unit parts; (1) Samples Inlet, (2) Digestion Process, (3) Gas Bag, and (4) Liquid Outlet.

The system itself is designed to refill with substrates daily to produce the proper amount of gas and liquid fertilizer. The system needs to moderate temperature on a scale of 100 $^{0}$C almost 45 $^{0}$C to facilitate bacterial work. The system is closed and that prevents any income from air, where the local oxygen will be consumed by aerobic bacteria that in turn will die after oxygen consumption and depletion; so, the conditions will be perfect for the anaerobic bacteria to begin their analysis of the organic matter and will start within few hours.

### 3.4.1 Preparation of Date waste solution

Date palm waste as 1 kg with 1 L of tap-water were mixed with until it becomes fragile as seen in Figure 3.5. Several preventive measures were adopted to protect the Date Waste Solution from bacterial and fungal contamination during its preparation. The solution received immediate use after preparation with clean tap water and fresh date waste in hygienic conditions to prevent microbial growth. Throughout the digestion process the system ensured anaerobic conditions which effectively suppressed the growth of aerobic microbes. The bio fertilizer unit's acidic-to-neutral pH range (5-6) combined with continuous temperature monitoring produced conditions that prevented pathogenic organisms from thriving. To prevent unwanted microbial growth the solution was kept in shaded containers within a cool warehouse which protected it from sunlight and temperature changes. The combined procedures maintained both the microbial stability and safety of the solution prior to use.


Figure 3.5: Mixing and preparing Date palm juice.

### 3.4.2 Testing of the system

The system was filled with 7 $m^3$ of water loaded with 25 L of Date waste solution and 25 L of cow manure solution (previously prepared) and mixed with anaerobic bacteria who obtained with the purchased system earlier. For the first time it runs 14 days tell the first byproduct seen the light, however in after the first month until the stability of the system, every 24 hours the system produced 2 $m^3$ of biogas around 4 kg, where it produced about 60 L of liquid fertilizer. The process was repeated, and the production of liquid fertilizer was daily until the filling of several barrels of liquid fertilizer stored in special cooled warehouse for the main experiment (Figure 3.6 and Figure 3.7).

Figure 3.6: Home biogas system ready to work with the first production of gas.

Figure 3.7: Liquid Fertilizer production and storage

## 3.5 Data Collection

In this section, the data collection steps consist of obtaining leaf and fruit parameters to measure the effect of treatments on grapevines. The scales used are important determinants of plant health, productivity and fruit quality. All these parameters were measured using precise instruments and standard methods to ensure the best possible results.

### 3.5.1 Leaf Parameters

#### 3.5.1.1 Size measurement (Area) using ImageJ software

The grapevine leaves were measured with ImageJ software (Figure 3.8). This software gave accurate dimensions of the leaf, its length and width. The leaf size as an area is one of the primary measures of plant. The leaves were pictured using a good resolution camera and analyzed.

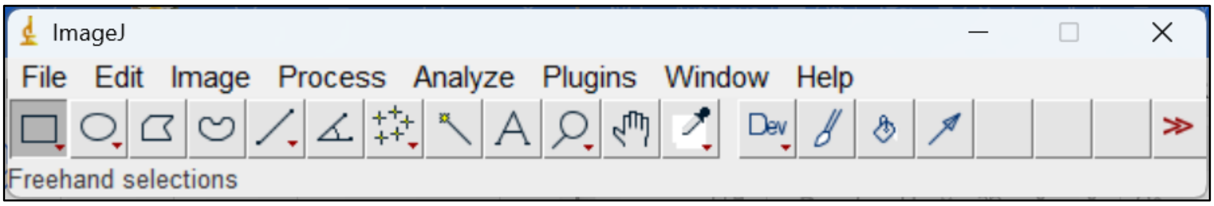


Figure 3.8: ImageJ software: Used to analyze and measure leaves area

#### 3.5.1.2 Softness and shine assessment

The softness and brilliance of the leaves were measured by touch and sight (Figure 3.9). Evaluation was determined on a scale between 1 and 10, where 1 is the highest rough and darker and 10 is the highest soft and shiner. Team of trained females was deployed to evaluate the qualitative parameters related to the leafvine.


Figure 3.9: Example of leaves assessment

#### 3.5.1.3 Chlorophyll content measurement using Chlorophyll meter

Chlorophyll levels were recorded with a handheld chlorophyll meter (Figure 3.10). This instrument measures how much chlorophyll is present in the leaves, a chemical compound directly proportional to the plant's ability to photosynthesis. Larger levels of chlorophyll often equate to more robust plants that are more productive.

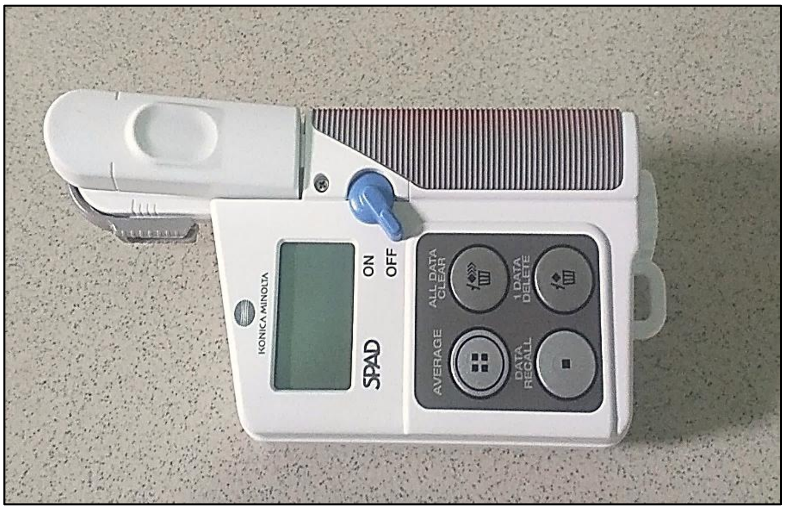


Figure 3.10: SPAD handheld chlorophyll meter

### 3.5.2 Fruit Parameters

#### 3.5.2.1 Fruit production per tree in number and weight

The productivity was calculated by measuring the number of grape clusters per tree and weighing its overall production (Figure 3.11). This measurement is essential to understanding how effective the treatments overall were in increasing or sustaining grape production. Using yield data for the control and treatment groups, the experiment tried to discern whether the bio-digested solution increased or decreased the productivity of the grapevines.

#### 3.5.2.2 Grape cluster size

The size of the grape cluster was determined by measuring their maximum length and maximum width as well as their weight. These measurements are useful to assess the mechanical quality of the grape clusters, a critical component in the commercial grape growing process. Larger and bulkier clusters have a greater market value and better overall fruit quality. If cluster size differs significantly between the groups, that could be a sign of how fertilizer treatments affect fruit development.

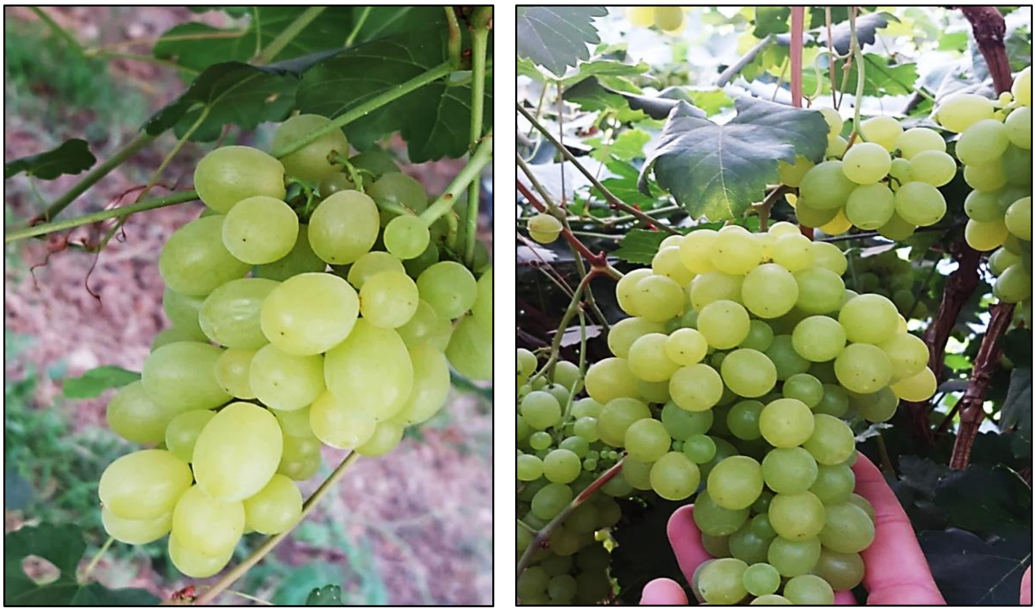

Figure 3.11: Example of grape clusters on a vine April 2024.

#### 3.5.2.3 Fruit color, maturity, brix, and measurement by Refractometer

Fruit quality was measured both visually and instrumentally. They measured the grapes by sight for color and ripeness, in accordance with the table grape industry. They measured the Brix, or the level of sugar in the grapes, using a refractometer (Figure 3.12). Brix is a measurement of sweetness of the fruit and is also used to judge taste and marketability. Higher Brix levels are more commonly associated with sexier, desired fruit. The study, using the Brix value of the different treatments, wanted to determine how the bio-digested solution affected fruit quality.

Figure 3.12: Example of brix meter for grape measurement and grape cluster size.

#### 3.5.2.4 Tasters' panel sensory evaluation

In addition to physical and chemical testing, the grapes were tasted by a sensory panel. A panel of expert tasters conducted a sensory test of taste. This qualitative index offered valuable feedback on the consumer acceptability of grapes in each treatment group. This sensory assessment was applied to amplify Brix measurements and give a holistic view of fruit quality.

Through the data-selection of leaf and fruit parameters, the research aimed to understand more fully how each fertilizer regime impacted grapevine health, yield and fruit quality. Quantitative data and sensory measurements meant that the grapes could be assessed objectively as well as subjectively, thereby yielding a balanced assessment of the effects of treatment.

The panel of tasters assessing grape quality adhered to international fruit evaluation standards for consistency and objectivity. The research study selected six professional tasters and educated them about the evaluation protocol. The research ensured objectivity by presenting each panelist with anonymized samples from three treatment groups under controlled conditions. The panel evaluated grapes by examining their appearance, texture, sweetness, acidity, and overall flavor using a 10-point rating scale. The tasting sessions occurred in a room with adequate lighting and neutral ambiance while palate cleansers such as water and plain crackers were presented between each sample. The data were recorded, each attribute score was recorded separately before conducting statistical analyses to determine fertilization treatments' effects on sensory quality. The methodology follows ISO sensory analysis standards which enables trustworthy fruit quality comparisons among different treatments (International Organization for Standardization ISO, 2003).

# Chapter Four

## Results and Discussion

### 4.1 Fertigation treatments effect on grapevine growth parameters

Leaf surface area was measured by ImageJ software, chlorophyll levels with a SPAD meter, leaf shine/softness was measured by a sensory panel using a standardized scoring system (1 – 10). Data statistically analyzed using one-way ANOVA and matched the means using Tukey's HSD test ($p \leq 0.05$).

The MIRA Solution (Group A) application had the highest leaf area, chlorophyll and leaf shine/softness of all treatments (Table 4.1). Chemical fertilizer (Group B) improved these parameters too but less than MIRA Solution compared with the control (Group C). ANOVA showed significant differences between treatments in every parameter that was analyzed ($p \leq 0.05$).

The leaf area is the most important measure of photosynthetic capacity and vine health. With the highest average leaf area of 237.0 ± 14.0 $cm^2$, Group A was followed by Group B (217.1 ± 12.0 $cm^2$) and Group C (190.0 ± 15.4 $cm^2$). ANOVA confirmed significant differences between the groups ($p = 0.001$), post hoc Tukey tests showed that leaf area of Group A was significantly higher than that of both B and C; therefore, MIRA Solution increases leaf growth more than either chemical fertilizers or no fertilization.

Table 4.1: Effect of fertilization treatments on grapevine leaf parameters

| Parameter | Group A (MIRA) | Group B (Chemical) | Group C (Control) | p-value |
|---|---|---|---|---|
| **Leaf Area ($cm^2$)** | 237.0 ± 14.0 a | 217.1 ± 12.0 b | 190.0 ± 15.4 c | 0.001 |
| **Chlorophyll Content (SPAD)** | 43.8 ± 3.0 a | 39.6 ± 2.7 b | 34.2 ± 2.5 c | 0.002 |
| **Shine/Softness Score** | 8.7 ± 0.6 a | 7.4 ± 0.5 b | 6.2 ± 0.7 c | 0.003 |

Values are means ± standard deviation. Different letters within rows indicate significant differences at $p \leq 0.05$.

The amount of chlorophyll is a measure of the plants' photosynthetic efficiency and nitrogen levels. Chlorophyll content: Group A had the most chlorophyll (43.8 ± 3.0 SPAD units), Group

B was at 39.6 ± 2.7, and Group C at 34.2 ± 2.5. There was statistical significance between the groups ($p = 0.002$), and Group A did better than the other groups. This means that MIRA Solution can increase nitrogen uptake or assimilation and increase chlorophyll production.

The shining and softness of the leaves are qualitative measures of plant health and usually go hand in hand with a high concentration of nutrients and hydration. Group A got the best value, 8.7 ± 0.6 followed by Group B 7.5 ± 0.5 and Group C 6.2 ± 0.7. There was a significant difference ($p = 0.003$) in ANOVA results for Group A with better quality leaves. This would mean that MIRA Solution helps with leaf texture and can also help photosynthetic productivity and disease resistance.

Since MIRA Solution has better results in leaf area, chlorophyll and leaf shine/softness, metabolized date palm fruit-waste is an excellent organic fertilizer for grapevines. It was probably the nutrients and organic matter of MIRA Solution that gave the soil a better fertility and structure, which allowed it to take up more nutrients and sustain vigorous vegetative development. Such results match Wu *et al.* (2024) who mentioned that organic fertilizers produced higher yields of grapes and improved the soil quality as compared with chemical fertilizers.

However, chemical fertilizer treatment, while preferable over control, was not as good as MIRA Solution. This is perhaps because chemical fertilizer releases nutrients too fast, which causes leaching and lower efficiency in use. Also, chemical fertilizers has no addition to soil organic matter, which is vital for healthy soil. Döring *et al.* (2015) found that organic and biodynamic management systems (that increased soil organic matter) decreased vine growth and yield relative to integrated systems demonstrating the significance of soil organic matter for vine productivity, but they also connected the result with downy mildew disease as the main reason for decreasing in yield.

It was the control group that had the lowest values of all measured parameters, showing that the best grapevine growth could not occur without fertilization. Lack of supplementation must have curtailed physiological processes of the vines, limiting leaf growth and production of chlorophyll.

In the long term, the findings show that MIRA solution made from reabsorbed date palm waste can be used as an alternative to chemical crop fertilizer for grapevines. Not only does its use promote green growth and leaf health, but it's also used to support sustainable agriculture, recycling agricultural wastes and promoting healthy soils. Additional long-term trials are advised to assess the combined effects of MIRA solution on grapevine yields and soil conditions.

These results lend a thumbs up to organic fertilization practices in viticulture, especially in areas with high dates and date waste to make viticulture circular and without needing synthetic fertilizers.

## 4.2 Impact of MIRA solution on grape yield and quality

Utilization of decomposed date palm waste as an organic fertilizer has received attention because of its potential to improve grapevine yields and fruit quality. The effect on yield and quality was significant. Clusters in MIRA Solution group were larger and heavier than the Groups B and C, showing it could increase yield and quality of fruits.

### 4.2.1 Grape yield enhancement

Date palm fruit-waste was applied to boost yields by more than three times as much as the control treatments. The average cluster weight of treated vines as mentioned in Table 4.2 was 320 ± 15 grams, which was higher than the control vines (250 ± 14 grams). Cluster size was measured by multiplied length and width, where length was measured as the distance from the cluster base (apart from the stem attachment) to the cluster end. And the width was from the broadest part of the cluster perpendicular to the length. Cluster size also boosted with the treated vines averaged 224 ± 1.1 $cm^2$, compared with 185 ± 1.3 $cm^2$ in control. These differences were statistically significant ($p = 0.002$).

Table 4.2: Impact of fertilization on grape yield and quality

| Parameter | Group A (MIRA) | Group B (Chemical) | Group C (Control) | ANOVA Significance (p-value) |
|---|---|---|---|---|
| **Cluster Weight (g)** | 320 ± 15 a | 295 ± 12 b | 250 ± 14 c | **0.001** |
| **Cluster Area ($cm^2$)** | 224 ± 1.1 a | 208 ± 1.0 b | 185 ± 1.3 c | **0.002** |

Values are means ± standard deviation. Different letters within rows indicate significant differences at $p < 0.05$.

Such results line up with those of Wu et al. (2024), who found that organic fertilizers even those made from farmyard excrement increased grape yields by restoring fertility and texture to the soil. Their experiment showed that organic amendments increased soil organic matter and nutrients, and improved grape yields.

The impact of MIRA solution on grape yield in the Jordan Valley was much greater than chemical fertilizers and control group (as indicated by the results shown in Table 4.3). Such findings emphasize how sustainable fertilization can enhance farm output.

Grapevines with MIRA solution yielded the most (6.7 ± 0.5 kg/tree), way more than the chemical fertilizer (5.6 ± 0.6 kg/tree) or control (4.0 ± 0.7 kg/tree) treatments. This finding suggests that the nutrient profile offered by digested date palm wastes is very good for vine development and yields, perhaps through enhanced soil fertility and plant absorption.

Group A's yield difference from Group B shows that organic fertilizers can equal, even exceed, the performance of chemical fertilizers.

Table 4.3: Productivity analysis (Yield and Cluster number)

| Parameter | Group A (MIRA) | Group B (Chemical) | Group C (Control) | ANOVA Significance (p-value) |
|---|---|---|---|---|
| **Total Yield (kg/tree)** | 6.7 ± 0.5 a | 5.6 ± 0.6 b | 4.0 ± 0.7 c | **0.001** |
| **Cluster Number (clusters/tree)** | 21 ± 1.5 a | 19 ± 1.1 b | 16 ± 1.3 c | **0.002** |

Values are means ± standard deviation. Different letters within rows indicate significant differences at $p \leq 0.05$.

Grape cluster number followed the same pattern and MIRA solution gave the most clusters (21 ± 1.5 clusters/tree) when compared with the chemical fertilizer (19 ± 1.1 clusters/tree) and the control (1.6 ± 1.3 clusters/tree). This increase in cluster number is due to bio-fertilizers supporting fruiting, possibly through increased aeration, microbial growth, and availability of nutrients.

ANOVA ($p < 0.05$) proves that there is a substantial difference in yield and cluster number among all three groups and not by accident.

The previous findings show how digested date palm waste can be an alternative to chemical fertilizers that are sustainable. MIRA bio-fertilizer provides productivity as well as sustainable farming, through organic waste recycling. That could mean enormous ecological and economic rewards in areas such as the Jordan Valley where temperate climates and scarce resources call for innovative and sustainable agricultural systems.

### 4.2.2 Fruit quality improvement

Use of digested date palm residue improved fruit quality parameters. Brix, the sugar content (See Table 4.4) who was measured using refractometer, was higher in treated grapes (19.6 ± 0.8% and 28.0 ± 0.9%) than in control (15.5 ± 0.7%), p-value under 0.001. Group B was sweeter than both groups, with a close brix level to MIRA solution.

Table 4.4: Impact of fertilization on grape brix level %

| Parameter | Group A (MIRA) | Group B (Chemical) | Group C (Control) | ANOVA Significance (p-value) |
|---|---|---|---|---|
| **Brix Level (%)** | 19.6 ± 0.8 a | 20.8 ± 0.9 b | 15.5 ± 0.7 c | **0.001** |

Values are means ± standard deviation. Different letters within rows indicate significant differences at $p < 0.05$.

Li *et al.* (2022) also noted the same quality improvements in grapes after organic fertilization. In their research, they concluded that organic fertilizers increased soil nutrients and microbe activity, leading to an increase in grape quality traits of sugar content and flavor.

Fertilization is also central to viticulture, affecting vine strength, yield and fruit quality. The study compared three sensory evaluation scores for grapes. Grapes were ranked on sweetness, taste and texture by a sensory assessment panel. Table 4.5 summarizes these findings. Grapes in Group A scored highest on sensory score, supporting the chemical data and displaying increased consumer value. On sensory testing, treated grapes rated higher on sweetness, flavor and texture with p-values less than 0.002.

Table 4.5: Sensory Evaluation Scores

| Attribute | Group A (MIRA) | Group B (Chemical) | Group C (Control) | ANOVA Significance (p-value) |
|---|---|---|---|---|
| **Sweetness** | 8.9 ± 0.4 a | 8.2 ± 0.5 b | 7.3 ± 0.6 c | **0.001** |
| **Flavor** | 8.7 ± 0.3 a | 8.1 ± 0.4 b | 7.5 ± 0.5 c | **0.002** |
| **Texture** | 8.8 ± 0.2 a | 8.3 ± 0.3 b | 7.4 ± 0.4 c | **0.001** |

Values are means ± standard deviation. Different letters within rows indicate significant differences at $p < 0.05$.

Sensory scores were evaluated through trained teams who are already working on the farm and evaluated the products that sold to the market. Their evaluation was based on a scale from 1 to 10, where 1 is the lower and 10 is the higher in the parameters. Brix measurement accurately measures grape sweetness but fails to reflect acid balance, texture, or aroma which also determines fruit quality. Unlike Brix measurement, sensory evaluation delivers a fuller evaluation because it includes additional crucial factors. Although a high Brix value indicates sweetness levels fruits achieve, they do not ensure superior sensory scores because acidity along with texture and aroma significantly impact consumer preferences. The combined use of these methods produces a comprehensive evaluation of grape quality which meets both scientific standards and consumer requirements.

### 4.2.3 Soil health and sustainability

Adding digested date palm manure improved the quality of soils by adding more organic matter and nutrients, helping them hold water and produce roots. This ecological activity aligns with circular economy principles by composting agricultural manure into fertile soil amendments.

Abid and Ammar (2022) reported on the advantages of date palm husk as a soil amendment improved soil structure and fertility, all key elements for sustainable farming.

## 4.3 Comparative analysis with chemical fertilizers

Chemical fertilizers also increased yield and quality relative to the control, but they did so more slowly than with digested date palm waste. Chemical fertilizers were unhygienic for soil and a threat to the environment through leaching and runoff.

Organic fertilizers can, as many studies have documented such as (Kaya *et al.*, 2024), be more effective than chemical fertilizers in increasing yield and quality of crops while supporting the environment. Organic fertilizers added moisture to the soil and produced more phenolics in grapes that improved the quality of the fruit.

Digested date palm manure can produce more grapes with higher yield and better quality than chemical fertilizers when used organically. This is not only more productive, but it is healthier for the soil and in keeping with the principles of sustainable agriculture. These results are matched by the literature and suggest the promise of organic viticulture amendments.

The beneficial effects of organic fertilization on grapevine growth factors along with what were expected. For instance, Döring et al. (2015), organic and biodynamic management systems excluding synthetic fertilizers caused lower vine yields than integrated systems. But they did note that quality metrics for fruit didn’t change in organic treatment. This implies that organic treatments such as MIRA Solution may help improve some growth parameters but the overall effect on fruit quality is an area that remains to be explored.

There is also work by Wu et al. (2024) showed that commercial organic fertilizers did not decrease the amount of nutrients in the soil or grape production when used instead of chemical fertilizers.

It’s consistent with what the present research suggests: that organic fertilization can have beneficial effects on vine growth and yield.

In this comparative analysis, we have found that MIRA Solution significantly increases grapevine growth measures like leaf area, chlorophyll content, leaf shine/softness compared to chemical fertilizers and zero fertilization. Such increases could be attributable to increased nutrient availability and absorption by organic fertilization. They were on the same page with other publications, suggesting the possibility of using organic fertilization in sustainable viticulture.

## 4.4 Sustainable practices and implications for grape cultivation

Sustainable viticulture takes environmental protection, economic sustainability and social justice into account to sustain vineyards and their communities over the long-term. This research shows that digested date palm and manure can be used as an organic fertilizer for sustainable grape production to improve soil health, grape quality and decrease chemical use.

### 4.4.1 Environmental Implications

Incorporating digested date palm manure in a soil is fertilizing by adding organic matter, improving soil texture and encouraging beneficial microorganisms. They also improve the water-retention and availability of nutrients, which are very important to vine in arid areas such as the Jordan Valley. Moreover, the utilization of agricultural waste is compatible with the concept of waste reduction for circular economy and environmental minimization.

Others have also shown the ecological value of organic amendments to viticulture. In fact, a study in Agronomy found that conservative soil management practices like organic fertilizers maintain biodiversity and soil fertility, which are important to healthy vineyard ecosystems (Cataldo *et al.*, 2020).

### 4.4.2 Economic Implications

The economics of sustainable fertilization can save the cost of chemical fertilizers and make the grapes better, resulting in more value at the market. Since more fruits and a higher yield have been obtained using digested date palm dung, the producers can profitably do this in a sustainable manner.

The economic value of sustainable viticulture is supported by the following report in the American Journal of Enology and Viticulture: Sustainable production can result in higher yields and better-quality grapes for greater returns to growers (Ingels, 1992).

### 4.4.3 Social Implications

On a social level, sustainable development benefits communities through the reduction of toxins from chemicals and safer labor. It also supports information exchange and training of farmers on sustainable farming resulting in healthier farming communities.

The social dimensions of sustainable viticulture have been emphasized in (Santini *et al.*, 2013) article which mentioned that sustainable winemaking has environmental, economic and social dimensions, all contributing to the sustainability of the local communities involved in grape production.

The encouraging findings of this research converge with other research worldwide for sustainable viticulture. For instance, (Cataldo et al., 2020) stated that organic fertilizers and soil management had a major impact on the quality of grapes and reduced biogenic amines, which are both positive for growers and consumers.

**4.4.4 Implications for the Jordan Valley - Jeftlik**

Sustainable fertilization in the Jordan Valley can solve certain regional issues, like soil erosion and water shortage. Not only is using locally generated organic matter such as date palm waste healthier for the soil, but it also offers a sustainable, cheaper alternative to chemical fertilizers.

Furthermore, these methods can make grape plantations more climate-resilient for the benefit of long-term agriculture in the area. Digestible date palm waste as an organic fertilizer could be a promising path to sustainable grape farming. This research and the ecological, economic and social benefits found here as also documented by related studies, prove the value of sustainable viticulture. In the Jordan Valley, it’s not just good for grapes but is better for the planet and the wellbeing of everyone.

# Chapter Five

# Conclusion and Recommendations

## 5.1 Conclusion

This research compared digested date palm waste (MIRA solution) with conventional chemical fertilizer and no fertigation for grapevine growth, production and fruit quality in the Jordan Valley. These results show that MIRA solution made a huge impact on vine health, soil fertility and grape yields. Fertilized grapevines were also larger in leaf area, chlorophyll content, and leaf quality (softness and shine) which confirm its effectiveness for vegetative growth. Grapevines fertilized with MIRA solution grew the most yield and higher-quality fruit by cluster size, weight, Brix and taste (compared to chemical fertilizer or control groups). Digested date palm waste helps in sustainable agriculture by recycling organic waste, improving soil structure and reducing chemical use. The findings indicate that digested date palm waste can provide an environmentally sustainable alternative to a typical fertilizer in the circular economy and underline agroforestry for arid and semi-arid environments.

Soil quality in the experimental vineyard saw significant improvements after using the MIRA solution created from digested Date palm waste. The solution's high organic matter content and nutrient-rich composition led to improved soil structure and increased cation exchange capacity (CEC) while supporting microbial activity which are important soil fertility indicators. Notably, the MIRA solution had a pH range between 5 and 6, while the baseline soil pH in the experimental site was measured at 8.3, indicating highly alkaline conditions. This contrast suggests that the slightly acidic nature of MIRA solution may have contributed to buffering the high alkalinity of the soil, promoting improved nutrient solubility and root uptake in an otherwise challenging environment for micronutrient availability. The healthier root environment and increased nutrient absorption resulting from these improvements led to observed superior vine performance.

The production of MIRA solution through anaerobic digestion served both to recycle agricultural waste and to produce biogas which supplied renewable energy for on-farm use. The two-fold advantage promotes circular economy strategies because it converts waste into agricultural resources and clean energy which helps decrease reliance on synthetic fertilizers and fossil fuels. The application of MIRA solution demonstrates a sustainable approach for improving soil health alongside energy self-sufficiency in dry farming regions such as the Jordan Valley-Jeftlik.

## 5.2 Recommendations

**This study recommends the following:**

1. Encourage MIRA solution adoption in grape farming in Jordan Valley and other dry areas to improve yield, quality and soil sustainability.
2. Complete a cost-benefit analysis comparing the long-term economic benefits of MIRA solution versus chemical fertilizers in terms of lower input costs and potential market price premiums for sustainably grown grapes.
3. Plan to repeat the experiment over several growing seasons to see how MIRA solution cumulatively impacts soil, vine growth, and fruit quality.
4. Build the infrastructure to scale the production and distribution of MIRA solution for general agricultural use including other crops and environments like that of MIRA solution.
5. Conduct farmer training in the manufacturing, use and uses of MIRA solutions to get its integration in traditional agriculture.

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**تأثير مخلفات ثمار التمر المهضومة على زراعة العنب**
**دراسة حالة: الجفتلك / غور الأردن**

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## الملخص

تبحث هذه الدراسة في تأثير مخلفات التمر المهضومة، التي تم تحويلها إلى سماد حيوي يُعرف باسم محلول ميرا (MIRA)، على نمو كروم العنب وإنتاجيتها وجودة ثمارها في منطقة غور الأردن/الجفتلك. يهدف البحث إلى استكشاف مدى فعالية محلول ميرا كبديل عضوي للأسمدة الكيميائية التقليدية، وتقييم دوره في تحسين أداء النبات مع تعزيز الممارسات الزراعية المستدامة.

تعتمد الدراسة على تصميم تجريبي يتضمن ثلاث مجموعات معالجة: المجموعة (A) تمثل كروم عنب مُسمّدة بمحلول ميرا، والمجموعة (B) تمثل كروم عنب مُسمّدة بالأسمدة الكيميائية، بينما المجموعة (Control) هي مجموعة بدون تسميد إضافي . تم تحليل المعايير الأساسية للنمو، مثل مساحة الأوراق، ومستوى الكلوروفيل، وملمس الأوراق، بالإضافة إلى عوامل الإنتاجية، مثل وزن العناقيد، والإنتاج الكلي لكل شجرة، وجودة الثمار المتمثلة بـ (مستوى البريكس، اللون، والتقييم الحسي).

أظهرت النتائج أن محلول ميرا يعزز بشكل كبير نمو وإنتاجية كروم العنب، حيث سجلت الكروم المعالجة به مساحة أوراق أكبر (237 سم²)، ومستوى كلوروفيل أعلى (43.8 وحدة سباد)، وتحسنًا ملحوظًا في ملمس الأوراق مقارنة بالمجموعات الأخرى. كما أظهرت النتائج تحسنًا واضحًا في الإنتاجية، حيث بلغ متوسط وزن العناقيد 320 جرامًا، والإنتاج الكلي 6.7كجم لكل شجرة، متجاوزًا المجموعتين المعالجة بالأسمدة الكيميائية ومجموعة عدم وجود سماد. أما جودة الثمار، فكانت أفضل بشكل ملحوظ، حيث سجلت مستوى بريكس 19.6%، إلى جانب تحسن في الخصائص الحسية مثل الحلاوة والملمس والنكهة.

بالإضافة إلى تحسين الإنتاجية، يساهم محلول ميرا في تحسين تركيبة التربة، وتعزيز خصوبتها، ودعم نشاط الكائنات الدقيقة، مما يعزز مبادئ الاقتصاد الدائري والزراعة المستدامة من خلال إعادة استخدام المخلفات العضوية. وتخلص الدراسة إلى أن محلول ميرا يُعد بديلًا واعدًا وصديقًا للبيئة للأسمدة الكيميائية، لا سيما في المناطق الجافة وشبه الجافة مثل غور الأردن. وبناءً على هذه النتائج، توصي الدراسة بتوسيع إنتاج محلول ميرا، وإجراء دراسات طويلة الأمد، ودمجه في ممارسات الري العضوي ضمن استراتيجيات الزراعة المستدامة.