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RESEARCH ARTICLE

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Soilless vs. Traditional Farming: A Study on Disease Suppression and Crop Yield Optimization in Cucumber Plants

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ABSTRACT

Sustainable agricultural production is a key objective for enhancing food security and safeguarding human health. This study investigates the impact of soilless agricultural systems on plant disease incidence and crop yield, specifically in cucumber plants, compared to traditional soil-based farming methods. The study collected data on these two styles of farming from farms in hot areas. Environmental parameters, including temperature and humidity, as well as irrigation water electrical conductivity (EC) and pH, were monitored to assess their suitability for plant growth. Maximum recorded temperatures of 45°C and humidity levels of 68% in greenhouses reflected conditions conducive to plant disease development. In soilless systems, the observed plant diseases included downy mildew and anthracnose with moderate severity (severity index of 2), whereas traditional systems exhibited a broader spectrum of diseases, including fungal, bacterial, viral, and nematode infections. Crop yield under soilless systems reached 89,435.5tons/ha, significantly higher than the 46,341.6tons/ha achieved in traditional systems. The findings suggest that soilless agricultural systems can reduce the need for disease control measures and substantially increase crop production. The study recommends adopting soilless systems, particularly in regions experiencing rising temperatures due to climate change, to effectively manage plant diseases and enhance agricultural productivity.

Keywords: Soilless agricultural systems, Traditional systems, Plant disease, Environmental conditions, Cucumber plants, Plant production

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INTRODUCTION

Soilless systems (SS) are one of the new agricultural trends used to save food in different areas of the world. The SS are distributed in urban areas due to the possibility of using them in different spaces. One of the significant advantages of SS is their crucial role in controlling plant pathogens by leveraging plant growth-promoting microorganisms and implementing effective disease management strategies (Mourouzidou et al., 2023). These systems reduce pathogen contamination and enhance plant productivity (Kumar et al., 2024). Aquaponic and hydroponic systems, as alternatives to traditional soil-based systems (TS), minimize the risk of soil-borne pathogens while improving crop yields. The health of plants in SS is further supported by the beneficial microbiota inherent to these systems, which act as protective and growth-promoting entities (Alsanius & Wohanka, 2019).

The SS plays a crucial role in reducing pathogens in different ways. The SS systems implement various techniques including biocontrol agents, the dynamic filtration system, and the suppressive bacteria. The SS systems offer a natural and eco-friendly approach by both water and plants without the use of chemicals or energy sources (Rajatha et al., 2022). The SS systems increase disease resistance as the experiments were approved on tomatoes and bananas (Khalil & Alsanius, 2011). Moreover, the use of organic-based nutrient solutions produces lower levels of pathogens compared to traditional inorganic fertilizers (Alneyadi et al., 2024). These findings contribute

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to the production of safe food, minimize environmental impacts, and promote sustainable crop production. SS offer controlled environments for plant growth by integrating various components alongside efficient nutrient delivery and environmental regulation. These systems incorporate advanced technologies, such as mist-generating units, nutrient solution storage, and gas jetting, to provide optimal growing conditions (Chen et al., 2022). Automated control technologies further enhance the transparency and precision of the cultivation process throughout the growing season, resulting in optimal plant development.

SS provide a sterile growing environment that reduces plant pathogens by promoting the growth of beneficial microbes that suppress harmful organisms (Mourouzidou et al., 2023; Ochieno, 2022). Unlike traditional soil-based systems (TS), the absence of soil contact in SS minimizes exposure to contamination sources responsible for plant diseases (Savvas & Gruda, 2018). In SS, the nutrient solution is collected and recycled within a closed system, reducing the risk of pathogen transmission to plants (Van Ruijven et al., 2017). By integrating microbiome conservation into SS technology, these systems achieve more sustainable and disease-resistant cultivation (Ochieno, 2022).

The hygiene practices in the SS systems reduce plant pathogens through the application of different control measures. In these systems, microbial inoculants, the nutrient solution circulation that allows microbial detections, and the suppressive growing systems will combat diseases (Gonnella & Renna, 2021; Mourouzidou et al., 2023). The substrate used in the SS system influences plant health and some substrates reduce plant diseases (Beaulieu et al., 2022). The use of developed technology will enable the control of pathogens (Mourouzidou et al., 2023).

The reservation of nutrient supply for the plants in the SS system ensures sustainable plant growth through the system. In contrast, TS are prone to nutrient imbalances, often resulting in physiological disorders in plants due to fluctuating environmental factors. These challenges can be mitigated in SS through the integration of advanced breeding techniques and technology designed to optimize nutrient delivery and alleviate such conditions (Birlanga et al., 2022). The use of organic fertilizer in the SS systems decreases the susceptibility of exposure to pathogens in SS systems.

Biological control, early detection, and intervention reduce the diseases in SS systems. Gilardi et al. (2022) have shown that utilizing non-pathogenic strains of *Fusarium oxysporum* reduces disease severity. The plant growth-promoting microorganisms demonstrated effectiveness in disease management which led to a reduction in disease severity through increasing the plant resistivity (Mourouzidou et al., 2023).

The countries experiencing water scarcity for irrigation started to benefit from the SS system as a source of saving water in the agriculture cultivation process as well as improving plant production due to the alleviation of plant pathogens existing in TS (Shtaya & Qubbaj, 2022). High temperature conditions and high humidity conditions increase the susceptibility of soil pathogens which increase under these conditions and reduce plant production. Jordan one of the countries suffering from water scarcity started to experience SS systems to face that and improve plant production. This study will investigate the effect of SS systems on plant pathogens and plant production. This study aimed to investigate the effect of the soilless system on the occurrence of plant diseases, vegetative growth, and production compared to traditional systems in cucumber plants.

MATERIALS & METHODS

Research Problem

Some areas are suffering from climate change and the distribution of plant diseases reduces plant production (Ma et al., 2024). Moreover, the scarcity of water increased and the lack of good protection environments increased plant diseases (Lahlali et al., 2024). The soilless agricultural systems are expected to save the closed and control system which helps protect and reduce the plants of diseases (Mourouzidou et al., 2023). These systems are expected to increase and improve the distribution of agricultural businesses due to the maximization of profits. Besides the increase in production quantity, the quality will be improved which is considered the key to improving agribusiness (Mourouzidou et al., 2023).

Research Objectives

The objective of this study is to investigate the soilless agricultural systems in protecting plants from common diseases compared to TS.

Experiment Locations

This study concentrated on collected observations from farms that apply this system in the Jordan Valley about 50kms from Amman in the western parts of Jordan and Mafraq areas about 68kms east of Amman. The experiment was executed in the period from August 2023 to October 2023.

Agricultural Practices

The observed farms apply the soilless closed agricultural systems. These systems use closed water and fertilization systems. These systems applied organic fertilizers. The collected drained water was pumped through the closed system which increased the benefits of using the organic fertilizers in these systems. The systems (Dutch Buckets) were provided by two layers of volcanic tuff (Al-Ajlouni et al., 2017; Al-Zboon et al., 2019). These systems contained two layers; the first layer consisted of course tuff and the upper layer consisted of fine tuff where the crop roots were located. These systems were sterilized before the planting process. The other farms are TS the common practices in the area.

Crop and Fertilization

Cucumber was used for planting. The number of cucumber seedlings used per treatment reached 180 seedlings according to practices in these areas. The filling practices were used to preserve an equal number of plants in the SS and TS for comparison and measurement purposes. Three fertilizer solutions were used. The first solution consists of 17kg of calcium nitrite in addition to 300gm of Fe EDDHA 6%; while the other solution consists of 17kg of NPK-12-12-36, 7 kilograms of NPK-10-3-43, and 8 kilograms of magnesium sulfate in addition to 400 grams of microelements; and the last solution consists of phosphoric acid as a pH buffer (Xu et al., 2021). Organic fertilizer was only applied with the amounts popular in the experiment area. In TS, manure was added as a source of fertilization and the NPK traditional fertilizers.

General Measurements

The panting environment including the air temperature (ºC) and the humidity (%) of the greenhouses were measured regularly. Irrigation water pH and electrical conductivity (EC) (dS/m) were measured regularly to ensure that the water was within the required characteristics.

Plant Measurements

Plant diseases were measured through the observation process in soilless and TS. The diseases observations included fungal, bacterial, viral, and nematode diseases. The severity of the disease was recorded through five scale measures. The very limited incidence was given (1), while the code (2) was given for the limited distribution of the diseases. Code (3) was given for the moderate distribution of plant disease, code (4) was given when most of the field was infected, and code (5) was given when the field was completely infected. Concerning the vegetative measurements, the plant height and production were measured.

Statistical Analysis

Descriptive analysis was used to analyze the environmental measurements, while the frequencies of observations were used to measure the presence of cucumber plant diseases. The three farms used in this experiment were visited twice a week. The total crop yield was analyzed in the three farms. The analysis of variance using the RCBD design was used to test the differences between the different treatments.

RESULTS

The Environmental Conditions of Plant Growth

The results indicate significant temperature fluctuations throughout the growing season, with recorded temperatures ranging from a minimum of 25°C to a maximum of 45°C. This variation in temperature creates an environment highly conducive to the proliferation of viruses and bacteria under traditional cultivation conditions (Fig. 1). The persistent temperature fluctuations during the growing season increase the likelihood of diverse plant diseases. Elevated temperatures were also associated with considerable variations in humidity, ranging from 55% to 68%. These conditions further promote the growth of viruses and bacteria under typical environmental circumstances (Fig. 2). The pH levels recorded in the irrigation water ranged from 5.8 to 6.4, indicating neutral conditions that are well within the tolerance range for cucumber plants, thus not adversely affecting their production (Fig. 3). The salinity levels of the irrigation water, measured as electrical conductivity (EC), remained within acceptable limits for cucumber cultivation, with both the minimum and maximum EC recorded at 1.5 dS/m (Fig. 4). This range is deemed suitable for sustaining optimal cucumber production.

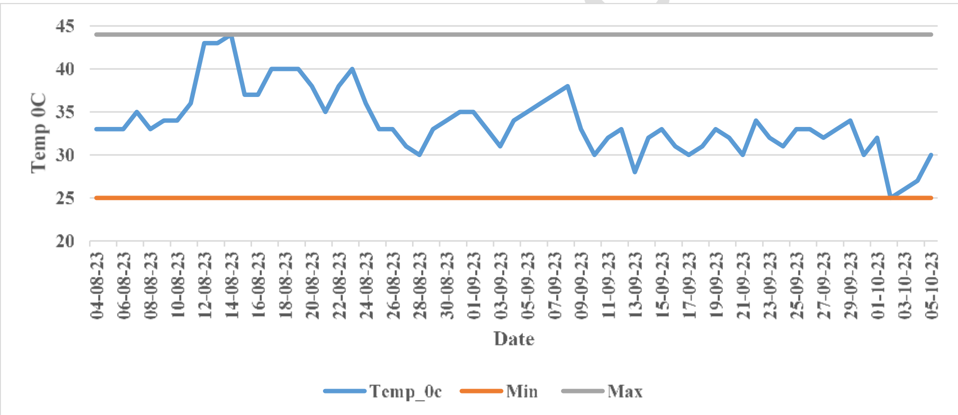

Fig. 1: The temperature (ºC) through the growing season

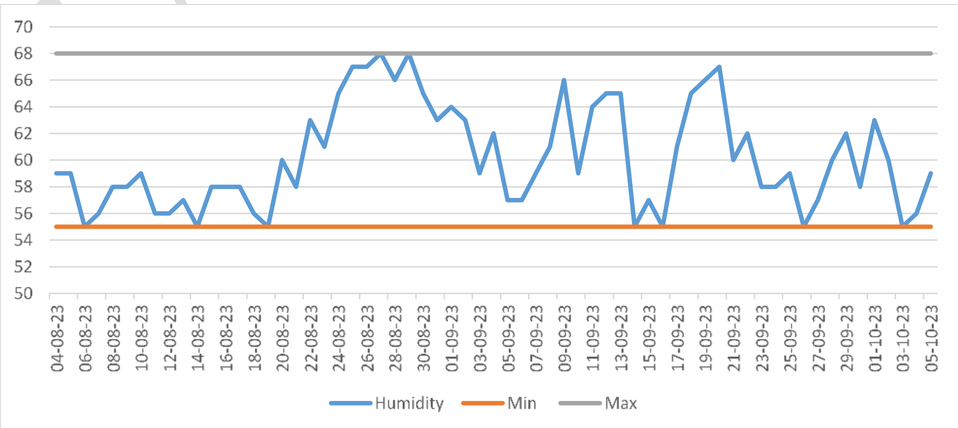

Fig. 2: The humidity (%) through the growing season

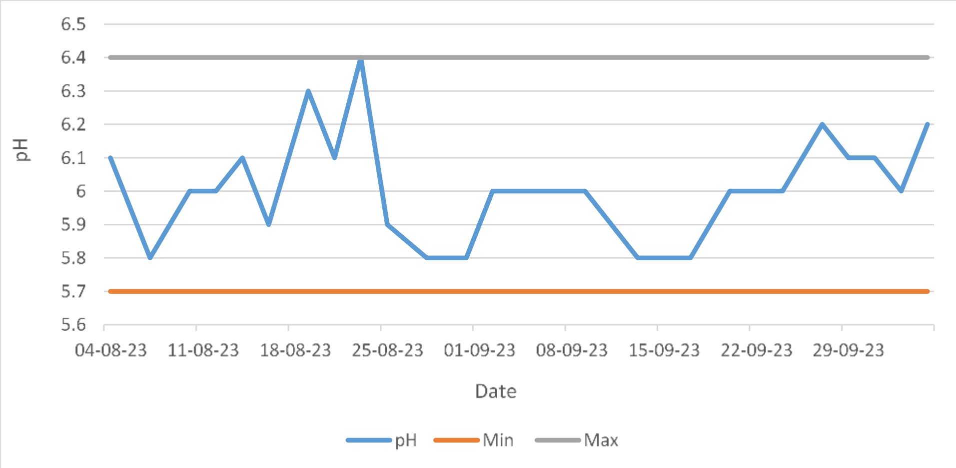

Fig. 3: The pH degrees recorded for the irrigation water through the season

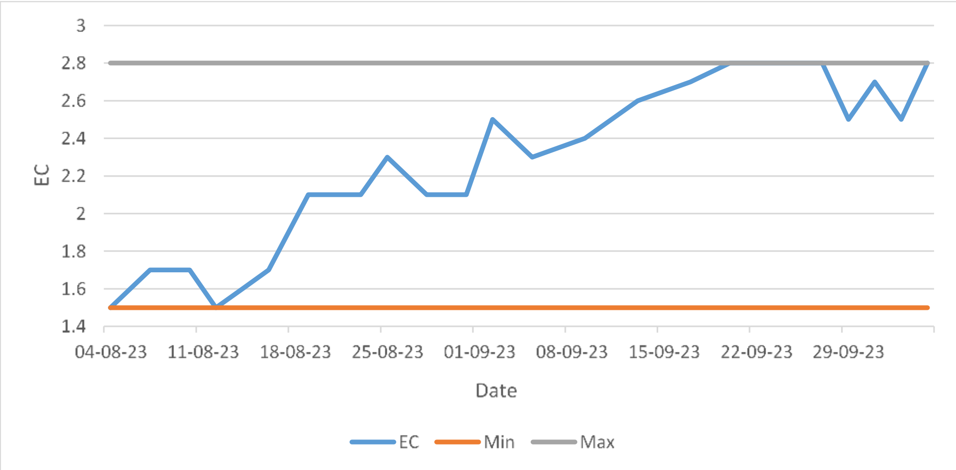

Fig. 4: The recorded EC (dS/m) values for irrigation water through the season.

The Plant Diseases Recorded under SS and TS

Wide variation in cucumber diseases was recorded between the soilless agricultural system compared to the TS. The results showed that downy mildew was recorded slightly in the SSs with a "2" severity rank. The other fungal disease recorded in cucumber in the SS was anthracnose with slight distribution. On the other hand, different diseases were recorded in the TS. The fungal diseases including powdery mildew, downy mildew, anthracnose, and fusarium wilt were recorded at different times through the growing season with severe distribution.

Moreover, bacterial diseases appeared in the TS including the bacterial wilt and angular wilt with medium to severe incidences. The viral diseases were distributed almost severely in the TS including the cucumber mosaic virus and Zucchini yellow mosaic viruses. The nematode disease related to root-knot nematodes appeared intensively in the TS.

Seasonal Cucumber Yield

The results showed that the average plant height recorded for the SSs was 2.27m compared to 1.28m for the TS with statistically significant differences ($P<0.05$). Moreover, the average production per cucumber plant under the SS was 4.39kg compared to 2.47kg for the TSs with statistically significant differences ($P<0.05$) (Table 1). The results show a wide variation in the production of the two agricultural systems. The records showed significant differences ($P=0.001$). The production in the SSs was 89435.5ton/ha double the production in the TSs (46341.6ton/ha) (Table 2).

Table 1: The distribution of cucumber plant diseases in the soilless and traditional systems, Severity score: 1: very limited, 2: limited, 3: moderately distributed in the field, 4: most of the field infected, 5: completely distributed in the field.

Cucumber diseases	Soilless	Severity score	Traditional	Severity score
Fungal diseases				
Powdery mildew	--		✓	
Downy mildew	✓	2	✓	5
Anthracnose	✓	2	✓	5
Fusarium Wilt	--		✓	4
Bacterial Diseases				
Bacterial wilt	--		✓	5
Angular Leaf Spot	--		✓	3
Viral Diseases				
Cucumber mosaic virus	--		✓	4
Zucchini yellow mosaic virus	--		✓	4
Nematode diseases	--			
Root-knot nematodes	--		✓	4

Table 2: The comparison of cucumber production (Ton/ha) for the soilless and traditional systems

Practices	Total Yield Ton/ha	t-value	P
Plant height			
SS	2.27	4.36	0.042*
TS	1.28		
Plant production			
SS	4.39	4.23	0.043*
TS	2.45		
Total production			
SS	89435.5	5.602	0.001**
TS	46341.6		

P: probability, *: $P<0.05$, **:$p<0.01$

DISCUSSION

This study aimed to investigate the effect of agricultural practices on plant diseases. The cucumber plant was used for this comparison as it can be used under soilless agricultural systems. The practices in the SS were completely different concerning the planting media, the fertilizer application, and the sterilization techniques applied. Organic materials were used as a source of nutrients for plants. Organic materials are known as contributors to plant protection and nutrition (Atzori et al., 2021). In the TS, the traditional fertilizers including the natural manure and the herbicides were used as a practice to provide adequate conditions for the plant growth. Moreover, the amounts of irrigation water applied were different between the two systems. In the SS, the amount of irrigation water added was less than that used in the TS. The irrigation water applied to the SSs was closed which minimized the evaporation and reserved the nutrients to be used through water circulation.

The elevated temperatures observed during the cucumber growing season indicate that TS create conditions conducive to the development of plant diseases. Research has demonstrated that high temperatures combined with increased humidity significantly enhance pathogen activity (Chai et al., 2023). Viral diseases, in particular, have been shown to proliferate as temperatures rise under standard growing conditions (Philosoph et al., 2019). Temperature fluctuations further exacerbate conditions favorable for mosaic viruses, which are known to adversely affect cucumber crops (Molad et al., 2021). Additionally, high humidity levels facilitate pathogen transmission and increase plant susceptibility to disease (Chai et al., 2023). Elevated humidity not only accelerates pathogen release but also prolongs their survival, leading to higher disease incidence and severity (Zhao et al., 2022).

The results showed a high distribution of fungal diseases in TS, while the effect on SSs was very limited. Hao et al. (2023) have shown that the use of *Trichoderma asperellum* PT-15 and the compound 6-pentyl-α-pyrone (6-PP inhibit *Fusarium oxysporum* which will reduce the disease severity. Moreover, the use of non-pathogenic strains reduces the infection of fungal diseases in soilless agricultural systems (Gilardi et al., 2022). Generally different findings found that the SSs will mitigate fungal diseases and improve cucumber health. Cultivation techniques without soil, such as hydroponics and aquaponics, are recognized for their ability to alleviate fungal diseases through various mechanisms. The presence of Plant Growth-Promoting Microorganisms (PGPM) like Bacillus, Pseudomonas, and Trichoderma is essential for disease management in hydroponic systems, as these microorganisms demonstrate strong antagonistic characteristics (Mourouzidou et al., 2023). They contribute to reducing the disease severity index by engaging in mycoparasitism, antibiosis and inducing systemic resistance.

Moreover, the controlled soil environment created through reductive soil disinfestation (RSD) in artificially managed soil plays a significant role in disease suppression. This is achieved by modifying soil conditions and fostering microbial communities that are suppressive towards diseases (Liu et al., 2019). Additionally, the implementation of nitrogen-reducing fertilization strategies has been found to lower the incidence and disease index of tobacco diseases by altering the fungal community within the soil. This underscores the importance of indigenous microbial communities in controlling diseases. Collectively, these discoveries underscore how soilless systems exploit microbial interactions and abiotic elements to effectively mitigate fungal diseases and improve plant health in agricultural settings (Shen et al., 2022).

Regarding the bacterial diseases, the soilless agricultural systems were found to control the soilborne diseases providing higher crop production and better growth conditions (Mourouzidou et al., 2023). The SSs minimize the impact of bacterial diseases by utilizing the beneficial bacteria that enhance plant health and control pathogens (Khatri et al., 2023). The research has approved that the microbial communities in the closed agricultural systems closely resemble those in TSs and that the closed systems have capabilities for disease suppression (Li et al., 2023). The use of anaerobic soilless substrates will help in controlling bacterial diseases (Yanez et al., 2024).

Studies have demonstrated that soilless agricultural systems effectively mitigate plant diseases. Viruses, which are often more resilient than other pathogens, pose a significant threat to plants, particularly through waterborne contamination. In traditional soil-based systems (TS), the soil environment provides favorable conditions for viral infections (Yan et al., 2023). However, the disease-suppressive measures implemented in soilless agricultural systems offer effective control and reduce the incidence of such infections (Wu et al., 2022). Notably, the use of Dutch Buckets has been associated with superior vegetative growth characteristics (Abul-Soud et al., 2021). Moreover, the research has found that the volcanic tuff is very efficient in improving plant growth through increasing healthy growth and improving the protection of plant diseases (Al-Zboon et al., 2019). The results of this study are consistent with these findings that approve the suitability of using Dutch Buckets and volcanic tuff in SSs. The SSs were found to have positive effects on cucumber production. The SSs offer advantages for the controlled conditions of plant production including water, fertilizers, and pathogens (Safvan, 2024). Cucumber growth was maintained through the high control of diseases and the possibility to increase control through techniques applied in these systems (Ding et al., 2022).

Conclusion and Recommendation

The objective of this study is to compare the incidence of plant diseases between soilless systems (SS) and traditional soil-based systems (TS). The research was conducted across farms utilizing these two different cultivation methods. Environmental conditions and crop production were monitored to assess the impact of each system on cucumber plants. The findings indicate that soilless agricultural systems offer superior control over plant growth, even under environmental conditions that typically increase disease incidence and severity, which can negatively impact production. Early disease detection and effective management in SS were shown to enhance plant productivity. The results revealed a significant difference in disease control between SS and TS, with the controlled SS yielding double the production compared to TS.

Future Research

Investigating the effect of closed chemical control systems on decreasing plant diseases compared to TSs under hot weather conditions.

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