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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

Efforts were invested to create sustainable agricultural systems that provide food security and preserve human health. Compared to conventional systems, this study aimed to investigate the effect of soilless agricultural systems on plant diseases and production in cucumber plants. The study collected data on these two farming styles from farms in hot areas. The environmental conditions, including the temperature and humidity, were measured. Also, the irrigation water EC and pH were measured to determine irrigation water's suitability for plant growth. Greenhouses' maximum temperature (45ºC) and 68% humidity reflected suitable conditions for plant disease infections. Under the soilless systems, the plant diseases that appeared included downy mildew and anthracnose with medium severity (2), compared to fungal, bacterial, viral, and nematode diseases were recorded among the traditional systems. The production under the soilless systems reached 89435.5ton/ha compared to 46341.6ton/ha in traditional systems. The study concluded that soilless systems decreased the costs of plant disease herbicides and maximized plant production. The study recommended the use of soilless agricultural systems to control plant diseases, especially in the areas that suffer increases in temperatures due to climate change.

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

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INTRODUCTION

One of the newest agricultural innovations utilized to preserve food in many parts of the world is the usage of soilless systems (SS). Because they can be used in a variety of settings, the SS are dispersed across cities. Mourouzidou et al. (2023) discussed the effectiveness of SS systems in managing plant diseases through the use of plant growth-promoting microorganisms and putting into practice well-organized disease-managing techniques providing efficient control. Under SS systems, Kumar et al. (2024) reported that plant infection decreased, and productivity increased. As alternatives to traditional systems (TS), Alsanius & Wohanka (2019) found that hydroponic and aquaponic systems increase agricultural yields and reduce the danger of soil-borne diseases. The health of plants in SS systems is further supported by the beneficial microbiota inherent to these systems, which act as protective and growth-promoting entities.

The SS systems diminish pathogens in different ways. Rajatha et al. (2022) found that the several approaches employed by SS systems, such as the use of biocontrol agents, a dynamic filtration system, and suppressive bacteria, are essential for improving plant protection. These strategies are free of chemicals or energy, the SS systems provide a natural and environmentally friendly solution that uses both water and plants. According to Khalil & Alsanius (2011), the SS systems increased plant diseases' resistance in tomatoes and bananas. Compared to standard inorganic fertilizers, reduced levels of pathogens were detected by using organic-based nutrient solutions. The beneficial outcomes of these practices include the provision of safe food, a reduction in environmental impact, and the promotion of sustainable agricultural production. Environmental controls and effective nutrient delivery are made possible by the regulated settings under SS systems. Chen et al. (2022) revealed that under the application of gas jetting, nutrient

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solution storage, and mist-generating equipment, the SS systems provide ideal growing conditions. Furthermore, during the growth season, automated control technologies improve the transparency and accuracy of the cultivation process, leading to the best possible development of the plants.

SS provides a sterile growing environment that reduces plant pathogens by promoting the growth of beneficial microbes that suppress harmful organisms (Ochieno, 2022; Mourouzidou et al., 2023;). On the contrary of the TS systems, the absence of soil contact in SS systems minimizes exposure to contamination sources responsible for plant diseases (Savvas & Gruda, 2018). In SS systems, the pathogen transmission to plants is sharply minimized as a result of the close systems providing nutrient solution and water (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 by 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 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 Location

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, 7km of NPK-10-3-43, and 8 kilograms of magnesium sulfate in addition to 400 grams of microelements. 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 temperature variation 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 1.5dS/m (Fig. 4). This range is deemed suitable for sustaining optimal cucumber production.

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. 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, including bacterial wilt and angular wilt, appeared in the TS with medium to severe incidences. Viruses, including the cucumber mosaic virus and Zucchini yellow mosaic viruses, appeared almost severely in the TS. The nematode disease related to root-knot nematodes appeared intensively in 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 2). 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		

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

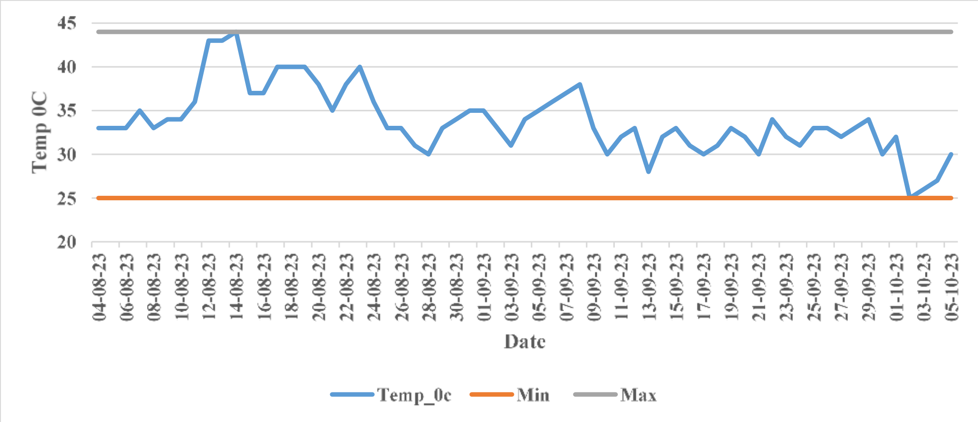

Fig. 1: The temperature (℃) through the growing season

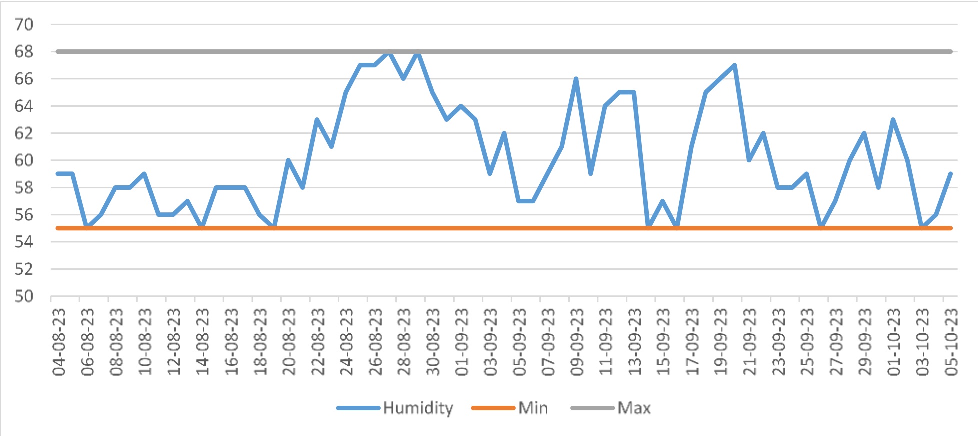

Fig. 2: The humidity (%) through the growing season

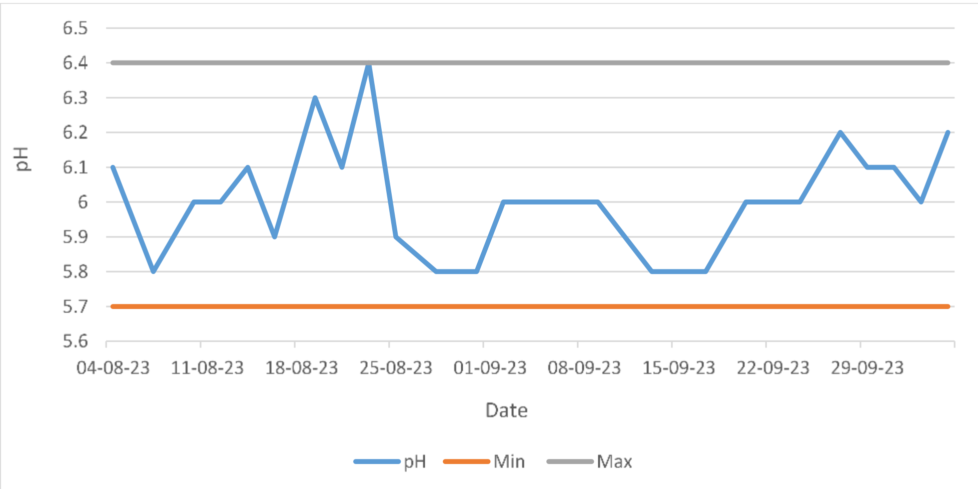

Fig. 3: The pH degrees recorded for the irrigation water through the season

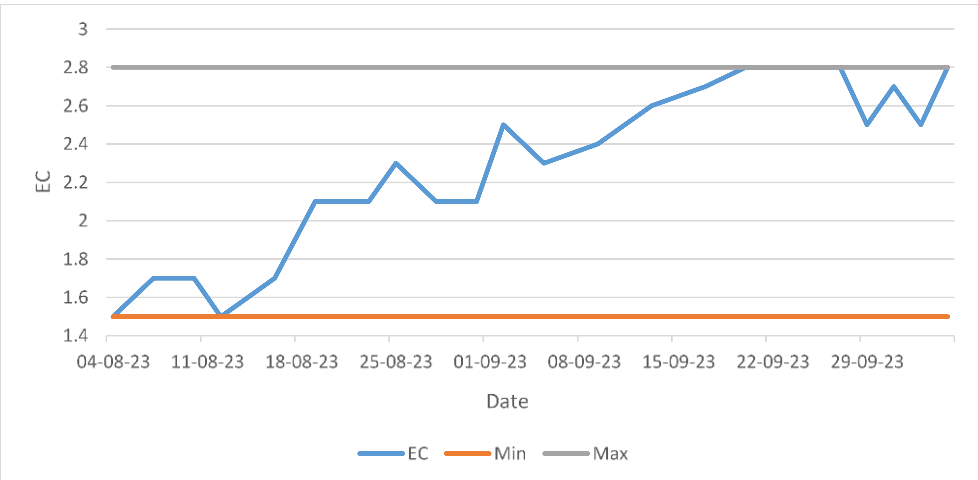

Fig. 4: The recorded EC (dS/m) values for irrigation water through the season.

DISCUSSION

This research investigated the effect of agricultural practices on plant diseases under cucumber plants by comparing SS systems vs. TS 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 SS systems, the amount of irrigation water added was less than that used in the TS. Close irrigation water systems applied to the SS systems minimized the evaporation and maximized the nutrients use efficiency through water circulation.

Under the TS system, high temperatures recorded through the cucumber growing season encourage the occurrence of plant diseases. Chai et al. (2023) reported that high-temperature degrees and high humidity values increase the dynamics of pathogens. Philosoph et al. (2019) highlighted that the high temperatures increased the virus diseases in traditional practices. Moreover, Molad et al. (2021) showed that fluctuating temperatures increased the incidence of mosaic viruses in cucumber plants. Chai et al. (2023) found that the high humidity percentage increased the transmission of pathogens and increased disease susceptibility. Elevated humidity percentages increase the pathogens and their survival times leading to higher disease indices (Zhao et al., 2022).

Compared to SS systems, TS systems recorded a high distribution of fungal diseases. To reduce disease severity, Hao et al. (2023) found that the use of *Trichoderma asperellum* PT-15 and the compound 6-pentyl-α-pyrone (6-PP) inhibit *Fusarium oxysporum* was very effective. Under SS systems, Gilardi et al. (2022) found that the use of non-pathogenic strains will control the fungal diseases. Generally, research findings support the role of SS systems in mitigating fungal diseases and improving cucumber health. In SS systems, cultivation techniques; hydroponics, and aquaponics, are recognized to minimize fungal diseases through various mechanisms. Mourouzidou et al. (2023) recognized that the presence of Plant Growth-Promoting Microorganisms (PGPM) like Bacillus, Pseudomonas, and Trichoderma is essential for disease management in hydroponic systems due to these microorganisms' strong antagonistic characteristics. They contribute to reducing the disease severity index by engaging in mycoparasitism, antibiosis, and inducing systemic resistance.

Disease suppression can be established through the controlled soil environment created through reductive soil disinfestation (RSD) in artificially managed soil. Liu et al. (2019) explained that modifying soil conditions and fostering microbial communities inhibited disease incidence. 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 SS systems exploit microbial interactions and abiotic elements to effectively mitigate fungal diseases and improve plant health in agricultural settings (Shen et al., 2022).

Regarding bacterial diseases, higher crop production and better growth conditions were obtained under the SS systems through the control the soilborne diseases (Mourouzidou et al., 2023). Beneficial bacteria under SS systems minimize the impact of bacterial diseases by enhancing plant health and controlling pathogens (Khatri et al., 2023). Compared to TS systems, SS systems suppress the diseases as a closed system (Li et al., 2023). The use of anaerobic soilless substrates will help in controlling bacterial diseases (Yanez et al., 2024). Research has proven that SS systems mitigate plant diseases. Resistant viruses, compared to other pathogens, can produce contamination through water. In TSs, the soil plays a very enriched condition for virus infections (Yan et al., 2023). The measures of effective control under soilless agricultural systems will work as disease suppressiveness (Wu et al., 2022).

The Dutch Buckets showed 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

This research investigated the incidence of plant diseases under soilless systems (SS) vs. 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 SS 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 systems enhanced 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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