44 Egypt. J. Soil Sci. **Vol. 63**, No. 4, pp: 571-579 (2023)

Egyptian Journal of Soil Science

http://ejss.journals.ekb.eg/

Comparison between Soil and Soilless Cultivation of Autumn Tomato Production under Spanish Net-House Conditions

Mohamed A. Sharaf-Eldin[a], **Farouk A. El -Aidy**[a], **Nabil A. Hassan**[a], **Ali E. Masoud**[b], and **Eman H. El-Khateeb**[b]

[a]*Horticulture Department, Faculty of Agriculture, Kafrelsheikh University, Kafr El-Sheikh,* 33516 *Egypt*

[b]*Horticulture Research Institute, Agriculture Research Center, Egypt*

SOIL degradation, desertification, fresh water scarcity, as well as the widespread of soil-borne diseases and nematodes all have an impact on plant production and food security. These issues encourage the development of soil-alternative systems. The current study aims to compare between tomato production in soil and soilless systems during the autumn season under Spanish style net-house and study their effects on growth, fruit yield and fruit quality. Four different substrates of soilless system of peat moss + vermiculite (1:1) peat moss + perlite (1:1), perlite + vermiculite (1:1) and peat moss + vermiculite + perlite (1:1:1) were evaluated. The results show that soil cultivation was better than soilless culture for plant growth and fruit yield. However, the substrate of peat moss + perlite was the best studied substrate. Cultivation in the soil did not significantly differ from the cultivation in the substrate of peat moss + perlite in plant height, leaves and flower numbers, early yield, fruits number and average fruit weight. The medium of peat moss + vermiculite + perlite had the lowest values of the studied measurements. The chemical quality of the fruit (total soluble solids, acidity, and vitamin C) and its firmness weren't significantly affected by the soil alternatives compared to soil cultivation. It could be concluded that challenging-to-cultivate tomato plants can be successfully grown using the soilless culture technique with a medium consisting of peat moss and perlite.

Keywords: *Solanum lycopersicon*, substrates, net-house, vegetative growth, flowering, fruit yield

1. Introduction

Tomato (*Solanum lycopersicon,* L.) is a member of Solanaceae family and is one of the important, popular, and nutritious vegetable crops. It is one of the world's major crops for both fresh and processed fruits. Tomato is the largest vegetables crop grown in Egypt. It is adapted to a wide variety of climate. Tomato ranks third, next to potato and sweet potato, in terms of world vegetables production **(FAO, 2020)**. The production volume of tomatoes in Egypt was 6731220 tons from the cultivated area of 170862 hectare **(FAO 2020)**. Tomato is grown all year round in Egypt although, it suffers from many troubles in soil grown system such as soil borne diseases, heavy metals contamination, poor soil fertility, limited freshwater resources and salinity. Moreover, heat stress during the late summer or autumn season can increase the bad effect of these problems **(Sharaf-Eldin, 2015 and 2023).** Soilless agriculture under protected cultivation is one of the suggested solutions to get out of these troubles. It is also created to face the rapid decrease in arable land due to urbanization, industrialization and desertification (**Praveen et al., 2022**).

Soilless agriculture is a technique of cultivating plants using nutrient solutions in water and other media. The roots of plants are merging in the solutions or in an inert medium (such as sand, gravel, vermiculite, rock wool, perlite, peat moss and sawdust) to offer mechanical support with nutrient solution **(Sharma et al., 2018)**. The hydroponics system is spreading around the globe and based on the recent data, is predicted to increase by 18.8% globally between 2017 and 2023 **(Jan, et al., 2020).**

A change in the growing medium can be a substitute strategy for sustainable crop production and the preservation of water and land resources that are in short supply **(Aurosikha et al., 2021; Ghazi, et al., 2023).** The world's most popular

*Corresponding author e-mail: mohamed.eldeen@agr.kfs.edu.eg
Received: 28/07/2023; Accepted: 18/08/2023
DOI: 10.21608/EJSS.2023.225734.1627

growing mediums for soilless agriculture are peat, rock wool, coconut fiber, perlite, and volcanic tuff. The media can be composed of inorganic substances like perlite, vermiculite, and mineral wool **(Vaughn et al., 2011)** or organic substances like peat, compost, tree bark, coconut, and chicken feathers or mixtures like peat and perlite **(Nair et al., 2011).**

When several media are used together, the outcomes are superior to each type used alone. Because of the increased water holding capacity and aeration, the plants have better growth and production **(Ghehsareh et al., 2011).** By combining materials with adequate qualities, difficulties may be avoided by mixing substrates in specified proportions **(Albaho et al., 2009; Johanson, 2010; Gutierrez et al., 2012)**. Depending on the kind of crop being grown, one should decide which substance to employ as a growing medium or component **(Aurosikha et al., 2021)**. Growing media characteristics must therefore satisfy the requirements for plant production, which are in turn determined by plant biology **(Fascella, 2015; Fawzy et al., 2023)**. Furthermore, the decision to use a specific growing medium depends also on its cost and availability. Growing media need to be environmentally friendly and consumer-focused if it is to endure the challenges of the future **(Gruda, 2009)**. The evaluation of developing media companies is no longer solely based on their financial performance. According to their environmental impact, sustainability, environmental preservation, and the employment of green technology in their manufacturing, growth media elements are now categorized using life circle evaluation **(Gruda, 2019)**.

The main goal of this cultivation technology is to get rid of issues with greenhouse soil, especially without using crop rotation as frequently as in protected cultivation **(Savvas, 2003)**. Replacing soil growing systems with soilless culture for plants, especially for tomatoes and other vegetables, controls plant nutrition and eliminates plant diseases that are caused by soil infection **(Asaduzzaman et al., 2015)**. Therefore, changing in cultivation medium is an alternative strategy for ensuring food security and preservation of water, land, and resources. The objective of the current study was to evaluate different combinations of substrates and study their effect on tomato growth, yield, and quality in comparison to soil cultivation grown under net-house conditions.

2. Materials and Methods

The current study was carried out under net-house conditions on tomato plants (*Solanum lycopersicon*, L.) cv. VT916 at the International Protected Cultivation Center (31º05′49″ N 30º57′15″ E), Faculty of Agriculture, Kafrelsheikh University, Egypt, in the autumn seasons of 2019/20 and 2020/21.

Treatments

Different types of soilless substrates were evaluated compared to soil cultivation as follow:

1. T1, soil cultivation
2. T2, peat moss plus vermiculite (1:1)
3. T3, peat moss plus perlite (1:1)
4. T4, vermiculite plus perlite (1:1)
5. T5, vermiculite plus perlite plus peat moss (1:1:1)

The treatments were arranged in randomized complete block design (RCBD) with three replicates was applied for data analysis. In 20-liter plastic pots, two tomato seedlings were transplanted 25 cm apart. A layer of pebbles was added to the bottom of the pot that contained a small hole for drainage. The irrigation tube was connected to the pots top, while the drainage tube was attached to the bottom holes. The pots were arranged in lines, 150 cm apart, with 50 cm between each pot (Photo 1).

Agricultural practices

The plants were grown on September 2nd in both seasons in plastic pots under a net-house of Spanish style that measured 30 m wide by 40 m long by 4 m high, and was covered by anti-insect proof net that provided 65% shading level. The mean temperature under net-house during experimental period ranged between 26-38 ◦C at daytime and 23-26 ◦C at night, and 30–80% RH%.

Two tanks (A & B) with 5 m^3 capacity were used for fertigation (Table 1). A system for automatic fertigation suitable for tomato growing was modified to operate four times each day. Soil and substrates analysis

Before transplanting, soil samples were obtained in both growing seasons at a depth of 0–30 cm for mechanical and chemical analysis using **Sparks et al. (2020) and Dane and Topp (2020)** methodology (Table 2). The substrates analysis was shown in Table 3.

Measurements

Vegetative growth parameters

Plant height (cm), main stem diameter (mm), number of leaves, plant leaf area (dm^2) using a portable leaf area meter (model LI-3000A, Lincoln, NE, USA), and plant chlorophyll as SPAD units using a portable leaf chlorophyll meter (Minolta Model SPAD 501) were all measured on five random plants from each individual treatment after 60 days from transplanting.

Flowering parameters

Number of clusters per plant, Number of flowers per plant, and Fruit set percentage (fruit set/ number of flowers * 100) were recorded for five plants from every individual treatment.

(A)

(B)

(C)

(D)

Soil cultivation **Soilless cultivation**

Photo 1. Growing substrates, irrigation/drainage system and cultivation systems (A) Growing pot perlite, vermiculite and peat moss (from left to right), (B) Irrigation and drainage system, (C) Spanish net-house and (D) growing plants.

Table 1: Composition of fertilization solutions for tomato plants.

Tank (A)	Tank (B)
Ammonium nitrate 4 kg	Nitric acid 1 liter
Phosphoric acid 1 liter	Calcium nitrate 1.5 kg
Potassium sulphate 5 kg	
Mg sulphate 1 kg	
Fe EDDTA 150 gm	
Cu sulphate 50 gm	
Mn sulphate 25 gm	
Zn sulphate 30 gm	
Uric acid 15 gm	
Borax 20 gm	
Ammonium molybdate 5 gm	

Yield and its components

As the average of all plants from each treatment, the yield was estimated. The average of all harvests prior to the peak of fruiting was used to determine the early yield. Data of total yield included fruit number, fruits weight and average fruit weight of all full-colored fruits as a total all harvests in both seasons. However, fruit shape index was calculated as a ratio of fruit length and diameter of 20 harvested fruits.

Fruit quality

A random sample from the fully colored fruits was taken to determine the chemical components (total soluble solids (T.S.S), titratable acidity, and ascorbic acid concentration). However, fruit firmness was assayed by using a digital penetrometer (PCE-PTR. MITPC, USA) with a needle of 8 mm in diameter.

Table 2: Mechanical and chemical analysis of the soil before conducting the experiments in 2019/20 and 2020/21 seasons.

Soil analysis	Seasons	
	2019/20	2020/21
A. Mechanical analysis		
Sand %	23.45	22.70
Silt %	25.60	2٧.06
Clay %	50.95	50.24
Soil texture	Clayey	Clayey
B. Chemical analysis		
Available nutrients (mg kg^{-1})		
N	44	175
P	17	27
K	234	954
pH (1:2.5, soil: water suspension)	8.2	8.0
EC (dS m^{-1})	3.9	2.5

Table 3: Some chemical and physical properties of the used substrates in the experiments.

properties		Peat moss	Vermiculite	Perlite
pH (substrate : water, 1:10)		4.9	7.7	6.2
EC (ds/m), 1:10 substrate : water		2.39	1.01	
Organic matter (%)		64.7	1.1	
Organic carbon (%)		37.32	0.62	
C/N Ratio		63.9	160	
Cations and anions (cmolc kg^{-1})	Na	21.7	0.04	
	K	0.3	-	
	Ca	1.78	0.24	
	Mg	0.89	1.02	
	Cl	22.1	0.6	
	SO_4	2.3	1.3	
Total macronutrients (%)	N	0.66	0.004	
	P	0.09	0.02٠	
	K	0.38	0.003	3.17
Available micronutrients (mg/kg)	Fe	2.12	0.7	
	Mn	11.27	-	
	Zn	3.66	-	
Bulk density (kg/m^3)		105.7	117.6	97.5
Moisture content (%)		31.6	25.7	22.4
Water holding capacity (g water/g dry sample)		3.28	4.3٠	2.67
Porosity (%)		90	89	91

Statistical analysis

The obtained data from both growing seasons of the study were tabulated and statically analyzed according to **Snedecor and Cochran (1989)**. MSTAT computer software program package was performed using analysis of variance method, and the means were compared by Duncan's multiple range test.

3. Results

Vegetative growth

Data in Table 4 demonstrate that after 60 days after transplanting, differences among soil and soilless culture were statistically significant for tomato plant growth characteristics such as plant height, stem diameter, number of leaves, leaf area (2021 season only), and chlorophyll content (2020 season only). Plant growth in soil cultivation generally demonstrated superior growth than soilless cultivation. However, plant growth was enhanced when peat moss and perlite (T3) were included in the growing medium. The lowest plant growth was obtained from the pots that contained peat moss, perlite, and vermiculite (T5). The other substrates (T2 and T4) had intermediate values.

Table 4. Comparison of soil and soilless cultivation on some vegetative growth parameters of tomatoes under Spanish net-house conditions during 2019/20 and 2020/21 seasons.

Treatments	Plant height (cm)	Stem diameter (mm)	Number of leaves/ plant	Plant leaf area (dm^2)	Chlorophyll (SPAD)
		2019/20			
T1, Soil cultivation	149.9 ab	13.85 b	29.9 a	118.50	48.09 a
T2, Peat + vermiculite	143.5 b	13.18 b	28.8 a	105.88	43.58 b
T3, Peat + perlite	158.0 a	15.27 a	29.6 a	116.05	43.15 b
T4, Perlite + vermiculite	141.8 b	13.08 b	28.1 ab	116.35	44.88 b
T5, Peat + vermiculite + perlite	131.1 c	13.40 b	25.9 b	99.11	44.13 b
F. Test	**	**	*	NS	**
		2020/21			
T1, Soil cultivation	198.9 a	14.98 ab	29.0 a	132.15 a	42.16
T2, Peat + vermiculite	152.3 bc	13.96 b	24.6 bc	113.07 bc	42.52
T3, Peat + perlite	168.2 b	16.03 a	25.3 b	122.06 ab	44.03
T4, Perlite + vermiculite	156.5 bc	16.14 a	25.0 bc	98.11 c	41.73
T5, Peat + vermiculite + perlite	143.7 c	14.97 ab	23.9 c	100.59 c	41.87
F. Test	**	*	**	**	NS

**,* and NS indicate significant differences at $p \leq 0.01$, $p \leq 0.05$ and not significant, respectively, according to F test. Values having the same alphabetical letter within each column are not significantly different at 5% level, according to Duncan's multiple rang test.

Flowering parameters

Data in Table 5 indicate that flowering parameters (number of clusters, number of flowers and fruit set percentage) are significantly affected by the studied treatments in both seasons. When compared to soilless culture, soil cultivation enhanced the number of blooms and the proportion of fruit set. In the case of soil alternative substrates, the treatment of perlite + peat moss (T3) enhanced blooming and fruit set compared to the other studied substrates. However, the soil cultivation did not significantly differ from the cultivation in peat moss plus vermiculite (T2), peat moss plus perlite (T3), and perlite plus vermiculite (T4) in the first season only. In contrast, the peat moss, perlite, and vermiculite substrate (T5) mixer had the worst effect.

Table 5. Comparison of soil and soilless cultivation on number of clusters per plant, number of flowers per plant, and fruit set percentage of tomato under Spanish net-house conditions during 2019/20 and 2020/21 seasons.

Treatments	Number of clusters/ plant	Number of flowers/ plant	Fruit set percentage
		2019/20	
T1, Soil cultivation	6.22 a	30.62 ab	79.17 a
T2, Peat + vermiculite	5.86 ab	30.37 ab	73.91 c
T3, Peat + perlite	6.30 a	33.90 a	76.25 b
T4, Perlite + vermiculite	5.88 ab	30.34 ab	55.31 d
T5, Peat + vermiculite + perlite	5.57 b	28.73 b	59.76 d
F. Test	**	**	**
		2020/21	
T1, Soil cultivation	5.45 a	25.00 a	70.07 a
T2, Peat + vermiculite	4.24 b	17.46 b	46.79 d
T3, Peat + perlite	4.16 b	17.12 b	54.26 b
T4, Perlite + vermiculite	4.06 b	18.21 b	48.86 d
T5, Peat + vermiculite + perlite	3.87 b	15.69 b	49.49 c
F. Test	**	**	**

** indicates significant differences at $p \leq 0.01$ according to F test. Values having the same alphabetical letter within each column are not significantly different at 5% level, according to Duncan's multiple rang test.

Fruit yield

The evaluated cultivation systems had a significant effect on the early and total yields, and these effects varied depending on the growth season (Fig. 1). In the first season, the contained substrates of peat moss plus vermiculite and peat moss plus perlite generated the highest early fruit production compared to soil cultivation and the three-mix substrate (peat moss plus perlite plus vermiculite). Whereas in the second season, early and total fruit yields from soil cultivation exceeded that of all soilless surfaces. In the first season only, the total yield of soil cultivation did not significantly differ from peat moss plus perlite substrate that both producing the highest total yield. According to the fruits number data, only the first season showed a difference between the tested treatments that was statistically significant, and all treatments produced more fruits than the peat moss plus perlite plus vermiculite substrate (Fig. 1).

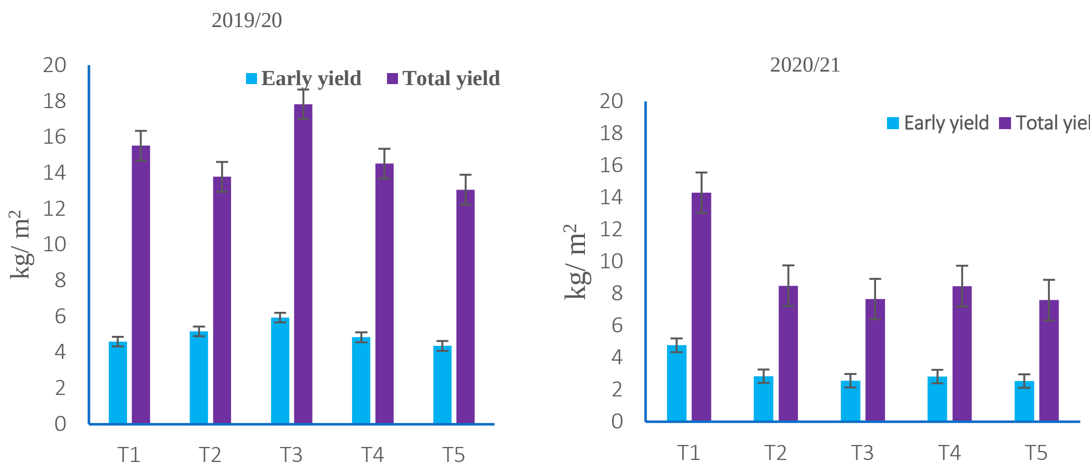

Fig. 1. Comparison of soil and soilless cultivation on early and total fruit yields of tomatoes under Spanish net-house conditions during 2019/20 and 2020/21 seasons. T1, soil cultivation; T2, peat moss plus vermiculite (1:1); T3, peat moss plus perlite (1:1); T4, vermiculite plus perlite (1:1); T5, vermiculite plus perlite plus peat moss (1:1:1). The standard error of the means recorded form three biological replicates.

Fruit quality

According to data in Table 6, soil cultivation (T1) peat moss plus vermiculite (T2), and peat moss plus perlite (T3) substrate all improved average fruit weight, without significantly differing in-between. While perlite plus vermiculite (T4) and three-mix substrates (T5) produced the lowest fruit weight. When compared to soilless substrates, soil cultivation significantly increased the fruit shape index in both growing seasons without insignificant differences with peat moss plus vermiculite substrate in the second season only (Table 6).

Table 6. Comparison of soil and soilless cultivation on fruit numbers, weight and shape index of tomatoes under Spanish net-house conditions during 2019/20 and 2020/21 seasons.

Treatments	No. fruits/ plant	No. fruits/ m^2	Fruit weight (g)	Fruit shape index
2019/20				
T1, Soil cultivation	13.09 ab	30.77 ab	119.36 a	0.69 a
T2, Peat + vermiculite	14.56 ab	34.21 ab	117.47 ab	0.65 b
T3, Peat + perlite	15.39 a	36.18 a	108.14 ab	0.64 b
T4, Perlite + vermiculite	13.82 ab	32.47 ab	99.91b c	0.65 b
T5, Peat + vermiculite + perlite	11.53 b	27.09 b	96.17 c	0.65 b
F. Test	*	*	**	*
2020/21				
T1, Soil cultivation	23.73	55.77	149.37 a	0.78 a
T2, Peat + vermiculite	16.60	39.01	143.12 a	0.77 a
T3, Peat + perlite	15.95	37.48	140.87 a	0.75 b
T4, Perlite + vermiculite	17.03	40.01	129.25 b	0.75 b
T5, Peat + vermiculite + perlite	17.83	41.89	126.88 b	0.74 b
F. Test	NS	NS	**	**

**,* and NS indicate significant differences at $p \leq 0.01$, $p \leq 0.05$ and not significant, respectively, according to F test. Values having the same alphabetical letter within each column are not significantly different at 5% level, according to Duncan's multiple rang test.

Chemical characteristics

The studied chemical composition included total soluble solids (TSS), acidity, and ascorbic acid (Table 7). We did not find any significant variation between soil cultivation and soilless ones in both growing seasons. Also, the differences among all studied substrates were not significantly detected. Moreover, fruit firmness had the same trend of chemical composition parameters (Table 7).

Table (7): Comparison of soil and soilless cultivation on some quality parameters of tomatoes under Spanish net-house conditions during 2019/20 and 2020/21 seasons.

Treatments	T.S.S (Brix)	Acidity (%)	Vitamin C (mg/100gm FW)	Firmness (gm/cm^2)
		2019/20		
T1, Soil cultivation	4.51	0.042	27.76	411.94
T2, Peat + vermiculite	4.63	0.044	25.68	408.61
T3, Peat + perlite	4.70	0.044	30.96	443.61
T4, Perlite + vermiculite	4.62	0.043	26.51	435.56
T5, Peat + vermiculite + perlite	4.77	0.049	28.78	441.08
F. Test	NS	NS	NS	NS
		2020/21		
T1, Soil cultivation	5.03	0.039	31.37	673.34
T2, Peat + vermiculite	5.38	0.042	29.85	638.76
T3, Peat + perlite	5.71	0.044	30.83	625.00
T4, Perlite + vermiculite	5.08	0.044	31.71	622.92
T5, Peat + vermiculite + perlite	5.99	0.048	30.17	681.25
F. Test	NS	NS	NS	NS

NS means that the differences were insignificant at 5% level, according to Duncan's multiple rang test.

4. Discussion

In our study, we attempted to provide an appropriate solution for the decline in fertile soil that occurred as a result of soil degradation and desertification, as well as the prevalence of soil-borne diseases and nematodes in association with freshwater scarcity, all of which have an impact on plant productivity **(Praveen et al., 2022)**. These issues encourage us to find soil-alternative systems that can help to increase food security. Tomato, as one of the most important vegetable crops, is strongly affected by the reduction in soil fertility particularly when the plant suffers from other stresses such heat stress during the late summer or autumn cultivation **(Sharaf-Eldin et al., 2023)**. So that, we tried to evaluate some soil-alternatives in comparison with soil cultivation on tomato production under net-house conditions during the autumn season. The current results indicate that the use of peat moss plus perlite as a medium increased plant growth compared to the other studied media and soil cultivation (Table 4). This beneficial effect might be attributable to its higher aeration, which in turn increased root oxygen demand and, eventually, resulted in greater water and nutrient absorption. These findings are in line with those made when perlite was presented in the media by **El-Sayed et al. (2015),** and when coco peat and perlite were used as a medium **(Sedaghat et al., 2017)**. As they mentioned, this increase related to the increase in leaves number, plant leaf area, plant height and chlorophyll content which was also reported in our study (Table 4). The substrate of peat moss plus perlite and the cultivation in the soil (with a slight increase in soil cultivation) increased number of flowers, flower clusters and fruit set percentage (Table 5). As blooming period is a sensitive stage of plant growth **(Sharaf-Eldin, 2023)**, the superior results of soil cultivation on flowering may be due to appropriate water availability to the roots, especially during the middle of the day when plants suffer from heat stress, the soil performed better than the soil alternative media. Moreover, the high contents of available N, P and K in the soil (Table 2). However, **Fascella and Zizzo (2005)** explained the superior effect of the mix of coco peat with perlite as a medium on flowers number was due to the effective interaction between air and water, leading to air-filled porosity and a water-holding capacity. Additionally, according to the results of the current study, soil cultivation and peat moss plus perlite medium, provided the highest early and total fruit yields compared to the other substrates (Fig. 1). These results are in harmony with those obtained by, **Tuzel et al. (2001)** and **Haghighi et al. (2016)** who mentioned that tomato grown in peat + perlite produced higher fruits number per plant and yield than plants grown in perlite alone. The high yields of soil cultivation (in the second season) and peat moss plus perlite substrate (in the first season) could be attribute to their contents of macro and micronutrients in addition to the high organic matter content (Tables 2 & 3). **Kitir et al. (2018)** reported that organic growing medium as peat moss was the favorable for most vegetables production because it retains moisture. However, adding perlite granules to peat moss which is very light and originates from silicon that forms in volcanoes can increase drainage and aeration in the soil **(Aurosikha et al., 2021)**, in addition to the role of silicon in decreasing heat stress **(Shalaby et al., 2021)**. The reuse of the investigated substrates after sterilization may be the cause of the observed decrease in the achieved yield from soilless cultivation compared to soil growth in the second season, which could have an impact on the substrate properties.

Although our results indicated that the chemical quality of fruits content of vitamin C, titratable acidity, Total soluble solids and firmness did not significantly affect by the studied treatments (Table 7), the earlier findings are conflict.

As, **Aktaş et al., 2013** had similar results on tomatoes. Also, **Mohamed and Hussien (2021)** and **Tilahun and Jeong (2018)** reported that organic and inorganic substrates did not affect fruit content of vitamin C of tomatoes. **Sofiadou and Tzortzakis (2012)** recorded the same effect on total soluble solids. Whereas **Olle et al. (2012)** reported that TSS, vitamins and acidity had better marks when plants were grown in soilless culture systems, compared to soil. Also, **Pinar (2018)** showed that the lowest TSS value was obtained of plants grown in perlite medium, compared with coconut fiber medium.

5. Conclusion

Due to the shortage in suitable agricultural soil caused by climate change, desertification, and extensive use of agricultural soil, hydroponic systems have been suggested as an alternative to soil farming. Additionally, the absence of crop rotation, particularly in greenhouses, degrades the soil and makes hydroponic farming more necessary. The soilless system with peat moss plus perlite (1:1, v/v) as substrate showed superior results and can be used as a suitable alternative for soil farming of tomato production under net houses during the autumn season, even though the current work indicated to the higher plant growth and productivity in soil cultivation. Moreover, there were no significant variations between soilless culture and soil-grown tomatoes in terms of fruit quality (vitamin C, TSS, acidity, and firmness). Finally, more studies are required to modify soilless agriculture techniques according to each crop's needs. Hence, infertile soil issues may be resolved and unused areas can be turned into productivity, as well as the efficient management of water and resources.

6. Conflicts of interest

There are no conflicts to declare.

7. Formatting of funding sources

This research is funded by the Nuffic OKP project at the title of "Enhancing water efficiency and food security through Egyptian TVETs" number, OKP-ICP-EGY-103150.

8. Acknowledgment

The authors would like to thank Nuffic OKP (OKP-ICP-EGY-103150) for funding the study and all members of the project for their grateful help.

9. References

Aktaş H, Daler S, Ozen O, Gencer K, Bayindur D, Erdal I (2013). The effect of some growing substrate media on yield and fruit quality of eggplant (*Solanum melongena* L.) grown and irrigated by drip irrigation system in greenhouse. Infrastrukt. Ekol. Teren. Wiej. 1(3), 5–11.

Alan R, Zuladir A, Padem H (1994). The influence of growing media on growth, yield and quality of tomato grown under greenhouse conditions, Acta Horticulturae 366, 429-436.

Albaho M, Bhat N, Abo-Rezq H, Thomas B (2009). Effect of three different substrates on growth and yield of two cultivars, Europe Journal of science Resource 28 (2), 227-233.

Asaduzzaman Md, Saifullah Md, Mollick AKMSR, Hossain MdM, Halim GMA, Asao T. (2015). Influence of soilless culture substrate on improvement of yield and produce quality of horticultural crops [Internet]. Soilless culture - use of substrates for the production of quality horticultural crops. In Tech. Available from: http://dx.doi.org/10.5772/59708

Aurosikha S, Chatterjee S, Viswanath M, Roy A, Biswas A (2021). Hydroponics in vegetable crops: A review. The pharma Innovation Journal 10(6), 629-634.

Dane JH, Topp CG (2020). Methods of soil analysis", Part 4: Physical methods (Vol. 20). John Wiley & Sons.

El-Sayed H, Hassan A, Mahmoud S (2015). Effect of some soilless culture techniques on sweet pepper growth, production, leaves chemical contents and water consumption under greenhouse conditions. Middle East Journal of Agriculture 04(04), 682-691.

FAOSTAT (2020). Food and Agriculture Organization Statistical Database.

Fawzy, ZF, El-Bassiony AM, El-Ramady H, El-Sawy SM, Shedeed SI, Mahmoud SH (2023). Broccoli biofortification using biological nano- and mineral fertilizers of selenium: a comparative study under soil nutrient deficiency stress. Egypt. J. Soil Sci., 63(1), 57-66.

Fascella G (2015). Growing substrates alternative to peat for ornamental plants, In: Asaduzzaman, M. D. (ed), soilless culture use of substrates for the production of quality horticultural. In Tech, London, UK.

Fascella G, Zizzo GV (2005). Effect of growing media on yield and quality of soilless cultivated rose. Acta Horticulturae 697, 133-138.

Ghazi DA, Hafez SH, El-Sherpiny MA (2023). Rice cultivation adaptation to water resources shortage in Egypt. Egypt. J. Soil Sci. 63(1), 113-126.

Ghehsareh A, Samadi N, Borji H (2011). Comparison of date-palm wastes and perlite as growth substrates on some tomato growing indexes. African Journal of Biotechnology 10(24), 4871-4878.

Gruda N (2009). Do soilless culture system have an influence on product quality of vegetables, Journal of Applied Botany and food quality 82, 141-147. DOI: 10.18452/9433.

Gruda NS (2019). Increasing sustainability of growing media constituents and stand-alone substrates in soilless culture systems. Agronomy 9(6), 298. https://doi.org/10.3390/agronomy9060298

Gutierrez GAM, Altamirano GZ, Urrestarazu M (2012). Maguey bagasse waste as sustainable substrate in soilless culture by melon and tomato crop. Journal of plant Nutrition 35, 2135-2144.

Haghighi M, Ngouajio M, Siomos A (2016). The effect of municipal solid waste compost, peat, perlite and vermicompost on tomato (*Lycopersicum esculentum* L.) growth and yield in a hydroponic system. International Journal of Recycling of Organic Waste in Agriculture 5, 231-242.

Jan S, Rashid Z, Ahngar TA, Iqbal S, Naikoo NA, Majeed S (2020). Hydroponics: A review. Int. J. curr. Microbiol. App. Sci. 9, 1779-1787.

Johanson JR, Hochmuth H, GJ, Maynard DN (2010). Soilless culture of greenhouse vegetables, Institute of Food and Agricultural science 218, 19-22.

Kitir N, Yildirim E, Şahin Ü Turan M, Ekinci M, Ors S (2018). Peat Use in Horticulture [Internet]. Peat. InTech. Available from: http://dx.doi.org/10.5772/intechopen.79171

Mohamed F, Hussien M (2021). The Impacts of different Substrates on the Growth, Yield and Fruit Quality of Greenhouse- Grown Cherry Tomato. Hortscience Journal of Suez Canal University 10 (1), 73-76.

Nair A, Ngouajio M, Biernbaum J (2011). Alfalfa – based organic amendment in peat compost growing medium for organic tomato transplant production. American society for Horticultural Science 46 (2), 253-259.

Olle M, Ngouajio M, Siomos A (2012). Vegetable quality and productivity as influenced by growing medium: a review. Žemdirbystė Agriculture 99(4), 399–408.

Pinar K, Erdal I, Aktes H (2018). Effect of different substrates on yield and fruit quality of tomato grown in soilless culture. Polish academy of sciences, Cracow Branch 1(2), 249-261.

Praveen KS, Senthilkumar N, Poonkodi P, Thiruppathi M (2022). Soilless substrates on vegetable production: A Review. International Journal of Creative Research Thoughts (IJCRT) 10(3), 49-59.

Savvas D (2003). Hydroponics: A modern technology supporting the application of integrated crop management in greenhouse. Food, Agriculture and Environment 1, 80-86.

Sedaghat M, Kazemzaadeh-Beneh H, Azizi M, Momeni M (2017). Optimizing growing media for enhancement to vegetative growth, yield and fruit quality of greenhouse tomato production in soilless culture system. World J. Agric. Sci. 13, 82-89.

Shalaby TA, Abd-Alkarim E, El-Aidy F, Hamed ES, Sharaf-Eldin M, Taha N, El-Ramady H, Bayoumi Y, Dos Reis AR (2021). Nano-selenium, silicon and H_2O_2 boost growth and productivity of cucumber under combined salinity and heat stress. Ecotoxicology and Environmental Safety, 212, 111962.

Sharaf-Eldin MA (2015). Mitigation heat stress on tomato plant by shading and fogging system: Influence microclimate, fruit set, yield and physiological disorders. Egypt. J. Hort. 42(2), 865 - 881.

Sharaf-Eldin MA, Yaseen, ZM, Elmetwalli AH, Elsayed S, Scholz M, Al-Khafaji Z, Omar GF (2023). Modifying walk-in tunnels through solar energy, fogging, and evaporative cooling to mitigate heat stress on tomato. Horticulturae 9, 77. https://doi.org/10.3390/ horticulturae9010077

Sharma N, Achary S, Kumar K, Singh N and Chaurasia OP (2018). Hydroponics as an advanced technique for vegetable production: An overview soil water conserve 17, 364-371.

Snedecor GW, Cochran WG (1989). Statistical methods, 8th ed. Iowa state Univ. Press Iowa, Ames.

Sofiadou E, Tzortzakis NG (2012). Olive mill waste as a substitute growing medium component in tomato seedling and crop production. International Journal of Vegetable Science 18, 272–283. DOI: 10.1080/19315260.2011.639857

Sparks DL, Page AL, Helmke PA, Loeppert RH (2020). Methods of soil analysis, part 3: Chemical methods (Vol. 14). John Wiley & Sons.

Tilahun S, Seo MH, Park DS, Jeong CS (2018). Effect of cultivar and growing medium on the fruit quality attributes and antioxidant properties of tomato (*Solanum lycopersicum* L.). Hortic. Environ. Biotechnol. 59, 215–223. https://doi.org/10.1007/s13580-018-0026-y

Tuzel IH, Tuzel Y, Gul A, Altunlu H, Eltez RZ (2001). Effect of different irrigation schedules, substrates and substrate volimes on fruit quality and yield of greenhouse tomato. Acta Horticulture 548, 285-291.

Tzortzakis N, Economakis GCD (2008). Impacts of the substrate medium on tomato yield and fruit quality in soilless cultivation. HORT. SCI. (PRAGUE) 35(2), 83-89.

Vaughn SF, Deppe NA, Palmquist DE, Berho MA (2011). Extracted sweet corn tassels as renewable alternative to peat in greenhouse substrates. Industrial crops and products 33(3), 514-517.