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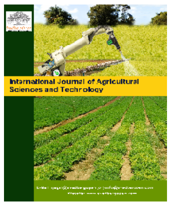

Research Paper

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Effect of Some Soilless Culture Systems on Growth and Productivity of Strawberry Plants

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Abstract

This research was carried out to investigate the effect of two soilless culture systems, i.e., solid substrates mixture as an open system and hydroponic (DFT technique) as a closed system on the vegetative growth, leaf anatomy and fruits yield and quality in comparison with traditional soil culture system during 2017 and 2018 seasons. The growth of strawberry plants cv. Festival cultivated in both applied culture systems was significantly enhanced in comparison with the traditional soil cultivated plants (control). Significant increases in the fresh and dry weights of root and shoots, root size, number of leaves and total leaves area/ plant were attained by the applied soilless culture systems, whereas a significant reduction in roots/shoots ratio was occurred. In addition, both applied soil alternative media caused a significant increase in the leaf content of photosynthetic pigments, nitrogen, phosphorous, potassium, calcium, magnesium and crude protein compared with the control. Anatomically, the applied alternative media led to obvious increases in the thickness of mid vein, length and width of main vascular bundle, thickness of phloem and xylem tissues, number of xylem vessels/bundle and thickness of lamina and its comprising tissues (upper and lower epidermis and mesophyll tissue). Moreover, the fruit yield/plant and fruit characteristics namely fresh and dry weight, dry matter/fruit were significantly improved as affected by the applied soilless culture systems compared to the control. Furthermore, a significant increase occurred in the concentrations of N, P, K, Ca, M, crude protein; reducing, non-reducing and total soluble sugars and vitamin C contents as well as Total Soluble Solids (TSS) estimated in the marketable fruits of strawberry plants cultivated in the two soilless culture systems (solid substrates mixture and hydroponic system), while, the titratable acidity % wasn't significantly affected. these advantageous effects on different studied growth, chemical anatomical and fruit yield and quality were most pronounced in case of the solid substrate cultivated plants followed by the hydroponically plants cultivated. These findings, therefore, strongly recommend the use of the applied soil alternative media as effective, safe and eco-friendly agricultural practices in the cultivation of strawberries and other vegetables to improve their growth, productivity and sanitary quality.

Keywords: *Soilless culture system, Hydroponics, Strawberry, Leaf anatomy, Fruit yield, Sanitary quality*

1. Introduction

Strawberry *(Fragaria ananassa,* Duch.) is one of the various, low-growing perennial plants of the genus *Fragaria* in the rose family (Rosaceae). It is one of the most sensitive vegetables in horticultural production and nutrient management

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is a key factor to ensure high yields with sanitary quality. Hence, an adequate management of nutrient elements is crucial to guarantee food safety and quality (Trejo-Téllez and Gómez-Merino, 2012). So the requirement of optimized media is very important because plant growth is largely dependent upon the physicochemical properties of the growing media used for high yield and economic production of crops (Shahzad et al., 2017).

Strawberry is commonly produced as early spring crop in open field or out-of- season in glasshouse or polyethylene tunnel. Pests and diseases in soil culture have always been problems especially in protected areas (Jafarnia et al., 2010). Strawberry plants require the use of non-saline soils, slightly acid and with a very good drainage system in order to prevent fungi diseases in the roots and crown of the plant (INIA, 1997). However, the agricultural system in Egypt suffers from many problems concerning the soil. Therefore, new methods are needed to produce strawberry crop with high physiological and sanitary quality (Giménez *et al.*, 2008). Thats why there is a modern trend in agriculture that doesn't use soil as a root environment "called soilless culture systems". Soilless Culture Systems (SCSs), the most intensive production method in today's horticulture industry, are based on smart and eco-friendly techniques, which can lead to higher yields, even in areas with adverse growing conditions (Gruda, 2009). SCSs permit crops to be grown where the soil is contaminated in some manner, where no suitable soil exists or where contraction of agricultural land (Wanas, 2018). It is more complete control of the environmental factors that affect plant growth and yield, i.e., root environment, fertigation, light, temperature, aeration, humidity, etc., (Jafarnia *et al.*, 2010).

Soilless farming systems have many benefits that are useful in solving many problems of land farming and provide the possibility of attaining a high yield in terms of quantity and sanitary quality (Wanas, 2018). Simplified soilless systems may be divided into two main categories, according to the destiny of the water drained after irrigation: closed system that enable to save up to 80% of the water commonly used in on-soil cultivation and open system which generally cheaper and require lower technology and skills for the management of plant nutrition (Putra and Yuliando, 2015). Also, these systems can be classified according to roots growing medium into: hydroponic system (liquid medium) where the plants are growing in nutrient solution by different techniques; aeroponic system (gas medium); solid substrates where plants are growing in different solid media, some of them are organic and the other are non-organic.

The present study aimed to improve growth and productivity of strawberry plants by using some soilless culture techniques as safe agricultural practices for human health and environment.

2. Materials and Methods

2.1. Experiment Design

The seedlings of strawberry (*Fragrria annanasa*, Duch.) cultivar Festival were obtained from the Agricultural Research Center, Giza, Egypt. The experiments were conducted at the Experimental Farm, Faculty of Agriculture, Damietta University during two successive winter seasons of 2017 and 2018. The experimental design included three systems of cultivation was done as follows:

2.1.1. Cultivation of Strawberry Seedlings in Traditional Soil (silt : sand 1:1 v/v)

Strawberry seedlings were sown in 60 agricultural plastic bags with 30 cm diameter (one seedling per bag) filled with clay and sand (1:1 v/v). Irrigation with tap water and other normal agricultural practices of growing strawberry were followed up as recommended.

2.1.2. Cultivation of Strawberry Seedlings in Solid Substrates Mixture

Sixty agricultural plastic bags of 30 cm in diameter were filled with solid substrates mixture consists of peat-moss, perlite and vermiculite (1:1:1 v/v/v), then strawberry seedlings were sown (one seedling per bag). In this system strawberry seedlings were irrigated with Cooper's nutrient solution (Table 1) according to their needs throughout the experiment.

2.1.3. Cultivation of Strawberry Seedlings Hydroponically, i.e., in Liquid Medium (Nutrient Solution)

One of the most popular techniques in hydroponic (deep flow technique, DFT) was used. It was designed in the form of A shape. The unit consists of 5 pipes (3 m long and 4 inches diameter). Each pipe had 12 slots in the upper side (9 cm diameter). A plastic net pot of 10 cm diameter was fixed in each slot and filled with perlite (as a stent for the plant) and covered with a thin layer of peatmoss to avoid the growth of algae on the upper surface of perlite. DFT unit was provided with reservoirs containing Cooper's nutrient solution. DFT unit was equipped with an electric pump for circulating the nutrient solution. The EC was adjusted at ~2.0 ± 0.2 dSm^{-1} using EC meter and pH value was adjusted at ~ 6.0 by adding

Table 1: Composition of Cooper's Nutrient Solution, Weights (mg) of Pure Substances to be Dissolved in 1 L of Water (Cooper, 1979)

Substance	Formula	Weight (mg)
Potassium dihydrogen phosphate	KH_2PO_4	263
Potassium nitrate	KNO_3	583
Calcium nitrate	$Ca(NO_3)_2.4H_2O$	1003
Magnesium sulphate	$MgSO_4.7H_2O$	513
EDTA iron	$[CH_2.N(CH_2.COO)_2]_2FeNa$	79
Manganous sulphate	$MnSO_4.\ H_2O$	6.1
Boric acid	H_3PO_3	1.7
Copper sulphate	$CuSO_{4.}\ 5H_2O$	0.39
Ammonium molybdate	$(NH_4)_6Mo_7O_{24}.4\ H_2O$	0.37
Zinc sulphate	$ZnSO_4.\ 7H_2O$	0.44

H_2NO_3 or KOH (0.1 M for each) using pH meter according to El-Banna and Abdelaal (2018). The nutrient solution was exchanged every week by a fresh one.

The strawberry seedlings were sown at the 20th of October for 2017 and 2018 seasons.

2.2. The Assigned Substrates

2.2.1. Peat Moss

A plantafoir sphagnum peat-moss with slightly to medium decomposed natural Baltic high bog peat without additives like lime and fertilizer, which prevent incrustation, sluding and drying up. According to its good physical characteristics, the peat is retaining water and soil temperature and improves the air content. Its ability to absorb water is 55-75 volume % and humidity ranges between 30-60 weight %.

2.2.2. Perlite

It was purchased from the Egyptian company for manufacturing perlite (E.C.P). The physical properties of the used perlite are given in Table 2.

Table 2: Physical Properties of the Used Perlite

Color	White
Refractive Index	1.5
Free Moisture, Max.	0.5%
pH	6.5 - 7.5
Specific Gravity	85 - 100 kg/m^3
Bulk Density	0.32
Fusion Point	1260 - 1343°C
Specific Heat	837 J/kg.k
Thermal Conductivity At (24°C)	0.04 - 0.06 W/m.k
Grain Size analysis	60 - 70% $\geq$ 2.36 mm

2.2.3. Vermiculite

It comprises hydrous phyllosilicates of magnesium, aluminium and iron, which in the natural state have a thin lamellar structure that retains tiny drops of water (Maucieri *et al.*, 2019). Exfoliated vermiculite is commonly used in the horticultural industry and is characterized by a high buffer capability and CEC values similar to those of the best peats, but, compared to these, it has a higher nutrient availability, 5-8% potassium and 9-12% magnesium (Perelli *et al.*, 2009). NH^{4+} is especially strongly retained by vermiculite; the activity of the nitrifying bacteria, however, allows the recovery of part of the fixed nitrogen. Similarly, vermiculite binds over 75% of phosphate in an irreversible form, whereas it has low absorbent capacity for Cl^-, NO_3^- and SO_4^-.

2.3. Sampling and Collecting Data

2.3.1. Vegetative Growth Characters

Four plants were randomly chosen from each system on the 70th day after planting in both seasons to estimate the growth parameters, namely; roots size (cm^3), roots fresh and dry weights (g) / plant, shoots fresh and dry weights (g) / plant, number of leaves / plant and total leaf area (cm^2) / plant. Total leaf area (cm^2) / plant was determined using the disk method (Derieux *et al.*, 1973).

2.3.2. Photosynthetic Pigments

Chlorophyll a, b and carotenoids were colorimetrically determined in strawberry leaves on the 70th day after sowing in both seasons according to the method described by Inskeep and Bloom (1985) and calculated as $mg.g^{-1}$ fresh weight.

2.3.3. Chemical Analysis of Leaves

Samples from strawberry leaves were taken on the 70th day after planting to determine total nitrogen (Jackson, 1967), phosphorus (Sandell, 1950), potassium (Horneck and Hanson, 1998) and calcium and magnesium (Jackson, 1967). Also, crude protein was calculated according to A.O.A.C (1990) using the following equation:

$$Crude\ Protein = Total\ Nitrogen \times 6.25$$

2.3.4. Anatomical Study

Leaf specimens 0.5 cm length from selected samples were taken during the second season from the terminal leaflet blade of the 3rd leaf for the anatomical investigation of leaf blade. Samples were killed and fixed for at least 48 h in F.A.A. solution (5 mL glacial acetic acid, 10 mL formalin and 85 mL ethyl alcohol 70%). Samples were washed in 50% ethyl alcohol and dehydrated in ethyl alcohol series (70, 90, 95 and 100%), infiltrated in xylene, embedded in paraffin wax of a melting point (56-58^{o}C), sectioned at 15 μ thickness using a rotary microtome, stained with safranin and light green combination and mounted in Canada balsam (Nassar and El-Sahhar, 1998).

2.3.5. Flowering and Fruiting Characteristics

Four plants from each system were randomly chosen, labeled and the following data were recorded:

i. Flower longevity (days): The time that passed between the existence of the first flower and last one.

ii. Number and weight (g) of total fruits /plant.

iii. Relative total yield / plant was calculated as a percentage of control yield.

iv. Average fruit weight (g): The weight of all harvested fruits / plant divided by the number of fruits per plant.

v. Average fruit dry weight (g): The dry weight of fruits / plant divided by the number of fruits per plant.

2.3.6. Chemical Constituents in Fruits

Samples from strawberry marketable fruits were taken to determine total nitrogen (Horneck and Miller, 1998), phosphorus (Sandell, 1950), potassium (Horneck and Hanson, 1998) and calcium and magnesium (Jackson, 1967), total and reducing sugars (Sadasivam and Manickam,1996), vitamin C and titratable acidity (A.O.A.C, 1990). Additionaly, total soluble solids (TSS) was measured in the juice of fresh strawberry fruits using a hand refractometer. Also, crude protein was calculated according to A.O.A.C (1990) using the following equation:

$$Crude\ Protein = Total\ Nitrogen \times 6.25$$

2.3.7. Statistical Analysis

Data of vegetative growth, flowering, yield and chemical composition of fruits were subjected to statistical analysis according to Snedecor and Cochran (1989) using LSD test at 0.05 level.

4. Results and Discussion

4.1. Growth Parameters

Data in Table 3 represent the mean values ($\overline{X}$) of roots size, root fresh and dry weights, shoots fresh and dry weights, number of leaves, total leaf area / plant and root/shoot ratio of strawberry plants cultivated in the two assigned soilless culture systems, i.e., solid substrates system using a mixture of peat-moss, perlite and vermiculite (1:1:1 v/v/v) as a growing medium and closed hydroponic system using the Deep Flow Technique (DFT) of nutrient solution (liquid medium), as well as those cultivated in traditional soil as a control. Data clearly indicated that different estimated growth parameters of strawberry plants cultivated in both soilless culture systems were significantly increased in comparison with those of the traditional soil cultivated plants during both seasons of this study. The highest values of shoots fresh and dry weights, roots dry weight and total leaf area/plant were obtained by using the solid substrates mixture as a growing medium. Meanwhile, the highest values of roots fresh weight and roots size were obtained by using the nutrient solution as a growing medium in the hydroponic system (DFT). On the other hand, the lowest values of all studied growth parameters were obtained by using traditional soil as a growing medium.

These findings are in conformity with the findings of El Sayed *et al.* (2016) who reported that the vegetative growth parameters of strawberry positively responded to using perlite: peat-moss mixture as a growing substrate. While, using perlite: peat-moss combined with mineral solutions had the highest values of all measured characteristics. Also, Raja *et al.* (2018) reported that the substrates directly influence growth and quality of strawberry cultivated in the soilless systems. All combinations of soilless substrates significantly improved the growth of strawberry compared to the sand. The substrates combination S7 (coco- peat + perlite, 25:75) and S15 (coco-peat + perlite + vermiculite, 50:25:25) were found superior among all applied combinations.

One of the advantages of plant nutrition in soilless culture systems is better control of root environment, particularly in relation to the aeration and management of the water and nutrient contents that affect plant growth and yield (Jafarnia *et al.*, 2010). Hence, the positive influence of the applied soil alternatives on the strawberry growth could be attributed to their ability to improve aeration and nutrients availability to the plants, thus forming greater root system accompanied with high efficiency of water, minerals and nutrients uptake leading to vigorous vegetative growth. That could be also reflected on further growth stages.

Table 3: Effect Some Soilless Culture Systems (Solid Substrates Mixture And Hydroponic Systems) on Some Growth Characteristics of Strawberry Plants After 70 Days from Transplantation During 2017 and 2018 Seasons

Measurements / Treatments	Roots Size (cm^3)/ Plant	Roots F.W (g)/ Plant	Shoots F.W (g)/ Plant	Roots D.W (g)/ Plant	Shoots D.W (g)/ Plant	Roots Shoot Ratio	No. of Leaves/ Plant	Total Leaf Area (cm^2)/ Plant
Season 2017								
Traditional soil	4.50	4.62	2.26	0.59	0.51	1.15	4.50	527.35
Solid substrates system	6.00	5.37	3.62	0.78	0.59	1.32	6.50	563.37
Hydroponic system	6.50	5.47	3.42	0.64	0.51	1.25	6.00	540.60
LSD $_{0.05}$	**1.06**	**0.08**	**0.17**	**0.04**	**0.02**	**0.07**	**1.06**	**19.25**
Season 2018								
Traditional soil	3.00	4.43	1.97	0.54	0.49	1.09	4.25	659.18
Solid substrates system	5.00	5.24	3.42	0.78	0.52	1.54	6.50	689.00
Hydroponic system	5.25	5.36	3.05	0.63	0.49	1.28	6.50	659.18
LSD $_{0.05}$	**1.16**	**0.13**	**0.23**	**0.05**	**0.07**	**0.27**	**1.13**	**102.26**

4.2. Photosynthetic Pigments

Data in Table 4 show the effect of the two applied culture systems on photosynthetic pigments levels in the leaves of strawberry plants after 70 days from transplantation. Data indicate that during 2017 and 2018 seasons, both soilless culture systems considerably increased the leaf content of chlorophylls (a and b) and carotenoids as well as their sum compared to the control (traditional soil) during both seasons of this study. Except for the reduction occurred in chlorophyll a level in the leaves of the hydroponically cultivated plants during both seasons. Similar results were obtained by Ebrahimi *et al.* (2012a) and Elsayed *et al.* (2016). Beside, Du *et al.* (2007) proved that substrates media strengthen activities of capturing light and the accumulation of photosynthetic products, so it improved the plant activities and increasing yeild. Because this mixture raise the availability of nutrients for absorption, the growth and development of plant were affected (Ebrahimi *et al.*, 2012a) where the availability of nutrients increased the photosynthesis process (Ayesha *et al.*, 2011).

Regarding the reduction existed in the leaf content of chlorophyll a in the hydroponically cultivated plants, it led to decrease in sum of each chlorophyll a + b and chlorophyll (a+b) + carotenoids (Table 4). These results are in harmony with the findings of Hikosaka *et al.* (2014). However, DFT A-shape structure allow availability of light resulted in higher photosynthetic rate than strawberry plants cultivated in traditional soil (Sharma and Godara, 2019). On the other hand, the increment of photosynthetic pigments levels in the leaves of the solid substrate cultivated plants could be attributed to the availability of some nutrients, particularly magnesium and iron. These nutrients is required for chlorophyll formation and plays a key role in photosynthetic activity (Farhat *et al.*, 2016).

Table 4: Effect of Some Soilless Culture Systems (Solid Substrates Mixture and Hydroponics) on Photosynthetic Pigments (mg G^{-1} F.W) of Strawberry Plants After 70 Days From Transplantation During 2017 and 2018 Seasons

Determinants / Treatments	Chlorophyll			Carotenoids	Chlorophyll (a+b) + Carotenoids
	a	b	a+b		
Season 2017					
Traditional soil	6.49	0.85	7.35	0.28	7.63
Solid substrates system	8.36	3.09	11.45	0.62	12.07
Hydroponic system	**6.13**	**0.88**	**7.01**	**0.34**	**7.35**
$LSD_{0.05}$	0.10	0.09	0.12	0.04	0.12
Season 2018					
Traditional soil	6.46	0.70	7.17	0.23	7.40
Solid substrates system	8.23	2.91	11.15	0.30	11.46
Hydroponic system	5.87	0.80	6.67	0.36	7.04
$LSD_{0.05}$	**0.18**	**0.03**	**0.18**	**0.06**	**0.40**

4.3. Chemical Constitute of Strawberry Shoots

Data in the Table 3 clearly show that both growing media (solid substrates mixture and liquid media “nutrient solution”) used in the two applied soilless culture systems significantly increased the shoots content of N, P, K, Ca and Mg as well as the calculated crud protein in comparison with those of the traditional soil cultivated plants during 2017 and 2018 seasons. The highest values of all estimated chemical constituents were obtained by using the solid substrates mixture as a growing medium followed by the nutrient solution used as a growing medium in the closed hydroponic system (DFT), while the lowest values were obtained by using the traditional soil as a growing medium. The enhancement of minerals content by using these soil alterative media, could be considered as a direct effect of these growing media upon stimulating minerals absorption through vigorous root system of the treated plants (Table 3). Besides, the increment of leaf area (Table 1) and photosynthetic pigments (Table 2), as well as enhancement of the dry matter accumulation in both roots and shoots, indicate the positive and stimulatory effects of the applied growing media upon the efficiency of minerals uptake and photosynthesis process and hence further growth stages.

These results and interpretations are in harmony with those of El-Sayed *et al.* (2016) who reported that the enhancement of minerals content by using perlite and peatmoss mixture as a growing medium due to the raise of available nutrients for absorption. Additionally, these substrates have a good aeration (Ebrahimi *et al.*, 2012b), low tension water potential (Ecrilsi *et al.*, 2005), high cation exchangeable capacity (Rostami *et al.*, 2014) and low bulk density due to its small pores, leading to its increased water conservation capacity. Hence, the substrates have a significant effect on chemical characteristics, consequently influenced vegetative growth parameters of strawberry plants efficiently (Ayesha *et al.*, 2011).

As for the the hydroponic grown plants, the absorption of nutrients occurs more easily than those of the traditional soil grown plants (Kumar and Saini, 2020), so the chemical characteristics were improved significantly.

Table 5: Effect of Some Soilless Culture Systems (Solid Substrates and Hydroponics Systems) on Some Chemical Constituents Levels (g $100g^{-1}$ D.W) in Strawberry Pant After 70 Days From Transplantation During 2017 and 2018 Seasons.

Measurements / Treatments	N %	Crude Protein %	P %	K %	CA %	Mg %
Season 2017						
Traditional soil	2.40	15.02	0.95	1.01	0.32	0.22
Solid substrates system	2.47	15.42	1.76	1.34	0.50	0.29
Hydroponic system (DFT)	2.45	15.32	1.03	1.16	0.47	0.24
$LSD_{0.05}$	0.04	0.30	0.25	0.16	0.07	0.04
Season 2018						
Traditional soil	2.38	14.89	0.84	1.12	0.37	0.23
Solid substrates system	2.44	15.28	1.68	1.39	0.49	0.27
Hydroponic system (DFT)	2.41	15.06	1.01	1.18	0.40	0.25
$LSD_{0.05}$	**0.03**	**0.21**	**0.11**	**0.07**	**0.04**	**0.02**

4.4. Leaf Anatomy

Data in Tables 6 and 7 represent the mean counts and measurements of some leaf anatomical features of strawberry plants grown in the applied culture systems, i.e., the solid substrates, hydroponic and traditional soil. Also, data in these

Table 6: Mid Vein Anatomy of Strawberry Leaves as Affected by Using Some Soilless Culture Systems

Measurements (µ) and Counts / Treatments	Thickness of Mid Vein		Length of Main Vascular Bundle		Width of Main Vascular Bundle		Thickness of Phloem Tissue		Thickness of Xylem Tissue		No. of Xylem Vessels/Main Bundle	
	X	± %	X	± %	X	± %	X	± %	X	± %	X	± %
Season 2017												
Traditional soil	398.73	00.00	144.65	00.00	225.28	00.00	62.89	00.00	81.76	00.00	44	00.00
Solid substrates system	482.46	+20.99	217.31	+50.23	207.34	+31.64	81.75	+29.98	135.56	+65.80	57	+29.54
Hydroponic system	488.08	+22.40	180.13	+24.52	225.28	+43.03	93.83	+49.19	86.30	+5.55	64	+45.45

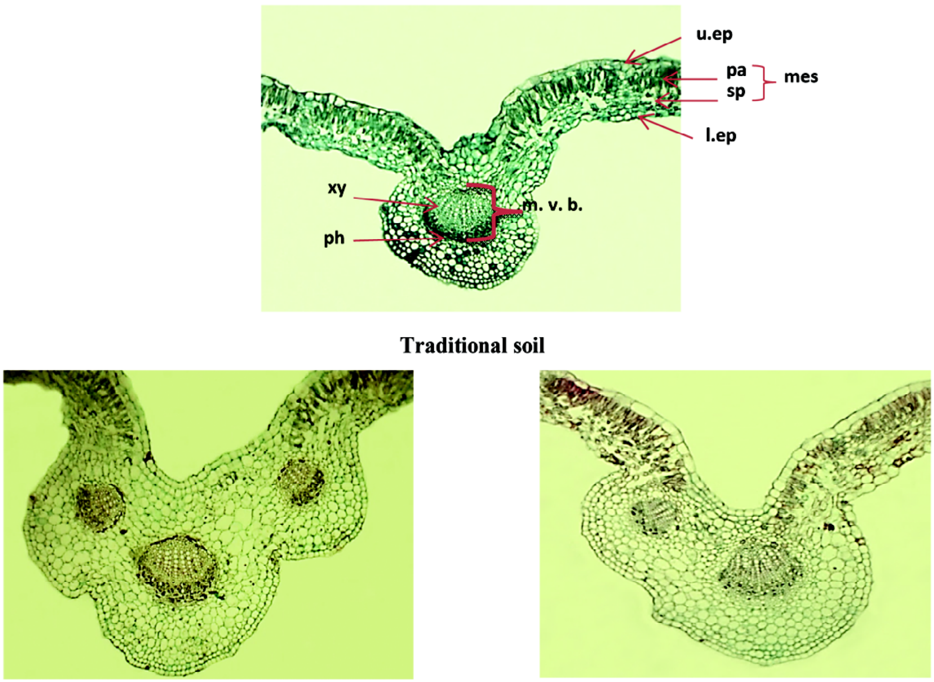
Note: Control values are considered as 100%; ± % = increase or decrease related to the control value.

Table 7: Lamina Anatomy of Strawberry Leaves as Affected by Using Different Soilless Culture Systems

Measurements (µ) and Counts / Treatments	Thickness of Lamina		Thickness of Upper Epidermis		Thickness of Lower Epidermis		Thickness of Mesophyll Tissue		Thickness of Palisade Tissue		Thickness of Spongy Tissue	
	X	± %	X	± %	X	± %	X	± %	X	± %	X	± %
Season 2017												
Traditional soil	145.48	00.00	22.55	00.00	13.76	00.00	109.17	00.00	49.25	00.00	59.92	00.00
Solid substrates system	167.39	+15.06	25.91	+14.90	15.37	+11.70	126.11	+15.52	61.54	+24.95	64..57	+7.76
Hydroponic system	**212.09**	**+45.79**	**24.19**	**+7.27**	**19.73**	**+43.39**	**168.17**	**+54.04**	**78.26**	**+58.90**	**89.91**	**+50.05**

Note: Control values are considered as 100%; ± % = increase or decrease related to the control value.

Tables as well as Figure 1 clearly show that different studied anatomical features of strawberry leaves were positively responded to the applied soilless culture systems compared to those cultivated in traditional soil (control). In this respect, thickness of the mid vein was increased over the control value (considered as 100%) by 20.99%; 22.40% as affected by the cultivation in the solid substrates mixture and the hydroponic system, respectively. Besides, the dimensions (length and width) of main vascular bundle were also increased with the two applied soilless culture systems compared with the control. The length of main vascular bundle reached highest value (217.31 µ) by using the solid substrates mixture, that represents 150.23% of the control value (144.65 µ), meanwhile the width of main vascular bundle reached its highest value (225.28) by using the hydroponic system and that represents 143.03% of the control value (225.28). Moreover, increment of the main vascular bundle length was accompanied with obvious increase in the thickness of its



Note: Abbreviations: ph = phloem, xy = xylem, m.v.b = main vascular bundle, l. ep = lower epidermis, u. ep = upper epidermis, pa = palisade tissue, sp = spongy tissue, mes = mesophyll tissue.

Figure 1: Transverse Section (100 x) Through the Terminal Leaflet Blade of the 3rd Leaf of Strawberry Plants Grown in Hydroponic System (dft) Affected by the Applied Soilless Culture Systems

component tissues, i.e., phloem and xylem tissues. The thickness of phloem tissue was increased to reach 93.83 µ by using the hydroponic system, that represent 149.19% of the control value (62.89 µ), while the xylem tissue thickness reached its maximum value (135.56 µ) by using the solid substrates culture system, that represent 165.80% of the control value (81.76 µ). Also the number of xylem vessels in the main vascular bundle was increased but reached highest value (64 vessels) by using the hydroponic system, that represent 145.45% of the control value (44 vessels).

Regarding the lamina thickness, as shown in Table 7 and Figure 1, it was obviously increased with the two applied soilless culture systems compared with the control (traditional soil) value which considered as 100%. Where the lamina thickness was increased over the control value by 15.06% with using the solid substrates and by 45.79% with using the hydroponic system. Increment of the lamina thickness was accompanied with obvious increases in thickness of its component tissues, i.e., upper epidermis, lower epidermis and mesophyll tissue, but the mesophyll tissue was the most affected lamina component. It was highly increased over the control value by 15.52% and 54.04% with using the solid substrates and the hydroponic system, respectively.

Herein, it could be concluded that strawberry plants exhibited anatomical responses to the soil alternatives media used in the two applied soilless culture systems better than the used traditional soil. Also, the alteration of different anatomical traits of strawberry leaves by using the soil alternatives as growing media is being of great interest. Because these alterations included an increase in the thickness of photosynthates creator (mesophyll tissue) and thickness of their passage (phloem tissue) as well as the thickness of different raw materials passage (absorbed by roots), i.e., xylem tissue. That means that these growing media improved translocation and caused more raw materials to be absorbed by roots and reached to leaves as well as more photosynthates to be allocated and partitioned to other plant parts. These could be positively reflected on further growth stages.

4.5. Fruit Yield

As shown in this Table 8, the flowering longevity of strawberry plants cultivated in the applied soilless culture systems was significantly increased compared with the traditional soil cultivated plants with the superiority of the solid substrates cultivated plants. Since, it was increased to reach 45.75 days and 47.50 days in the solid substrates cultivated plants during 2017 and 2018 seasons respectively, meanwhile it was 40.00, 39.25 in case of the traditional soil cultivated plants during the same seasons, respectively.

Table 8: Effect of Some Soilless Culture Systems (Solid Substrates Mixture And Hydroponic) on Fruit Yield of Strawberry Plants During the Season of 2017

Characteristics / Treatments	Flowering Longevity	Total Fruit Yield (G) / Plant	Relative Total Yield	No. Of Fruits/ Plant	Fruit F.W (g)	Fruit D.W (g)	% of Dry Matter / Fruit
Season 2017							
Traditional soil	40.00	95.32	100.00	4.25	22.56	2.30	10.19
Solid substrates system	45.75	149.71	157.06	6.25	23.98	2.67	11.13
Hydroponic system	42.75	120.38	126.29	5.25	22.98	2.41	10.48
$LSD_{0.05}$	1.46	12.50	-	0.79	1.91	0.20	-
Season 2018							
Traditional soil	39.25	80.57	100.00	3.75	21.47	2.12	9.87
Solid substrates system	47.50	132.27	164.16	5.75	23.01	2.49	10.82
Hydroponic system	44.50	105.38	130.79	4.75	22.17	2.27	10.23
$LSD_{0.05}$	**1.57**	**18.04**	**-**	**0.79**	**0.82**	**0.08**	**-**

Regarding the total fruit yield (g) /plant as indicated by relative total yield, it was significantly increased to exceed the control yield (considered as 100%) by 57.06% and 26.29% in the solid substrates and hydroponically cultivated plants, respectively during the first season, while the increment reached 64.16% and 30.79% over the control yield in the same order during the second season. In addition, the increment of total fruit yield/plant was accompanied with a significant increase in its components, i.e., fruit number/plant, fresh and dry weights (g)/fruit and percentage of dry matter/fruit with both applied soilless culture systems compared with the control (Table 8).

These results go along with (Raja *et al.*, 2018) who found that the substrates directly influence fruits quality of strawberry plants cultivated in soilless system. While, Sheel *et al.* (2019) lighten that fruit characteristics improved by using soilless culture systems.

The improvement of total fruit yield by using solid substrates mixture or hydroponic system as soil alternative culture media could be attributed to their capacity to improve aeration and nutrients availability to the plants, thus forming greater root system with high efficiency of water, minerals and nutrients uptake leading to attain vigorous vegetative growth (Table 3) accompanied with high photosynthetic efficiency (Table 4), formation more assimilates as well as enhancement the leaf anatomy (Tables 6 and 7), and hence improving the fruit growth rate. These results and interpretation are in conformity with the findings of Abou-Hadid *et al.* (1993 and 1998) and Shylla *et al.* (2018).

4.6. Chemical Constituents of Fruits

Data in Table 9 represent the mean values of N, P, K, Ca, M, crude protein (mg/g D.W); reducing, non-reducing and total soluble sugars (g 100 g^{-1} D.W) and vitamin C (mg 100g^{-1} D.W) as well as Total Soluble Solids (TSS) and titratable acidity % estimated in the marketable fruits of strawberry plants cultivated in the two applied soilless culture systems as well as traditional soil as a control during 2017 and 2018 seasons. Data clearly show that different estimated mineral nutrients, bioconstituents and TSS of strawberry fruits were significantly increased as affected by using the solid substrates mixture and hydroponic as growing media in comparison with using the traditional soil (control), whereas no significant differences were existed in the titratable acidity % during both seasons of this study. Also, it could be noticed that all estimated mineral nutrients and bioconstituents in strawberry fruits raised up to highest values by using the solid substrates as a growing medium followed by the hydroponic system.

The increment of total sugars content in the strawberry fruits could be attributed to improvement the strawberry growth concerning efficient photosynthesis and improvement the translocation of their products as well as N, P and K

Table 9: Effect of Some Soilless Culture Systems (Solid Substrates Mixture And Hydroponic System) on Some Chemical Constituents of Strawberry Fruits During 2017 and 2018 Seasons

Characteristics / Treatments	mg g^{-1} D.W.						D. W. g $100g^{-1}$			F.W.		
	N	P	K	Ca	Mg	Crude Protien	Red. Sugars	Non Red. Sugars	Total Sugars	Vit. C mg $100g^{-1}$	TSS (brix°)	Titratable Acidity (%)
Season 2017												
Traditional soil	8.38	0.22	0.82	0.21	0.07	52.38	10.98	3.15	14.13	86.47	6.65	0.43
Solid substrates system	9.29	0.31	0.92	0.23	0.12	58.06	11.35	3.28	14.63	88.10	7.21	0.45
Hydroponic system	8.88	0.31	0.86	0.21	0.11	55.50	11.18	3.25	14.43	87.12	6.97	0.46
$LSD_{0.05}$	**0.04**	**0.01**	**0.03**	**0.01**	**0.02**	**0.23**	**0.14**	**0.09**	**0.19**	**0.47**	**0.22**	**0.04**
Season 2018												
Traditional soil	8.17	0.21	0.81	0.16	0.06	51.06	11.03	3.05	14.08	86.48	6.61	0.41
Solid substrates system	8.49	0.31	0.90	0.21	0.12	53.06	11.46	3.15	14.61	87.60	7.35	0.45
Hydroponic system	8.39	0.31	0.85	0.19	0.10	52.44	11.32	3.20	14.52	87.28	7.14	0.46
$LSD_{0.05}$	**0.19**	**0.01**	**0.01**	**0.02**	**0.02**	**0.59**	**0.16**	**0.06**	**0.13**	**0.19**	**0.22**	**0.05**

to the ultimate fruits as affected by using soil alternatives as growing media. Thereby, the obtained strawberry fruits under these soilless cultivation conditions were of good quality.

5. Conclusion

The present results and interpretation are confirmed by the findings of El Sayed *et al.* (2016), who showed that the vegetative growth parameters and leaf chemical contents positively responded to using soilless culture systems, which leads to raise in chemical constituents of strawberry fruits.

These findings, therefore, strongly support the use of the solid substrates mixture and the closed hydroponic system (A-shape) with deep flow technique of nutrient solution (DFT) for their numerous advantages and as effective, safe and smart eco- friendly agri-techniques in strawberry cropping.

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