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EFFECT OF DIFFERENT SUBSTRATES ON YIELD AND FRUIT QUALITY OF TOMATO GROWN IN SOILLESS CULTURE

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Abstract

Purpose of this study was to examine plant growth, yield, and fruit quality responses of tomato cultivar „Delgado F_1" grown in different soilless culture substrates, such as perlite, rock wool, and coconut fiber, under greenhouse conditions. Horizontal bag culture was used as a growing system. The yield, plant biomass, leaf, height, width, fruit taste, aroma, acidity, water-soluble solids content (TSS) and lycopene content were measured. According to the results, the best fruit quality was determined for the coconut fiber media, while the highest total yield was obtained for the perlite media.

Keywords: Soilless culture, Solanum lycopersicum, rock wool, perlite, coconut fiber, yield and quality

INTRODUCTION

Due to inadequate agricultural area and climatic factors in the world, an increasing trend of using soilless culture has been observed worldwide (Pardossi *et al.* 2011). Soilless cultivation, which is especially important for the protection of the environment, is being extensively used in many countries (Holland, Israel, UK, Japan, France, New Zealand, etc.). Many diseases and pests originating from soil can have a very negative effect on vegetable production. For this reason, controlled cultivation of plants is now more important. Furthermore, soilless culture system can improve water use efficiency, as well as water and fertilizer management in vegetable production (Savvas *et al.* 2013). Thus, 95% of tomato cultivated in Europe's greenhouses is grown by soilless farming techniques and the most used growing medium is rock wool and coconut fiber (Peet and Heuvelink, 2005). In addition, many researchers have suggested that plant growth, yield, and quality in soilless cultures are better than those in soil cultivation (Savas *et al.* 2013 Putra and Yuliando 2015). There have been many studies conducted on substrate media, but these studies were mostly based on mixed media at a certain rate. However, some of the researchers support inorganic media, while others report that organic media are more advantageous for growing. For example: coconut fiber, perlite, and peat are used in the cultivation of cucumber (Alifar *et al.* 2010) and tomato (Borji *et al.* 2010), and in these studies coconut fiber has shown better yield and fruit quality than others. Mazuela *et al.* (2012) recommended using compost, an organic material, while studying the effects of organic and inorganic substrates on tomato yield and quality. In another study examining the effects of rock wool, perlite and coconut fiber media on yield and nutrient content of cucumber and pumpkin cultivation, coconut fiber had higher yield than rock wool and perlite (Cardarelli *et al.* 2012). A good growing medium provides sufficient anchorage or support to the plant, serves as a reservoir for nutrients and water, allows oxygen to diffuse to the roots and permits gaseous exchange between the roots and atmosphere outside the root substrate. However, different substrates have various materials and structure which could have direct and/or indirect effects on plant growth and development. These substrates can be used alone, but mixtures of the substrates, such as peat and perlite, coir and clay, peat, coconut fiber and compost (Gutierrez *et al.* 2012), are also used widely.

The main goal of mixing substrates in specific proportions is to eliminate the problems that may arise by combining the superior properties of materials. For example, the water-holding capacity can be increased by using inorganic and organic media at certain ratios which eliminate problems related to nutrition (Albaho *et al.* 2009; Johnson 2010; Gutierrez *et al*. 2012). As a matter of fact, a lot of researchers have been working on mixing organic and inorganic substrates at different ratios. The most commonly used growing media in soilless cultivation in the world are rock wool, coconut fiber, perlite, volcanic tuff, and peat. However, research on the comparison of solely used organic and inorganic media is very limited.

Purpose of this study was to examine plant growth, yield, and fruit quality responses of tomato cultivar „Delgado F1" grown in different soilless culture substrates, such as perlite, rock wool, and coconut fiber, under greenhouse conditions.

MATERIALS AND METHODS

The experiment was carried out in the polyethylene greenhouse during the autumn growing season. During the experiment, temperature, humidity, ventilation and irrigation were measured by a fully automated (Hortimax, Netherlands) greenhouse measurement system. The temperature inside the greenhouse was kept between 20-28°C at daytime and 13-18°C at nighttime. The relative humidity in the greenhouse was kept between 65-85%. Irrigation was calculated by using the solar radiation method, considering the radiation from the sun. Irrigation level was arranged according to the radiation obtained with sensors: 1 $(J \cdot m^{-2}) \cdot h^{-1}$ equals 1 mm water$\cdot h^{-1}$. Rock wool, coconut fiber, and perlite were used as a growing medium. The excess of the fertilizer solution used was collected with the drainage gutters on the sides of the slab transport system and drained out of the greenhouse. The amount of nutrient solution was adjusted by the drippers.

In the study, Delgado F1 (beef) tomato (*Solanum lycopersicum*) cultivar was used as plant material. In substrate growing system, plants from a commercial nursery (Hishtil Toros, Antalya, Turkey), were transplanted (24 days after sowing) into the perlite, coconut fiber, and rock wool growing media. The substrates in bags, with 20 dm^3 (1.00 x 0.22 x 0.10 m) each, were used, with four plants in each bag (2.5 plant$\cdot m^{-2}$).

The dry weight of the prepared material amounted to approximately 1 kg. However, as a result of the saturating process, about 5 dm^3 of growing medium was provided for each plant.

Table 1. Nutrient solution concentration according to plant growth period (ppm)

Nutrient element concentration (ppm)			
	Flowering period*		
Elements	**1**	**2**	**3**
Nitrogen Nitrogen	88	177	177
Phosphorus	48	62	69
Potassium	383	417	446
Calcium	145	119	119
Magnesium	63	67	67
Iron	2	2	2
Manganese	2	2	2
Zinc	1	1	1
Boron	1	1	1
Cupper	0.2	0.2	0.2
Molybdenum	0.05	0.05	0.05

*1 – From planting to seventh flower cluster, 2 – From seventh flower cluster to tenth flower cluster, 3 – From tenth flower cluster to fifteenth flower cluster (last harvest time).
Source: Own study

The coconut fiber was 70% thick and 30% fine or powdery, and this material was also placed in a horizontal PE bag. Initially, the pH range of the material was 5.5-6.8 and the electrical conductivity varied between 250-500 $\mu S \cdot cm^{-1}$. Perlite was filled with horizontal bags of the same size and placed in the growing areas. Before planting, humidity of all the bags was increased to approximately 80%. The rock wool and perlite material were saturated with solutions with following values: EC 1.8 dSm^{-1}, pH values: 5.5. The coconut fiber bags were saturated with a solution of calcium nitrate (150 g $\cdot$ 100 dm^{-3} water) with EC at the level of 1.8 dSm^{-1}, pH – 5.5. The saturation was done with drip irrigation systems in all three media. The plants were planted one day after reaching full saturation in growing conditions. Subsequent irrigation was carried out with nutrient solutions as specified in Table 1.

Table 2. Average of daily nutrient solutions used per plant, EC and pH values during experiment

Months	Growing Media	Nutrient solution $ml \cdot day^{-1}$	EC dSm^{-1}	pH
September	Rock wool	1200	2.0	5.7
	Coconut fiber	1500	2.0	5.7
	Perlite	1750	2.0	5.7
November	Rock wool	1800	2.2	5.6
	Coconut fiber	1950	2.2	5.6
	Perlite	2000	2.2	5.6
December	Rock wool	400	3.1	5.5
	Coconut fiber	550	3.1	5.5
	Perlite	550	3.1	5.5
November	Rock wool	600	3.0	5.5
	Coconut fiber	600	3.0	5.5
	Perlite	800	3.0	5.5
January	Rock wool	500	3.1	5.5
	Coconut fiber	550	3.1	5.5
	Perlite	650	3.1	5.5
February	Rock wool	400	3.1	5.5
	Coconut fiber	550	3.1	5.5
	Perlite	550	3.1	5.5

Source: Own study

The EC value of the top water used for irrigation was in the range of 0.7-0.8 dSm^{-1}, and the EC value was increased to 1.7-1.8 dSm^{-1} by the nutrient solution during planting. The EC value was increased to 2.2 dSm^{-1} in the first flower period and 3.1 dSm^{-1} in the later developmental stage (Table 2). The humidity was kept between 60-65%. Moisture of the bags was measured between 12:00 and 13:30 daily with a bed humidity meter (Grodan, Netherlands). The amounts of nutrient solutions of the growing media, EC and pH values were adjusted daily by Hortimax fertilizer system. The used nutrition solution was measured monthly (Table 2).

Total number of leaves, height, width, and the index, as well as 10 leaves of each plant were counted before and after pruning and counted as number. Leaf width and length measurements were done with a steel tape measure. The index was calculated as the ratio of leaf width to length. Plant height was measured with a steel tape measure. Measurements were performed every 10 days. Fruits were weighed with a digital ± 5 g scale, counted every week and harvested when the fruit variety had its own specific size and color. Total yield was obtained by adding up the weights of all the fruits harvested at each harvesting period. 12 harvests were made during this period. Fruit firmness was determined using a digital texture machine (LF Plus Ametec Ins.) and measured via compression using a 50 N load cell and a stainless steel, 5.1 mm diameter cylindrical probe with a constant speed of 100 $mm \cdot min^{-1}$ at a day of harvest and during storage period.

Taste and flavor of fruits were evaluated using the following scale: 1 – very poor, 2 – poor, 3 – mild, 4 – good, 5 – excellent. Titratable acidity (TA) was determined by a digital pH meter (Hanna Instruments HI 9231) and titrimeter (Digital, Isolab), and was expressed as percentage of grams of citric acid equivalent per 100 g fresh weight. pH was also measured by a digital pH meter. The soluble solid content (SSC) was measured using a digital refractometer (Atago Pocket PAL-1) and SSC was expressed as percentage of soluble solids per 100 g fresh weight. Fruit color of tomato was determined using a Minolta CR-300 colorimeter (Minolta Ramsey, NJ, USA). A white calibration plate (Y = 92.3, x = 0.3136 and y = 0.3194) was used for calibration. The values were expressed by the CIE L* (brightness-darkness), a* (+a*: red, – a*: green) and b* (+b*: yellow, – b*: blue) system. Lycopene measurements were performed using the method of Fish *et al*. (2002). For this purpose fruits were used at full maturity stage and 0.5 g of fruit was weighed into 250 ml test tubes, 20 ml of the hexane:acetone:methanol (2:1:1) mixture was added to the tube, later the tube's cap was capped and the mixture was shaken on the shaker for 30 minutes. Then 3 ml of purified water was added and the mixture was shaken for an additional 5 minutes. After shaking, the remaining hexane phase was filtered through Whatman blue band filter paper and the resulting filtrate was analyzed in order to determine hexane concentration, using a spectrophotometer (Shimadzu UV-1208) at 503 nm. The absorbance value at A_{503} spectrophotometer was fixed at 0.0312. The total amount of lycopene was calculated according to the following formula:

$$\text{Lycopene} = A_{503} \text{ x } \frac{0,0312}{\text{kg tissue}} = \text{mg kg}^{-1}$$

The measurements were carried out twice a month, with a total of 12 measurements. During the production, 10 harvests were made and the yields of each harvest were evaluated as total yield expressed as kg·m^{-2} and kg.

The experiment was carried out as a randomized block design with 3 replicates (n: 40). The experimentals were arranged randomly in the greenhouse. Data was analyzed using the MINITAB statistical analysis program and LSD test. Results marked with different lower case letters are different at a significance level of $P \leq 0.05$.

RESULTS

Leaf number, width, length and index

Leaf number was affected by growing media and months. The maximum number of leaves was found for coconut fiber. The plants grown in perlite showed longest leaf and leaf length, while the shortest leaf length was determined for the rock wool growing media (Table 3). The widest leaves were determined for perlite, while the narrowest leaves were determined for rock wool. The leaf index was not different for growing media and time. Plant height varied for time and the fastest growth was determined in the perlite media (Table 3).

Table 3. Plant height, number of leaves length, width and index according to monthly

Months	Growing media	Plant height [cm]	Number of leaf plant^{-1}	Leaves length [cm]	Leaves width [cm]	Leaves Index
September	Rock wool	67.0 b	13.6 b	33 b	30 c*	1.1
	Coconut fiber	75.7 a	15.7 a	38 a	35 b	1.1
	Perlite	75.9 a	15.0 a	40 a	40 a	1.0
October	Rock wool	230.1 b	24.6 c	35 b	35 b	1.0
	Coconut fiber	220.0 b	28.6 a	37 b	37 b	1.0
	Perlite	247.8 a	27.0 a	42 a	42 a	1.0

Months	Growing media	Plant height [cm]	Number of leaf plant^{-1}	Leaves length [cm]	Leaves width [cm]	Leaves Index
November	Rock wool	267.1 b	35.4	35 b	35 b	1.0
	Coconut fiber	250.1 b	36.0	37 b	37 b	1.0
	Perlite	280.9 a	35.0	43 a	42 a	1.0
December	Rock wool	283.7 b	43.5	36	36	1.0
	Coconut fiber	271.4 b	45.0	38	37	1.0
	Perlite	315.8 a	44.3	40	39	1.0
January	Rock wool	302.6 b	50.2 b	37	37	1.0
	Coconut fiber	300.7 b	53.0 a	38	38	1.0
	Perlite	340.6 a	52.5 a	39	38	1.1

*Means followed by different letters are significantly different at $P < 0.05$.Values with different letters appended are statistically different from one another as indicated by *ANOVA* analysis (n = 40)
Source: Own study

Mean number of fruits and fruit weight

The average number of fruits per plant was observed in rock wool with 75 fruits, followed by the perlite media with 65, and coconut fiber with 50. The average fruit weight for perlite, coconut fiber and rock wool were 320, 305 and 257 g, respectively (Table 4).

Table 4. Number of fruits per plant and mean fruit weight

Growing media	Number of fruits	Fruit weight
Rock wool	75 c	257 c
Coconut fiber	65 b	305 b
Perlite	50 a	320 a
LSD 5%	5.05	3.25

Values with different letters appended are statistically different from one another as indicated by *ANOVA* analysis (n = 40)
Source: Own study

Fruit quality parameters

Titratable acid in fruit: Titratable acidity value in fruit juice was highest for coconut fiber (0.43 mg·100 ml^{-1}) and lowest for perlite (0.31 mg·100 ml^{-1}) wheras in Table 5.

Fruit soluble solid content (TSS %): The highest TSS was determined for coconut fiber, while the lowest value was determined for the perlite growing media. The highest average TTS value (6.0%) was found for coconut fiber and the lowest average TTS value (4.1%) was found in fruits of the plants grown in perlite (Table 5).

Table 5. Fruit titratable acid, soluble solid content (Brix), lycopene, firmness and fruit sensory attributes

Months	Growing Media	Titratable acid mg·100^{-1}	Brix sold %	Fruit lycopene mg·kg^{-1}	Fruit firmness kg·m^{-2}	Fruit sensory attributes
September	Rock wool	0.40 a	5.5 a	50.12 b	3.42 a	3 b
	Coconut fiber	0.43 a	5.9 a	65.37 a	2.16 b	4 ab
	Perlite	0.31 b	4.0 b	53.12 b	2.56 c	4 ab
October	Rock wool	0.40 a	5.4 b	53.30 b	3.53 a	3 b
	Coconut fiber	0.44 a	6.0 a	68.72 a	3.15 b	5.0 a
	Perlite	0.33 b	4.2 c	55.66 b	2.80 c	2 c
November	Rock wool	0.42 a	5.4 b	52.66 b	3.61 a	3 b
	Coconut fiber	0.44 a	6.2 a	67.09 a	3.08 b	5.0 a
	Perlite	0.30 b	4.2 c	57.63 b	2.66 c	3 b
December	Rock wool	0.41 a	5.2 b	55.78 b	3.45 a	4 ab
	Coconut fiber	0.42 a	6.2 a	68.87 a	3.07 b	5.0 a
	Perlite	0.30 b	4.2 c	58.08 b	2.73 c	3 b
January	Rock wool	0.40 a	5.5 a	50.12 b	3.42 a	3 b
	Coconut fiber	0.43 a	5.9 a	65.37 a	2.16 b	4 ab
	Perlite	0.31 b	4.0 b	53.12 b	2.56 c	4 ab

*Means followed by different letters are significantly different at $P < 0.05$. Values with different letters appended are statistically different from one another as indicated by *ANOVA* analysis (n = 40)
Source: Own study

Fruit lycopene content: According to the lycopene analysis, the highest value of lycopene was found for the coconut fiber medium in February with 68.87 mg·kg^{-1}, while the lowest value of lycopene was found for the rock wool growing media with 50.12 mg·kg^{-1} in November. The lycopene levels in fruits of the plants grown in the coconut fiber medium were found to be much higher than in those grown in the other analyzed media (Table 5).

Fruit firmness (kg·m^{-2}): The most high-value fruit firmness was determined with 3.61 kg·m^{-2} for rock wool during November, the lowest one was determined with 2.56 kg·m^{-2} for perlite during January. Considering all the months, fruit firmness was the highest for rock wool, but there was no statistically significant difference for perlite and coconut fiber media in December and February (Table 5).

Fruit sensory attributes: The fruit taste and flavor in the experiment was evaluated using the 1-5 scale (Koyuncu, 2005). Fruits from the plants grown in coconut fiber had the best taste aroma value for all months, while in the case of the perlite media – the lowest value in this group was recorded (Table 5).

Fruit Colour*:* There was no significant difference among the fruit color values for growing media in time. Data not showed.

Yield: The harvest started 60 days after planting and in total 15 harvests were carried out. As shown in Table 7, the yield per plant was determined as 14.09, 15.06 and 15.24 kg, for the rock wool, coconut fiber, and perlite growing media, respectively. While the yield per plant was the lowest in the case of the rock wool medium, there was no significant difference for the coconut fiber and perlite media (Table 6).

Table 6. Marketable and unmarketable per plant after 10 cluster fruit set

Growing media	kg·plant^{-1}	unmarketable kg·plant^{-1}
Rock wool	14.09	0.325
Coconut fiber	15.06	0.257
Perlite	15.24	0.263
Mean	15.25	0.281
LSD 5%	ns	ns

Values with different letters appended are statistically different from one another as indicated by *ANOVA* analysis (n:40)
Source: Own study

DISCUSSION

The characteristics of yield and quality of the green component of the plant is closely related to the growing media used in soilless culture and the amount of nutrient solution used (Ta *et al*. 2011). In this study, it was determined that by applying perlite and coconut fiber, a larger leaf size, a higher number of leaves and higher plant height (Table 3) can be achieved during the whole growing season than in the case of using rock wool. Uysal (1998) used soil, perlite, and peat as a growing media and determined that the plants grown in the perlite medium were superior to those grown in other media in terms of stem diameter, stem length, and leaf number. However, some researchers have reported longer leaf length and plant length for coconut fiber, compared to perlite growing media, in cultivation of tomato (Mavrona *et al*. 2001) and strawberry (Tehranifar *et al*. 2007). As for the fruit number, plants grown on rock wool and coconut fiber produced more fruit than in the case of applying the perlite growing media. In terms of fruit weight, the opposite result was observed. The highest average fruit weight was found for perlite growing media with 320 g (Table 4). In a similar study, which compared yield and fruit quality of tomatoes grown in perlite and rock wool media, the best result was obtained for the perlite growing media (Paranjpe *et al*. 2008). Fruit weight, firmness, soluble solid, titratable acidity, color, carotenoids are closely related to fruit quality and these parameters can be affected by growing media (Alifar *et al*. 2010; Ghehsareh *et al*. 2012, Albaho, 2013). However, some researchers have reported that the growing media used in soilless culture have little effect on yield and fruit quality (Angelis *et al*., 2001, Schnitzler and Gruda, 2002, Lopez *et al*. 2004; Mazurella *et al*. 2012). In this study, average fruit weight (Table 4), fruit firmness, fruit flavor and aroma evaluation (fruit sensory attributes), fruit titratable acidity, fruit soluble solid and fruit lycopene content were affected by growing media (Table 5). Results showed that the highest fruit set was observed in the case of samples grown on rock wool, whereas for perlite 20% heavier fruit was noted than for the rock wool growing media (Table 4). This situation can be explained by fruit number as less fruit set (less fruit) is in the perlite growing media could uptake more nutrition and water to fruits that increase to fruit weight. It is known that there is a positive relationship between the EC level of the growing media and the fruit flesh firmness (Stamatakis *et al.* 2003). In this study, it was determined that the fruit firmness of tomatoes grown on rock wool with high EC value (EC: 5.05 dSm^{-1}) was higher than for the fruits grown on the coconut fiber (EC: 4.2 dSm^{-1}) and perlite (EC: 4.0 dSm^{-1}) medium (Table 5). This is thought to be due to the increase in the amount of wax on the surface of the fruit in the high EC growing conditions, such as rock wool. The coconut fiber growing media gave better results than the other two, considering such characteristics as fruit taste and flavor, fruit acidity, fruit water soluble dry matter and fruit lycopene content (Table 5). In particular, it has been determined that in the growing conditions of the research coconut fiber is very advantageous in terms of amount of water-soluble dry matter. Increase in yield in plants is closely related to plant biomass. In this study, perlite was found to be more advantageous for plant biomass development than the other growing media (Table 3). This situation is also reflected in the yield (Table 6).

REFERENCES

Albaho M., Bhat N. Thomas B.M., Isathali S., George P., Ghloum D. (2013). *Alternative Growing Media for Production of Cucumber Cultivar 'Banan' for Soilless Culture in Kuwait*. Acta Hortic, (Ishs) 1004: 115-121.

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.

Alifar N., Ghehsareh A.M., Honarjoo N. (2010). *The Effect of Growth Media on Cucumber Yield and It Is Uptake Of Some Nutrient Elements in Soilless Culture*. Journal of Science and Technology of Greenhouse Culture, 1, 19-25. *And Earliness of Cucumber on Autumn Growing Period*. Acta Hortic, 492: 259-264.

Angelis G., Papadantonakis N., Spano T., Petrakis C. (2001). *Effect Of Substrate and Genetic Variation on Fruit Quality in Greenhouse Tomatoes*: Preliminary Results. Acta Hortic. 548: 497-502

oBorji H., Ghahsareh A.M., Jaforpour M. (2010). *Effect of The Substrate on Tomato in Soilless Culture*. Research Journal of Agriculture and Biological Sciences, 6 (6): 923-927.

Cardarelli M., Rauphael Y., Darwich S., Rae E., Fiorillo A., Colla G. (2012). *Substrate Type Effect Growth, Yield on Mineral Composition of Cucumber and Zucchini Squash*. Journal Of Life Sciences, 6: 766-770.

FAO (2013). http://faostat.fao.org/site/567

Fish W.W., Perkins-Veazie P., Collins J.K. (2002). *A Quantitative Assay for Lycopene That Utilizes Reduced Volumes of Organic Solvents. Journal of Food Composition and Analysis*, 15: 309-317.

Ghehsareh A.M., Hematian M., Kalbasi M. (2012). *Comparison of Date-Palm Wastes and Perlite as Culture Substrates on Growing İndices in Greenhouse Cucumber*. International Journal of Recycling of Organic Waste in Agriculture, 10: 1-5.

Gutierrez G.A.M., Altamirano G.Z., Urrestarazu M. (2012). *Maguey Bagasse Waste as Sustainable Substrate in Soilless Culture by Melon and Tomato Crop*. Journal of Plant Nutrition, 35: 2135-2144.

Johnson Jr. H., Hochmuth G.J., Maynard, D.N. (2010). *Soilless Culture of Greenhouse Vegetables.* Institute of Food and Agricultural Sciences, 218: 19-22.

Koyuncu M.A. (2005). *Quality Changes of Three Strawberry Cultivars During The Cold Storage*. Europe Journal Horticultural Science, 69: 125-131.

Lopez J.F., Vásquez Ramos F. (2004). *Effect of Substrate Culture on Growth,* Yield and Fruit Quality Of The Greenhouse Tomato. Acta Hortic, 659: 417-424.

Mavrona T.E., Gerasopoulos D., Pritsa T., Maloupa E., (2001). *Growth, Fruit Yield and Quality of Tomato in Relation to Substrate and Nutrient Source in a Soilless Culture System*. Acta Hortic, 548: 173-180.

Mazuela, P., Trevizan, J.F., Urrestarazu, M., (2012). A *Comparison of Two Types of Agrosystems for The Protected Soilles Cultivation of Tomato Crops in Arid Zones*. Journal of Food, Agriculture and Enviroment. 10 (1): 338-341.

Paranjpe A.V., Cantliffe D.J., Stoffella P.J., Lamb E.M., Powell C.A., (2008). *Relation of Plant Density to Fruit Yield Of 'Sweet Charlie' Strawberry Grown in a Pine Bark Soilless Medium in a High-Roof Passively Ventilated Greenhouse*. Scientia Hortic, 115: 117-123.

Pardossi A., Carmassi G., Diara C., Incrocci L., Maggini R., Massa D. (2011). *Efficient Use of Inputs in Protected Horticulture*. Department of Biologicial Agriculture, University of Pisa, Italy, p. 260.

Peet M.M., Heuvelink, E. (2005). *Irrigation and Fertilization in Tomatoes*. Cabi Publishing, Wallingford U.K, p. 198.

Putra P.A., Yuliando H. (2015). *Soilless culture system to support water use efficiency and product quality*: a review. Agric. Sci. Procedia 3: 283-288.

Savvas D., Gianquinto G., Tuzel Y., Gruda N. (2013). *Soilless Culture*. FAO Plant Production and Protection Paper No. 217: Good Agricultural Practices for Greenhouse Vegetable Crops.

Schnitzler W.H., Gruda N. (2002). *Hydroponics and Product Quality, Hydroponic Production of Vegetables and Ornamentals*. Embrio publications, Athens, 463.

Stamatakis A., Papadantonakis N., Savvas D., Lydakis-Simantiris N., F Kefalas P. (2003). *Effects of Silicon And Salinity on Fruit Yield and Quality of Tomato Grown Hydroponically*. Acta Hortic, 609: 141-145.

Ta T.H., Shin J. H. Ahn T.I., Son J.E. (2011). *Modeling of Transpiration of Paprika (Capsicum Annuum L.) Plants Based on Radiation and Leaf Area İndex in Soilless Culture*. Horticultural Environment Biotechnology, 52(3): 265-269.

Tehranifar A., Poostchi M., Arooei H., Nematti H. (2007). *Effects of Seven Substrates on Qualitative and Quantitative Characteristics of Three Strawberry Cultivars Under Soilless Culture*. Acta Hortic, (ISHS) 761: 485-488.

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