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Effect of Some Soilless Culture Techniques on Sweet Pepper Growth, Production, Leaves Chemical Contents and Water Consumption under Greenhouse Conditions

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ABSTRACT

This study was carried out in the fiberglass greenhouse at the farm of the vegetable crops department, Faculty of Agriculture, Cairo University, Giza, throughout the two growing seasons of 2012/2013 and 2013/2014 to investigate the effect of some soilless culture techniques (perlite, rice straw and modified plant plane hydroponic) on the growth and yield of sweet pepper (*Capsicum annuum* L.), cv., 7158 comparing with sandy soil. The experiment included 4 treatments with 3 replicates arranged in a randomized complete block design. Data indicated that sweet pepper plants grown on any used soilless culture substrate consumed lower quantities of water and nutrient solution than in sandy soil, the plants grown on straw, followed by perlite then plant plane hydroponic, respectively, in this regard. Growing pepper plants on perlite and plant plane hydroponic caused a significant decrease in all vegetative growth characters during the early stage of the growth periods (90 days after transplanting), as compared with sandy soil. In contrast, vegetative growth characters of pepper plants cultured on modified plant plane hydroponic and perlite media were generally better than those recorded on plants grown on sandy soil, 120 days after transplanting. Nonmarketable yield, as well as N and K % in leaves of plants cultured on modified plant plane hydroponic and perlite substrate were significantly lower than those recorded on plants cultured on sandy soil, while the reverse was recorded concerning Ca and P concentrations in leaves. Plants grown on plant plane hydroponic significantly exceeded sandy soil in total and marketable yield, whereas the reverse was true concerning culturing on perlite substrate. Plants grown on straw medium significantly exceeded all other media; i.e. plant plane hydroponic, perlite and sandy soil, in their vegetative growth characters. So, transplanting pepper plants on straw culture media produced significantly higher root fresh weight, number of leaves per plant, number of branches per plant and plant height as compared with sandy soil. Weight of early, marketable and total yield obtained from plants grown on rice straw were significantly higher than recorded on plants grown on sand or any other used media. N and K concentrations in leaves were the highest in sandy soil while they were the lowest in straw culture. In contrast, the reverse was recorded concerning P and Ca. Data indicated that straw gave the highest value treatment to leaf chlorophyll content, phosphorus percent and calcium percent in pepper leaves at 120 and 180 days of the two seasons. Straw culture may be recommended for the high sweet pepper production and reducing water consumption under greenhouse conditions.

Key words: Sweet pepper, soilless culture, greenhouse, water consumption.

Introduction

Sweet pepper is one of three important Solanaceae vegetable crops grown for their fruits. It is a profitable local marketing and export crop grown under protected cultivation in Egypt. Its fruits characterized with high value of vitamin C (Zhuang *et al*., 2012). In Egypt, greenhouse pepper production is based on nine-month cycle. The transplants go into the production in plastic house in approximately first of August at age of six weeks; the first pick of fruits begins in about mid-December and continues until June (Bar-Tal *et al*., 2001b). The most important problems facing sweet pepper production in Egypt is soil-borne pathogens, nematodes and soil salinity. These problems resulted from the intensive mono culture and continuous cropping. Recently, water scarcy become very serious problem in Egypt due to building Ethiopian dam. Similar problems are faced the majority of Middle East countries (El-Sayed, 1990). Soilless culture techniques have been developed to avoid monoculture plant growing problems (Alan, 1990). It also contributes to the improvement of plant growth, earliness and yield (Grangvist, 1981) and increases crop quality, which results in higher competitiveness and economic incomes (Tuzel *et al*., 2006).

Peat, wood shaving, bark, sand, gravel, perlite, vermiculite, rockwool, pumice, zeolite, volcanic tuff, cocopeat etc. are used as organic and inorganic media (Sevgican, 1999b). A good growing media should have some characteristics such as to provide aeration and water, allow for maximum root growth and support

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physically the plant (Bilderback *et al*., 2005).

Tuzel *et al*. (2001) mentioned that tomato grown in perlite + peat resulted higher fruit number per plant than plants grown in perlite alone. Higher total yield of tomato was obtained from plants grown in perlite + peat and perlite than from pumice, volcanic ash, pumice + peat and volcanic ash + peat. Sixteen media prepared from peat, coir, vermiculite, or perlite was used to determine the optimum growing media for tomato transplants. Transplants grown with >50% coir exhibited reduced plant growth compared to peat-grown transplants, a response that may be associated with high N immobilization by microorganisms and high C: N ratio (Arenas *et al*., 2002). No significant difference was observed for growth of tomato transplants cultivated in wood fiber substrates or white peat (Gruda and Schnitzler, 2004).

Agricultural wastes (include straw, stubble, leaves, residues from cereal crops and corn cobs and tree limbs from crops and orchards (Loehr, 1974)) are among the causes of environmental pollution. Burning straw causes producing many harmful substances, such as sulfur dioxide, silicon dioxide and inhalable particles, which are emitted into the air (Xiongnian, 2010). Rice straw represents an important summer crop by-product in Egypt. About 5 million tons of rice straw is produced every year from the rice fields. No organized practical use for this waste until now. Moreover, it causes serious pollution when disposed by burning (Abd-Sattar *et al*., 2008).

Conversion straw into useful products may ameliorate the problems. In the last decades, burning as a disposal method for getting off straw is being reduced and more of the material is being utilized. A small fraction of the residue, such as straw, is being used as bedding for farm animals. Animal wastes can be composted alone but frequently are combined with wastes that may have high carbon content, such as sawdust, corncobs, paper, and municipal refuse (Loehr, 1974). Straw of crops are used in China as fertilizer, feedstuff, base material, industrial raw material (paper pulp, heat insulating material, packing material, light-weight sheets and basketry), fuel (methane production), and medium for culture of edible fungus (Xiongnian, 2010). Adding rice straw and legume waste (peas and beans) alternatively in five trenches dug with a thick layer of clay into the soil of plastic house gave the highest yield and improved fruit quality of sweet pepper (Salama and Mohamaedien, 1996). It is suggested that adding straw into soil improves soil characteristics, the supplement of organic matter, soil disinfection and soil change (Sevgican, 1999a) and improved soil conditions for growing green pepper in greenhouses (Choe *et al*., 1991).

The high amount of rice straw that produced in Egypt (more than 5 million tons every year), the very cheap price (a ton of rice straw equals to 60 Egyptian pounds) and the components of rice straw (silica, lignin and hemicelluloses), which are not attractive or favorable for soil fungi or nematodes, it could represent a good substrate for sowing instead of natural infested soil under open field conditions (Abd-Sattar *et al*., 2008). Abdel-Sattar (2005) reported that the growth of cucumber plants was more vigorous in straw medium than in the soil. Similarly, Abdel-Sattar *et al.* (2008) stated that strawberry plants grown on rice straw bales had greater vegetative growth, roots fresh weigh and more yield as compared with those grown in natural soil.

Therefore, the objective of the present work was to reach a local industrial environmental suitable for the production of sweet pepper under greenhouses conditions.

Materials and Methods

This study was carried out in the greenhouse of the vegetable crops department, Faculty of Agriculture, Cairo University, Giza, throughout the two growing seasons of 2012/2013 and 2013/2014. The study was conducted in a fiberglass greenhouse fan and bad cooling system with an area of 9 m wide, 20 m length and a height of 3.5 m. The experiment included 4 treatments, viz., culturing media rice straw, perlite, modified plant plane hydroponic (6 layers of jute between 2 polyethylene (200 microns) sheets) and sandy soil (control).

The sides of all plots were built with bricks , which were covered with ceramic, while the base of the plot were separated from the soil by covering the soil with polyethylene (200 microns) to prevent the sides and down leaching of water and nutrient solution. The experiment was set in a randomized block design with three replicates. The plot area was 3 m^2 (1m wide × 3 m length) and each medium was 30 cm depth, except sandy soil which was 1 m deep. Straw was cut into small pieces 2 to 3 cm, thereafter 100 g ammonium nitrate, 350 g super of calcium phosphate, 350 g of potassium sulfate, 100 g magnesium sulfate and 70 grams ferrous sulfate was added per straw ball to modify C/N ratio to be suitable for plant culture. Water was added daily to the straw for a month before transplanting to cause straw fermentation and to prevent reduction of its volume during growing season. Plants were transplanted after straw temperature dropped to less than 25˚C.

Plant materials

Transplants of sweet pepper hybrid 7158 from Zraaim Co. were transplanted on 10^{th} August of 2012 and 15^{th} August of 2013. Fourteen plants were transplanted per plot, spaced 40 cm between plants.

Nutrient solution

The used nutrient solution is illustrated in Table 1, according to Cooper (1979). EC and pH values of the nutrient solution were adjusted at the optimum range of growth, i.e., 2.5 $dS.cm^{-1}$ and 6.2, respectively. The nutrient solution for each system was collected in a separate 100 liter plastic tank. Each tank was connected with the three represented replicates through hose of irrigated system. Irrigation combined with fertilization was carried out at 1-2 hour/day intervals, depending on the needs of the plants, the climatic conditions and moisture content in the substrate. Dripping fertigation was applied in a closed system without nutrient solution recirculation. Pepper plants were fertigated with 75%, 100%, 125% and 100% of Cooper nutrient solution during vegetative growth (day 1 to day 45), flowering initiation (day 46 to day 60), fruiting set and harvest stage (day 61 to day 180) and aging stage (day 181 to day 200), respectively.

Table 1: Elements concentration in 1000 liters of water (Cooper, 1979)

Element	ppm	The fertilizer source	
N	200	Calcium nitrate	$Ca(NO_3)_2$
P	60	Phosphoric acid	H_3PO_4
K	300	Potassium sulfate	K_2SO_4
Ca	170	Calcium nitrate	$Ca(NO_3)_2$
Mg	50	Magnesium sulfate	$MgSO_4$
Fe	12	Iron chelate	Fe EDTA (12%)
Mn	2	Manganese chelate	Mn EDTA (12%)
Cu	0.1	Copper sulfate	$CuSO_4$
Zn	0.1	Zinc chelate	Zn EDTA (12%)
B	0.3	Boric acid	H_3BO_3
Mo	0.2	Ammonium molybdate	$(NH_4)6MO_7O_{24}$

Data recorded

Data were recorded on three plants, randomly selected from each replicate on plant height, number of leaves and number of branches (90 and 120 days after transplanting), leaves contents of chlorophyll (using Chlorophyll Meter SPAD-501 where, SPAD unit = 10 mg/100 g fresh weight of leaves), N, P, K and Ca concentrations in leaves (according to Chapman and Pratt, 1961) 120 and 180 days after transplanting and fresh root weight at the end of each season. Fruits yield (as weight and number at red color stage), as early (the first five harvests), total (cumulative yield throughout the harvest season), marketable (healthy sound fruits), and non-marketable yield (healthy distorted and disordered fruits) were also determined. Water consumption was estimated for each soilless culture system at the end of the season, by calculating the amount of nutrient solution taken from each tank separately throughout the season.

Statistical analyses

The obtained data were statistically analyzed using the analysis of variance method according to Waller and Duncan (1969) (Mstat). Duncan's multiple range test at 5% level of probability was used for comparison of means.

Results

Effect of soilless culture techniques on Vegetative growth

The influence of different soilless culture techniques used on the vegetative growth parameters of pepper plants viz., number of leaves, plant height and number of branches during the two studied seasons of 2012/2013 and 2013/2014 of pepper plant at 90 and 120 days from transplanting is presented in Table 2. Data indicated that there were significant differences among treatments on these characters during the two studied seasons.

Data indicated that straw medium caused increases in the vegetative growth parameters of pepper plants after 90 and 120 days during the two studied seasons as compared with sandy soil (control); however, such increases were significant after 120 days after transplanting. On the contrary, modified plant plane hydroponic significantly decreased the vegetative growth parameters of pepper plants after 90 days, while this medium caused a significant increase for the vegetative growth characters compared with sand (control). Perlite showed a significant increase in all vegetative growth characters 90 days after transplanting but significant reduction in number of leaves/plant and number of branches/plant and no significant differences in plant height, 120 days after planting, as compared with the sandy soil. These results were confirmed in the two studied seasons.

Table 2. Effect of some soilless culture techniques on vegetative growth of sweet pepper plants, 90 and 120 days after transplanting during 2012/2013 and2013/2014 seasons.

Soilless culture technique	No. of leaves/plant	No. of branches/plant	Plant height (cm)	No. of leaves/plant	No. of branches/plant	Plant height (cm)
	2012/2013			2013/2014		
	90 days after transplanting					
Straw culture	128.5 a	20.30 a	71.07 a	130.6 a	19.20 ab	68.07 a
Modified plant plane hydroponic	102.6 c	15.13 c	59.87 c	111.9 c	14.87 c	56.00 c
Perlite culture	115.8 b	17.50 b	62.45 b	120.2 b	18.20 b	65.43 b
Sandy soil (control)	127.6 a	18.45 ab	69.60 ab	126.8 ab	21.37 a	69.60 a
	120 days after transplanting					
Straw culture	192.7 a	28.27 a	83.50 a	196.2 a	25.50 a	82.80 a
Modified plant plane hydroponic	184.5 b	22.50 b	79.10 b	180.1 b	23.41 ab	77.23 b
Perlite culture	183.5 b	21.40 b	75.30 c	175.2 bc	20.23 b	75.83 c
Sandy soil (control)	171.6 c	20.60 c	73.10 c	170.2 c	18.88 c	74.43 c

Means followed by the same letter are not significantly different according to Duncan's multiple range test (P at 0.05 level).

Effect of soilless culture techniques on yield and its components

a. Early yield

Data presented in Table 3 showed the early yield per m² under different soilless culture techniques during both seasons. Data revealed that there were significant differences among different treatments on this character during the two seasons.

Straw culture showed the highest value of early fruit weight yield; however, with no significant difference between it and sandy soil. On the other hand, plant plane hydroponic and perlite revealed significantly lower weight of early yield than sandy soil. Generally, the lowest early yield fruits weight per m² was recorded for perlite culture. Meanwhile, the highest number of early fruit was obtained from plants grown in sandy soil with significant differences as compared with all other techniques. The lowest number value was recorded for straw culture and modified plant plane hydroponic in the both seasons.

b. Total yield

The results presented in Table 3 showed that there were significant differences among treatments in total yield per m², in both tested seasons. Pepper plants grown on straw culture produced the highest weight of total yield. The differences between straw medium and all other media in the total yield as weight were significant in the both season, while such differences were only significant in the second season as compared with sandy soil. Plants grown in sandy soil produced significantly higher total yield as weight than perlite culture. Meanwhile, total yield of fruit weights recorded on plants grown on plant plane hydroponic were similar to that recorded on plants grown on sandy soil.

On the other hands, data showed that sandy soil produced significantly a higher total number of fruits per m² than all soilless cultures. The lowest numbers were preceded from modified plant plane hydroponic and straw culture in both seasons compared with the control.

c. Marketable yield

Data presented in Table 3 showed the effect of different soilless cultures on marketable yield in the two growing seasons. Straw culture gave significantly the highest marketable yield weight and exceeded perlite in this regard in both seasons compared with sandy soil. On the other hands, data showed that the highest number of marketable yield was recorded for sandy soil, whereas the lowest value was preceded for straw culture with significant differences with all other treatments, in both cases.

d. Unmarketable yield

Data presented in Table 3 showed the effect of different soilless culture on unmarketable yield in the two growing seasons.

Both of sandy soil and modified plant plane hydroponic gave significantly higher than other techniques unmarketable yield (as weight) in both seasons. In this concern, the highest number of unmarketable yield was recorded by sandy soil; the lowest value was preceded by straw culture during both seasons compared with the control (sandy soil).

Table 3. Effect of some soilless culture techniques on yield and its components of sweet pepper plants during 2012/2013 and 2013/2014 seasons.

Soilless culture technique	Early yield/m²		Total yield/m²		Marketable yield/m²		Unmarketable yield/m²	
	Weight (kg)	No. of fruits	Weight (kg)	No. of fruits	Weight (kg)	No. of fruits	Weight (kg)	No. of fruits
	2012/2013							
Straw culture	6.500 a	38.085 c	11.150 a	64.050 c	9.300 a	55.050 c	1.850 c	9.00 d
Modified plant plane hydroponic	5.800 b	40.070 c	9.660 b	67.077 c	7.100 b	57.030 b	2.567 b	10.044 c
Perlite culture	5. 100 c	47.077 b	8.467 c	74.130 b	6.400 c	59.010 b	2.067 b	15.020 b
sandy soil(control)	5.900 ab	57.500 a	10.300 ab	86.080 a	6.600 c	65.050 a	3.73 a	19.030 a
	2013/2014							
Straw culture	6.900 a	40.500 c	10.950 a	66.500 c	9.00a	55.033 c	1.950 c	11.017 d
Modified plant plane hydroponic	5.500 b	39.400 c	9.134 b	64.073 c	7.100 bc	51.330 bc	2.034 a	13.443 c
Perlite culture	4.980 c	48.053 b	7.917 c	77.083 b	6.267 c	59.000 b	1.650 b	18.083 b
Sandy soil(control)	6.100 a	59.083 a	9.40 b	90.470 a	7.267 b	69.033 a	2.133 a	21.437 a

Means followed by the same letter are not significantly different according to Duncan's multiple range test (P at 0.05 level).

Effect of soilless culture techniques on chemical components

The leaves content of pepper plant

Data presented in Table 4 showed that there were significant differences between soilless culture techniques and sandy soil in their the leaves content of pepper plant at 120 and 180 days in the two successive seasons. Straw and modified plant plane hydroponic culture gave higher values of leaf chlorophyll content, phosphorus percent and calcium percent in pepper leaves at 120 and 180 days of the two seasons, in both seasons compared with sandy soil. On the other hand data revealed that the highest potassium and nitrogen percentage were obtained with sandy soil with significant differences as comparing with all soilless culture techniques. Perlite culture had the lowest potassium and nitrogen concentrations in leaves.

Table 4. Effect of some soilless culture techniques on chlorophyll and mineral concentration in sweet pepper leaves during 2012/2013 and 2013/2014 seasons.

Soilless culture technique	Chlorophyll (spad)	N%	P%	K%	Ca%	Chlorophyll (spad)	N%	P%	K%	Ca%
	120 days after transplanting					180 days after transplanting				
	2012/2013									
Straw culture	60.00 a	1.30 b	0.511 a	1.98 b	2.22 a	57.21 a	1.28 b	0.508 a	1.95 b	1.95 a
Modified plant plane ydroponic	54.35 b	1.32 b	0.500 a	2.29 ab	2.12 ab	52.56 b	1.29 b	0.502 a	2.20 ab	1.89 ab
Perlite culture	50.40 c	1.25 c	0.488 b	1.84 c	2.02 b	49.12 c	1.23c	0.478 b	1.80 c	1.75 b
Sandy soil (control)	50.10 c	1.40 a	0.470 c	2.40 a	1.75 c	48.56 c	1.39 a	0.460 c	2.24 a	1.52 c
	2013/2014									
Straw culture	59.00 a	1.29 b	0.523 a	2.26 b	2.07 a	58.01 a	1.25 b	0.505 a	2.20 b	2.00 a
Modified plant plane ydroponic	56.33 b	1.27 b	0.462 ab	2.24 b	1.98 a	53.12 b	1.21 b	0.472 ab	2.22 b	1.90 ab
Perlite culture	52.00 c	1.15 c	0.441 b	2.00 c	1.90 b	50.14 c	1.10 c	0.451 b	1.95 c	1.86 b
Sandy soil (control)	50.33 c	1.35 a	0.435 c	2.47 a	1.75 c	51.12 c	1.37 a	0.430 c	2.40 a	1.60 c

Means followed by the same letter are not significantly different according to Duncan's multiple range test (P at 0.05 level).

Effect of soilless culture techniques on water consumption and fresh weight of root

Water consumption

The influence of different soilless culture techniques on water consumption of pepper plants at end of the seasons is presented in Table 5. Data showed that there were significant differences among treatments on this character in the two successive seasons. Pepper plants grown on straw consumed the lowest quantities of water in the two seasons. In contrast, the heights water consumption was recorded for sandy soil during the two tested seasons. Relative to sandy soil, the percentage of water consumption in straw, perlite and modified plant plane hydroponic was 65.39, 73.01 and 83.49 in the first season, and 62.25, 76.22 and 88.70 in the second season, respectively.

Fresh weight of root

The results of fresh weight of root of the two growing seasons are shown in Table 5. It is clear that there were significant differences among treatments on this character during the two tested seasons. Fresh weight of roots of plants grown on straw or perlite were significantly greater, while on plant plane hydroponic were less, than those from sandy soil, 215 days after transplanting.

Table 5: Water consumption and root fresh weight of sweet pepper during 2012/2013 and 2013/2014 seasons.

Soilless culture techniques	Water consumption		Fresh weight of root	Water consumption		Fresh weight of root
	(l/m²)	(%)	(g)	(l/m²)	(%)	(g)
	2012/2013			2013/2014		
Straw culture	206.7 d	65.39 d	69.90 a	193 c	62.25 c	68.66 a
Modified plant plane hydroponic	263 b	83.49 b	53.70 c	275 b	88.70 b	54.00 c
Perlite culture	230 c	73.01 c	65.95 ab	2363 bc	76.22 bc	68.00 a
Sandy soil (control)	315 a	100 a	61.85 b	310 a	100 a	59.67 b

Means followed by the same letter are not significantly different according to Duncan's multiple range test (P at 0.05 level).

Discussion

Agriculture sector in Egypt faces many serious problems at the present time that may hinder the agriculture production in the near future for both local consumption and exportation. However, the most serious ones are water secrecy and soil borne diseases. Soilless culture offers an alternative to soil culture and water problems (i.e., soil born pests, soil and water salinity, chemical residues in soil, water salinity, lack of fertile soil, water shortage) (Tuzel *et al*., 2008). Peat, wood shaving, bark, sand, gravel, perlite, vermiculite, rockwool, pumice, glasswool, expanded clay, zeolite, volcanic tuff, cocopeat etc. are used as organic and inorganic media (Sevgican, 1999b). A good growing media should have some characteristics such as to provide aeration and water, allow for maximum root growth and support physically the plant (Bilderback *et al*., 2005). In the present work three substrates were chosen to compare their performance on vegetative growth and yield of colored sweet pepper plants as compared with sandy soil, which is considered the main soil for greenhouse sweet pepper production for exportation. The first substrate was rice straw, which also presents a serious pollution when rice straw is disposed by burning. The second medium was the plant plane hydroponic, as a very successful system for vegetable production in Germany. The third medium was perlite which is commercially used in some Egyptian agriculture companies for sweet pepper production as alternative medium for sandy soil.

Growing pepper plants on perlite medium caused a significant decrease in all vegetative growth characters during the early stage of the growth periods (up to 90 days after transplanting), as compared with sandy soil. The physical properties of perlite used in the present study was as follows: bulk density, 0.13 g/cm, moisture content, water holding capacity, 69.7% ; pH, 7.8 and porosity, 68%. Michael and Lieth (2008) stated that the increase in bulk density is associated with a decrease in total pore space and thus affects growth mainly through the effects of reduced free pore space. This finding supports the findings of Haddad (2006) who found that plant height, stem diameter and root fresh weight in sand were significantly greater than in perlite.

The vegetative growth characters of pepper plants cultured on perlite medium were generally greater than those recorded on plants grown on sandy soil, 120 days after transplanting. Sandy soil neither keeps water or nutrient solution due to its high total spore spaces. Such character may lead to lower growth rate for the plants grown in sandy soil as compared to plants grown on perlite medium. The results of Alan *et al*. (1994) support this conclusion. They found that the best growth of stem diameter occurred in 100 % peat, which may be because this substrate has a large capacity to keep water and contains more organic matter than other substrates. On the other hand, the thinnest stem thickness was obtained in 100 % pumice substrate, which has the lowest capacity to keep water and nutrient elements.

It was clear that perlite caused a significant decrease in total fruits yield as compared with sandy soil control. It was noticed that perlite medium was very compact during fruiting stages. This led to falling of many flowers, which was reflected as a low fruits yield. According to Michael and Lieth (2008) a decrease in total pore space will often decrease oxygen transport and decrease root penetration. A decrease in total pore space may also increase the water retention as pore diameters decrease, which is to say that loss of physical structure often results in an increase in water retention of the remaining material. Water retention forces might be high enough in the present study to cause falling of many flowers and reduced plant yield of fruits. This finding supports the findings of Alan *et al*. (1994) who found that number of fruits per plant and total yield of tomato in perlite was lower than in sandy soil.

Marketable yield on perlite substrate was significantly lower than those recorded on sandy soil (Table 3). Haddad (2006) found that total marketable yield was higher in the sand culture, where blossom-end rot (BER) was higher in perlite medium. However, in the present study the low marketable yield of the plants grown on perlite may be attributed to the general low total yield and not to the higher incidence of blossom-end rot (BER) in perlite medium, where the percentage of marketable to total yield in perlite medium was higher than those recorded in sandy soil (75.6% and 79.1% versus 71.3% and 77.3% in the first and second season, respectively). The lower nonmarketable yield in perlite substrate, as compared to sandy soil (Table 3) and the high calcium concentration in pepper leaves collected from plants grown on perlite substrate (Table 3) support such conclusion.

Modified plant plane hydroponic caused significant reduction to all vegetative growth characters 90 days after planting, but it significantly increased such characters120 days after planting. Such effect was constant in both seasons (Table 2). Plant plane hydroponic consists of a growing medium, which is a polyester fleece (80 g/m^2). The fleece material is sandwiched between two layers of plastic sheets. The greenhouse floor is sealed off with the lower sheet. The top layer is made of a white polyethylene that helps in reducing evaporation of the nutrient solution, prevents drying of roots and growth of algae. It also acts as a reflective surface. The system is called "plant plane" because the nutrient solution flows across a flat plane rather than a narrow channel (Schroder, 1994). Because the polyester fleece is very expensive for the Egyptian growers, old jute bags were used in the present study, as an alternative propagation medium for hydroponic cultivation. Jute was selected because of its favorable drainage properties and low cost. In addition, in contrast to several other soilless media, only decomposable organic waste remains after harvest. The present experiment was motivated by the general concept that rhizosphere conditions during the vegetative growth phase may significantly influence the yield and quality of hydroponic pepper. The significant reduction in all vegetative growth characters of pepper plants during the early stage of plant growth may be attributed to the very limited root growth (Table 5) that caused a very low flow for the nutrient solution across jute cloth. Plant plane hydroponic depends mainly on the following of the nutrient solution across a flat plane, which results in a condense root growth over the flat fleece. The jute cloth used in the present study did not have the ability of the horizontal movements of the nutrient solution across between the two plastic sheets of the system; therefore, the plant roots were much districted. Nevertheless, the high water holding capacity of jute cloth may enable plant roots to uptake nutrient excessively and consequently enhanced plant growth at 120 days after transplanting as compared with sandy soil which have inferior water holding capacity (Gruda *et al.*, 2013).

Plants grown on plant plane hydroponic significantly exceeded sandy soil in total and marketable yield, whereas the reverse was true concerning the nonmarketable yield. The increase in total yield in plant plane hydroponic may be attributed to the superiority of vegetative growth characters in such medium as compared with sandy soil (Table 2). On the other hand the high marketable yield and low nonmarketable yield in plant plane hydroponic (Table 3) was attributed to the lower incidence of blossom end rot due to the higher calcium concentration in leaves of the system's plants (Table 4).

Plants grown on straw medium significantly exceeded all other used media; i.e. plant plane hydroponic, perlite and sandy soil, in their vegetative growth characters. So, the highest root fresh weight, number of leaves per plant, number of branches per plant and plant height were significantly observed for straw culture media. These results might be attributed to different theories, like the superiority of the physiochemical properties in straw medium over the other media (Olympious, 1992), increasing medium temperature over the other media, low pH and salinity of straw medium (Abdel-Sattar, 2008; Mohamed 2010) or/and increasing CO2 and photosynthesis. (Elings *et al*., 2007, Hao *et al*., 2008, Stanghellini *et al*., 2009).

The proper conditions with a view to bulk density and porosity in straw medium allowed the plant root penetrate in substrate easily and caused better support of water and nutrient elements for plant leading to good growth (Olympious, 1992).

As shown in Table 4, N, P, K and Ca concentrations in leaves were significantly affected by growing media. N and K were the highest in sandy soil, and they were the lowest in straw culture. In contrast, the reverse was recorded concerning P and Ca. Sandy soil got the highest amounts of nutrients. Therefore, the leaves of plants grown in this soil contained the highest N and K concentrations. Moreover, plants grown on straw culture showed the highest vegetative growth and fruits yield. These plants used the available N and K in medium to meet their high requirements for building their vegetative growth and high yield, respectively. Meanwhile, pepper plants grown on sandy soil were the shortest, had the lowest number of branches, leaves and the lowest concentration of P. Picha (1999b) reported that pH in most Egyptian soils, which typically have pH of 8.0 or greater. Alkaline soils lower strawberry yield by tying P and the micronutrients Fe, Mn and Zn. The high sandy soil pH led to fixation of phosphorous by calcium. Therefore, phosphorus and calcium were not available to the plants and a low concentration for these two elements was occurred (Table 4). It was reported that low P decreased shoot branching in bean (Lynch *et al*., 1991), Leaf area, leaf numbers, and leaf expansion decreased under P stress (Lynch *et al*., 1991; Halsted and Lynch, 1996). Phosphorus deficiency symptoms in plants include severe stunting, thin stems, and erect and dark green leaves. Phosphorus deficiency reduces seedling height, tiller number, stem diameter, leaf size, and leaf duration (Fageria *et al*., 2003).So, planting in rice straw bales (pH 5.8–6.6) instead of natural soil (pH 7.4–8.3) can solve the problems of alkalinity and salinity in rhizosphere of pepper plants.

Straw mineralization is considered an advantageous phenomenon, because then CO2 is released, which is used by plants in the process of photosynthesis. The increased CO2 concentration in the air in glasshouse causes yield increase. In the atmospheric air the concentration of CO2 equals about 350 ppm, in a glasshouse it should be 900–1000 ppm (Elings *et al*., 2007, Hao *et al*., 2008, Stanghellini *et al*., 2009).

The present results agreed with those of Gasperavicute (1977) who reported that the growth of cucumber plants was more vigorous when grown in loose or pressed straw than in the soil. Abdel-Sattar (2005) found that cucumber plants grown in rice straw bales under greenhouse conditions showed better growth compared with those grown in natural soil. Abdel-Sattar *et al*. (2008) stated that strawberry plants grown in rice straw bales increased the number of leaves/plant, plant height; shoot system wt/plant, root length, the number and weight of roots as compared with those grown in natural soil.

The low rate of vegetative growth at the early stages of plant growth, up to 90 days from transplanting, may be attributed to the low available nitrogen at this period. Hardgrave and Harriman (1995) and Babik (2006) showed that in the soilless culture of cucumber on straw mats, in the initial stages of growth, nitrogen was being blocked as a result of microbiological activity and the structure of the substrate deteriorated. According to Kowalczyk and Dyśko (2006), the nitrate nitrogen content of the drainage solution in a tomato culture on straw was very low (no more than 20 mg·dm-3) until the 7th week of culture as a result of microbiological activity. This also had a negative effect on plant nutritional status in the initial period of plant growth. Rice straw contains NPK, (3-7 kg N, 1.5 kg P and 15 kg K) per ton of rice straw. But10-15 kg of N is needed for rice straw decomposition. So, a shortage of N in the period of establishment of the crop will be appeared in rice straw medium. This, confirm the necessity of continues supplement of nitrogen (Sadek *et al*., 2014).

Weight of early yield obtained from plants grown on rice straw was higher than recorded on plants grown on sand or any other media. The fact that early yield of plants grown on straw was higher than in the other substrates could be attributed to the higher substrate temperature recorded. Tzortzakis and Economakis (2015) recorded on average by 1.6°C and 2°C higher during day and night, respectively in shredded maize stems medium. The increased temperature of the organic substrate should be caused by the microbial decomposing activities. The higher substrate temperature occurring in organic materials could be beneficial for crops grown under unheated glasshouse conditions. Root temperature is thought to be one of the major factors that directly affect plant growth (Ikeda and Osawa, 1984) and increases yield (Moss, 1983). Similarly, the highest early yield was observed in pepper plants grown on the peat medium compared with perlite, pumice, sand and soil (Padem and Alan, 1994).

The fact that straw medium gave higher yields than other substrates (perlite, plant plane hydroponic and sand) suggested better nutritional conditions in the straw medium, being in accordance with Padem and Alan (1994) in pepper cultivation. El-Aidy (1992) in Egypt found that the best results were obtained from the half burned treatment (Straw bales half buried in the soil) during winter cultivation and from full burned treatment (Straw bales full buried in the soil) during spring cultivation. The increases of the total yield between the best treatments and control (normal cultivation in the soil) were 0.7 and 0.33 kg/plant in winter and spring cultivations respectively. Abdel-Sattar (2005) found that cucumber plants grown in rice straw bales under greenhouse conditions showed increased fruit number and weight compared with those grown in natural soil.

Generally, the worldwide wheat, maize, and rice are produced in the field in greater quantities than any other crops. Rice straw constitutes a readily available organic material that can be used in soilless greenhouse culture as a substrate because of its light weight, low cost, content of some of the essential elements required by plants in sufficient quantity to satisfy crop requirements, and its availability. Although perlite, rockwool, and pumice also possess some of these qualities, rice is easier to dispose of than such mineral substrates whose recycling causes serious environmental problems.

Conclusions

Based on the present results, with considering to low cost (the ton of rice straw equals 60 Egyptian pounds), availability and abundance of rice straw in Egypt (5 million tons of rice straw was produced every year from the rice fields) (Abdet-Sattar *et al*., 2008), rice straw could be recommended as a growing substrate in replacing naturally infested soil, as it can improve the production of pepper plants under greenhouse conditions in Egypt, with saving 35-38% of irrigation water and fertilizers. Also, it presents a solution for soil salinity and alkalinity and avoiding the serious pollution resulted from burning rice straw to get of its disposed. In addition, rice straw substrate can participate in increasing exportation of organic sweet pepper due to avoiding using soil chemical disinfectants and nematicides that used against soil borne fungi and nematodes.

References

Abdel-Sattar, M.A., 2005. Using compacted rice straw bales, as growing media instead of naturally infested soil for improving cucumber production under greenhouse conditions in Egypt. In: “Proceeding of the 6th Arabian Conference for Horticulture”, Ismailia, Egypt, pp. 265–278.

Abdet-Sattar, M. A., H. A. El-Marzoky and A. I. Mohamed, 2008. Occurrence of soilborne diseases and knot nematodes in strawberry plants grown on compacted rice straw bales compared with naturally infested soils. Journal of plant protection research, 48, (2) : 224-235 .

Alan, R., 1990. Characteristics of some of the growth media used in greenhouse. Turkey 5. Greenhouse Symposium, October 17- 19, Izmir, Turkey, pp.401-410.

Alan, R., A. Zulkadir and H. Paden, 1994. The influence of growing media on growth, yield and quality of tomato grown under greenhouse conditions. Acta Horticulturae, No. 366:429-436.

Arenas, M., C. S. Vavrina, J. A. Cornell, E. A. Hanlon and G. J. Hochmuth, 2002. Coir as an alternative to peat in media for tomato transplant production. HortScience, No. 37: 309-312.

Babik, J., 2006. The organic substrates in greenhouse cucumber production as an alternative to the rockwool.Acta Agrophysica, No. 7: 809-820.

Bar-Tal, A., B. Aloni, L. Karni and R. Rosenberg, 2001b. Nitrogen Nutrition of Greenhouse Pepper. II. Effects of nitrogen concentration and NO3: NH4 ratio on growth, transpiration, and nutrient uptake. HortScience, 36 (7): 1252-1259.

Bilderback T. E., S. L.Warren, J. S. Owen Jr. and J. P. Albano, 2005. Healthy substrates needphysicals. Hort Technology, 15: 747–751.

Chapman, H. D. and P. F. Pratt, 1961. Methods of Analysis for Soil, Plant, and Water. University of California, Division of Agriculture Science, 175 pp.

Choe S., K. H. Kank, Y.C. Um and Y.H. Choe, 1991. Effect of rice straw application on improvement of soil circumstances for growing green pepper under vinly greenhouse. Hort. Exp. Station, Korea Republic, Horticulture Abstract, 1- 63 pp.

Cooper, A., 1979.The ABC of NFT . London, Growersbook, 215 pp.

Elings, A., E. Meinen, J. Campen, C. Stanghellini and A.Gelder, 2007. The photosynthesis response of tomato to air circulation. Acta Horticulture, No.761: 77–84.

El-Aidy, F., 1992. Preliminary results on the possibility of using straw as natural substrate for growing cucumber under plastic greenhouse. Acta Horticulture, No. 323: 423-427.

El-Sayed S.F., 1990. Technology of Vegetable production in Greenhouses and Low Tunnels in Desert Lands [in Arabic]. Egyptian bookshop for Publishing, Alexandria, 478 pp.

Fageria, N. K., N. ASlaton and V. C. Baligar, 2003. Nutrient management for improving lowland rice productivity and sustainability. Advanced of Agronomy, No. 80 : 63–152.

Gaspervicute, G., 1977. Using straw for cucumber growing in polyethylene houses. Horticulture Abstiract, No. 48 : 550 –559.

Grangvist, G., 1981. Recent experience in the use of subsrates for vegetable production under glass in Sweden. Acta Horticulture, No. 126 : 259-262.

Gruda, N. and W. H. Schnitzler, 2004. The effect of wood fiber substrates and their volume weights on the growth of tomato transplants. Scientia Horticulturae, No. 100 : 333-340.

Gruda N., M. M. Qaryouti and C. Leonardi, 2013. Growing media. Good agricultural practices for greenhouse vegetable crops. FAO Plant of Production and Protection. No. 217: 271–302.

Haddad, M., 2007. Effect of three substrates on growth, yield and quality of tomato by the use of geothermal water in the south of Tunisia . Journal of Food, Agriculture & Environment, 5 : 175-178.

Hao, X., Q.Wang, and S. Khosla, 2008.Responses of greenhouse tomatoes to summer CO2 enrichment. Acta Horticulture, No. 797: 241–246.

Hardgrave, M. and M. Harriman, 1995. Development of organic substrates for hydroponic cucumber production. Acta Horticulture, No. 401: 219-224.

Ikeda, H. and T.Osawa, 1984. Lettuce growth as influenced by N source and temperature of the nutrient solution. International Society for Soilless Culture. Proceedings of 6th International Congress on soilless culture, pp. 273-284.

Kowalczyk, W. and J.Dyśko, 2006. Nitrogen status of greenhouse tomato plants grown in rye straw slabs. Acta Agrophysica. No. 7, 959-967.

Loehr, R. C., 1974. Agricultural waste management. Academic pree.inc. (London) L T D. 576 p.

Lynch, J., A. Lauchli, and E. Epstein, 1991. Vegetative growth of the common bean in response to phosphorus nutrition. Crop Science, 31:380–387.

Michael, R. and J. H. Lieth, 2008. The influence of growing media on growth , yield and quality of tomato grown under greenhouse conditions. Acta Horticulturae, No. 366: 429-436.

Mohamed, A. I., 2010. Comparative Studies on Disease Occurrence of Some Vegetables Grown on Compacted Rice Straw Bales and Natural Soil. Master of Science, Suez Canal University Faculty of Agriculture. Botany Department .88p.

Moss, G. I., 1983. Root-zone warming as a means to save energy in the production of greenhouse crops in Australia. Acta Horticulture,133: 31-38.

Olympious, C.M., 1992. Soilless media under protected cultivation rock wool, peat, perlite and other substrates. Acta Horticulture, No. 401: 443-451.

Padem H. and R. Alan, 1994. The effect of some substrates on yield and chemical composition of pepper under greenhouse conditions. Acta Horticulturae, No. 366: 445–451.

Picha, D., 1999b. Soil preparation and strawberry transplantation. Agricultural Technology Utilization and Transfer Project, Publication No. 106.

Sadek, I. I., Fatma S. Moursy, E. A. Salem, A. Schüch, M. A. M. Hegg, 2014. Enhancing rice straw media for growing eggplant under modified climatic conditions using compost and bacterial inoculation. Nature and Science,No. 12: 8-20.

Salama, G.M. and S.A. Mohammedien, 1996. A study on productivity of sweet pepper grown on agricultural wastes under protected cultivation conditions. Egypt. Journal of Horticulture, No. 23: 1–10.

Schroder, F., 1994.Technological development, plant growth and root environment of the plant plane hydroponic system. Acta Horticulturac, No. 361: 201-209.

Sevgican, A., 1999a. Protected vegetable growing. I. Ege University. Agriculture Faculty. Izmir, Turkey. No. 528.

Sevgican, A., 1999b. Protected vegetable growing (Soilless Culture).II. Ege University. Agriculturae Faculty, . Izmir, Turkey. No. 526.

Stanghellini, C., F.L.K. Kempkes and L. Incrocci, 2009. Carbon dioxide fertilization in Mediterranean greenhouses: when and how is it economical?. Acta Horticulture, No. 807: 135–142.

Tüzel, I. H., K. M. Meric and Y.Tüzel, 2006. Crop Coefficients in Simplified Hydroponic Systems. Acta Horticulture, No.719: 551-556.

Tuzel, Y., G.B. Oztekin and A.Gul, 2008. Recent Developments In Protected Cultivation In Turkey. 2nd Coordinating Meeting of the Regional FAO Working Group on Greenhouse Crop Production in the SEE Countries.7-11 April. Antalya, pp. 75-86.

Tüzel, I. H., Y.Tüzel, A. Gül, H. Altunlu and R. Z. Eltez, 2001. Effect of different irrigation schedules, substrates and substrate volimes on fruit quality and yield of greenhouse tomato. Acta Horticulture, No. 548: 285-291.

Tzortzakis, G. and D.Economakis, 2015. Shredded maize stems as an alternative substrate substrate: effect on growth, flowering and yield of tomato in soilless culture. Journal of Vegetable Science, 11(2): 57-70.

Waller, R. A. and D. B. Duncan, 1969. A bays rule for the symmetric multiple comparison problem. Journal of the American Statistical Association. No. 64: 1485-1504.

Xiongnian,Y., 2010. Reuse of agricultural wastes and increase of income of farmers. www.iprcc.org.cnuserfilesfileB1_ EN_ppt.

Zhuang, Y., L. Chen, L. Sun, and J.Cao, 2012. Bioactive characteristics and antioxidant activities of nine peppers. Jornal of Function Foods, 4: 331–338.