Effect of different substrates on growth, yield and quality of tomato by the use of geothermal water in the South of Tunisia

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Abstract:

Purpose: With growing concern about climate change and the need to reduce the use of fossil fuels, there is increasing interest in the use of renewable energy. In this regard, geothermal energy has a great importance in agriculture activity in southern of Tunisia. By using geothermal heating for greenhouses in this part of Tunisia, production of vegetables attains 30000 tons of which 35% are exported. However, this activity faces some problems of soil diseases and salt accumulation.

The main objective for the present research is to solve these problems by soilless cultivation using palm trees wastes as substrates after composting. These substrates give the opportunity to valorise these wastes produced with large amounts every crop season.

Methods: The experiment was carried out under a green house involving five replicates and five treatments (1) Control: soil, (2) Palm trees compost, (3) Compost of oasis wastes and animal manure, (4) River sand and (5) Coconut fiber witch is an imported substrate. Plots were planted on with tomato. The measurements determinate were growth, yield and quality.

Results. *Comparison* of means showed that yield of fruits had not any significant difference between treatments. Substrates had no influence on the average fruit weight, ranged from 91.17 g to 95.59 g. The marketable yield and the fruit weight of the tomatoes grown in oasis wastes and animal manure compost were slightly higher compared with those grown in other substrates. The results of data length and stem diameter on seven occasions, showed that plant height and diameter had a significant difference between treatments. The tallest plants were produced by tomato cultivated in soil (382.64 cm). The most vigorous plants were grown in coconut fiber (19.02 mm). TSS (°Brix) content of the fruit was found to differ significantly between substrates. Plants grown on soil and sand produced highest TSS values (5 °Brix). The pH and the EC of the tomato fruit juice were not significantly different in tomato cultivation with different substrates.

Conclusion: Local substrates can constitute a promising alternative for soilless cultivation in the South of Tunisia.

Keywords Soilless cultivation, palm trees compost, compost of oasis wastes and animal manure, river sand, coconut fiber,

INTRODUCTION

In Tunisia, vegetables production under greenhouses occupies a large area in littoral zones. These crops were increasing very rapidly since 1976 to reach a surface of 1200 ha in 1984. After this date, the surface were stabilised between 1200 and 1400 ha to date. This stabilisation is related to the non-compliance of the quality produced by the farmers with the quality required by the international market (Haddad et al 2003). Whatever the materiel of cover of greenhouse, low winter temperatures prevent normal pollination and fruit development. The minimum night temperatures were mostly below 7°C and, particularly, lower than 5°C in the desert regions, during all the wintry period; however the new hybrids cultivated under greenhouse require nocturnal temperatures between 15 and 17°C. The possibility of using geothermal water has been shown as an economic and effective option to solve these problems and to maintain a minimum temperature of 12°C (Haddad, 2007).The circulation of geothermal waters in greenhouses heat them and by the way it permit to cool water down to be acceptable by roots of vegetables. That is how the surfaces of the cultures under greenhouses galloped in the region of Gabes to achieve 140 ha in 2017. Salt concentration of geothermal water is relatively high, it's ranged between 1.5 and 2.5 gl^{-1}. This salinity has a negative effect on the yield, but it improves the gustative quality. Tomato and melon exported have a special savour and taste which are in high demand in European markets and generate noticeable prices (Haddad et al 2003). However, the concentration of salts in the soils after the irrigation during several years with geothermal water causes uneven and stunted growth of plants and low yields.

To solve these problems, soilless cultivation has been introduced in greenhouses heated and irrigated by geothermic water in the south of Tunisia, in order to release the cultivation of plants from all the problems related to the soil. It can avoid problems with monoculture of plants in the same land for years (Alan, 1990). It can provide several major advantages in the management of both plant nutrition and plant protection. Research studies reported that commercial production

of greenhouse vegetables with soilless media adopted to reduce economic losses caused by soil-borne pathogens (Louvet, 1982). While other researchers reported that soilless culture can provide more efficient use of water and fertilizers (Jensen, 1997), reduce root diseases (Reed, 1996), and facilitate cultivation of crops in areas where normal cultivation is not possible (Jensen, 1999).

Soilless culture is in the process of becoming an interest part of agriculture in Tunisia and gained crescent attention among farmers especially under greenhouses heated and irrigated by geothermic waters (Hadded, 2007). However, it remains limited for a big geothermic companies because of the high installation cost compared to soil, it is predominantly, based on artificial imported substrates. This situation rekindled the search of alternatives within the local, available, renewable and low cost one (Radhouani et *al*., 2011).

There are many indigenous and locally available soilless substrates in this region suitable for growing system in the South of Tunisia.

This study was carried out to evaluate the impacts of five substrates on tomato yield and fruit quality, two local composts: palm trees compost and compost of oasis wastes and animal manure, sand of the river, an imported substrate (coconut fiber) and soil as control; while adopting a simple and easily practicable method by the farmers.

MATERIALS AND METHODS

Location, plant material and experimental design

This study was carried out in a 300 m² tunnel (9.6 x 31 m) covered with a 200 µm polyethylene film, at the experimental station of Technical Center of Protected and Geothermal Crops. Control of daily temperature occurred by ridge ventilation controlled by a climate computer. Transplant took place in December 2017 using the hybrid tomato F_1 'Cencara' grafted on 'Maxifort'. Plants were grown under natural light conditions. They were grown with one stem and pruned above the fifteenth cluster. An open soilless cultivation system was adopted. This system is an open trench system, where we basically dug a ditch in the ground and then covered it by a plastic film. The length of the trenches is 28 m and its width at the top is 40 cm and at the bottom is 30 cm, its depth at the beginning is 30 cm and ends by 50 cm with a decline of 1.43%. After that, we disposed perforated PVC tubes, then a fine layer of gravel to drain excess of water, finally

substrate (Fig.1). The drains were connected at the lower end to a main drain that sinks into a 1 m^3 nutrient tank. The experiment was carried out in a complete randomized blocks in five replications.

Fig 1: The open soilless system adopted

Data collection and analysis

At each harvest, fruits were collected and weighed to determine marketable yields and average marketable fruit weight. Fruit firmness was determined using fruit penetrometer pressure test. The juice was extracted using fruit juicer and filtered using Whatman filter paper to exclude precipitates. Total soluble solids (TSS), was measured using refractometer, pH using a pH meter, electrical conductivity (EC) was measured. Height growth rate was determined for each substrate. At the end of the study, whole plants were collected and weighed; length and fresh weight of roots were measured.

Statistical analysis

Results were subjected to univariate statistical analyses: one-way analysis of variance (ANOVA) was performed as a post hoc analysis for means comparison. All the tests were achieved with a significance level ($P<0.05$) and all statistical analyses were performed using SPSS statistical software version 16.0.

RESULTS AND DISCUSSION

Table 1: Marketable yield of tomato 'Cencara' grown in different substrates (kg/60 m^2)

Date	of	Compost of oasis	Palm trees	Coconut	River	Soil	Total

harvest	wastes and animal manure	compost	fiber	Sand		
30 march	3,005	2,32	4,635	2,955	3,515	16,43
14 april	12,26	9,235	10,39	9,89	12,32	54,095
21 april	16,975	14,635	18,52	12,21	19,24	81,58
28 april	49,73	39,715	41,395	32,83	44,86	208,53
5 may	35,91	33,85	30,905	27,78	32,475	160,92
12 may	54,24	53,69	49,22	39,665	48,67	245,485
19 may	75,295	69,44	62,895	61,945	63,045	332,62
26 may	40,725	33,86	33,15	33,38	32,84	173,955
2 june	65,665	72,59	57,13	59,465	64,32	319,17
9 june	65,44	55,055	46,07	52,81	51,935	271,31
16 june	43,875	48,255	35,725	50,455	46,225	224,535
23 june	22,835	23,1	23,15	19,85	26,905	115,84
Total	485,955	455,745	413,185	403,235	446,35	2204,47

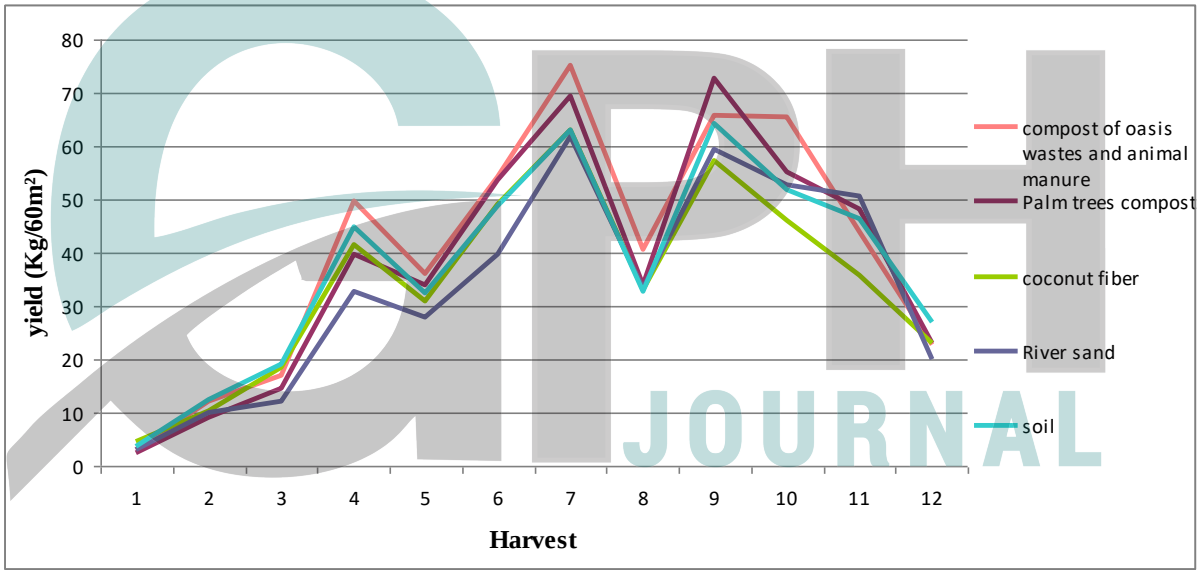

Fig. 2: Effect of substrates on yield rate of tomato hybrid 'Cencara' grown under greenhouse

The yield of tomato hybrid 'Cencara' grown in compost of oasis wastes and animal manure and palm trees compost was higher compared with tomato grown in Coconut fiber, sand and soil with an insignificant differences (table1). Higher early yield (in the beginning of harvesting) was obtained from the tomatoes grown in Coconut fiber (Fig.2).

Comparison of means showed that yield of fruits had not any significant difference between treatments. Highest amount of fruit yield related to the compost of oasis wastes and animal manure treatment. It related to the physical properties of substrate (Fig.3).

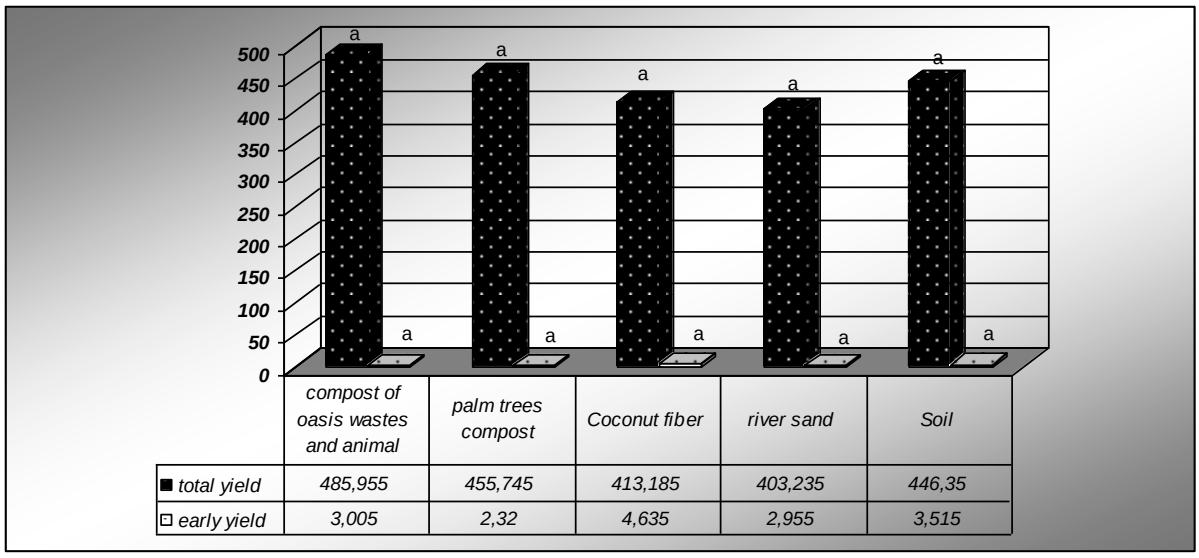

Fig.3: Effect of substrates on total and early yield of tomato hybrid 'Cencara' grown under greenhouse

Even though plant growth on compost of oasis wastes and animal manure presented a highest total yield, in the middle of June, a decline in productivity was noticed in comparison with palm trees compost, sand and soil (Table 1). The decline in yield on compost of oasis wastes and animal manure should be attributed to the reduction in volume of this material due to decomposition.

Blossom-end rot (BER) is a main cause for non marketability of some tomato fruits in our experience. The yield of non marketable fruits from the tomatoes grown in Date-palm compost and Coconut fiber was the same: 0.25 kg m^{-2}, 0.16 kg m^{-2} from tomatoes grown in sand and soil and 0.20 kg m^{-2} in Oasis compost. Blossom-end rot (BER) is not a disease or the result of pest damage, it is a physiological disorder. The root cause of the problem is the lack of available water in the growing medium leads to a calcium deficiency in the fruits as the plant has difficulty moving calcium to the fruit and diverts it to the stem and foliage. Higher yield of non marketable fruits caused by BER was obtained from plants grown in organic media as compared with inorganic media; this is because the compost is most likely to dry out in container especially in hot weather. It can be proposed that the tomatoes grown in coconut fiber, compost of oasis wastes and animal manure and palm trees compost substrates demonstrated a higher water demand compared with the tomatoes grown in soil and sand.

Table 2: Effect of substrates on average fruit weight of tomato hybrid 'Cencara' grown under greenhouse

Substrates	Average fruit weight (g)
Soil	92,35 a
Compost of oasis wastes and animal manure	95,59 a
Palm trees compost	91,62 a
River Sand	91,17 a
Coconut fiber	93,19 a

The average fruit weight ranged from 91.17 g to 95.59 g. The substrate had no influence on the average weight of the fruit. The fruit weight of the tomatoes grown in compost of oasis wastes and animal manure was slightly higher compared with those grown in other substrates (table.2).

Table 3: Roots fresh weight, stem diameter, length and plant fresh weight of collected plants of tomato hybrid 'Cencara' grown under greenhouse

	soil	Compost of oasis wastes and animal manure	Palm trees compost	River sand	Coconut fiber
Roots fresh weight (g)	97.6 b	148.2 a	104 ab	89.2 b	114 ab
Stem diameter (mm)	15.66 ab	15.48 ab	13.94 b	14.7 ab	15.9 a
Length (cm)	382.64	370.48	379.68	369.64	380.2
Plants fresh weight (g)	1280.6 a	1401.6 a	1224.2 a	1112 a	1282 a

The physical properties of organic media were better than those of mineral media that cause increasing of growing indexes. The low amount of bulk density and the high amount of porosity related to the compost of oasis wastes and animal manure, Coconut fiber and Palm trees compost media (Fig.4)) allowed the plant root to penetrate in substrate easily and to use more volume and space of media, thus available water and nutrient elements were sufficient for plants grow up in these media. Roots of plants developed on the compost of oasis wastes and animal manure have shown superiority through their fresh weight in comparison to those of plants cultivated on other

substrates (Table 3), due to the enormous development of lateral thin roots. The dominance of such roots can be explicated by the high holding water capacity of this substrate (Figure 4).

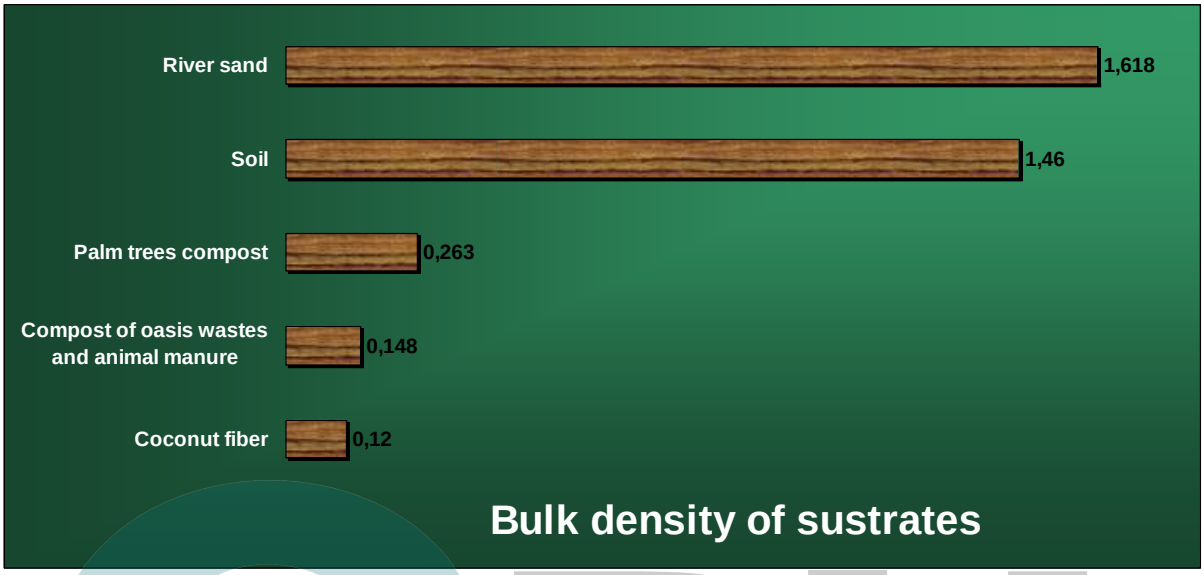

Fig 4: Bulk density of different substrates

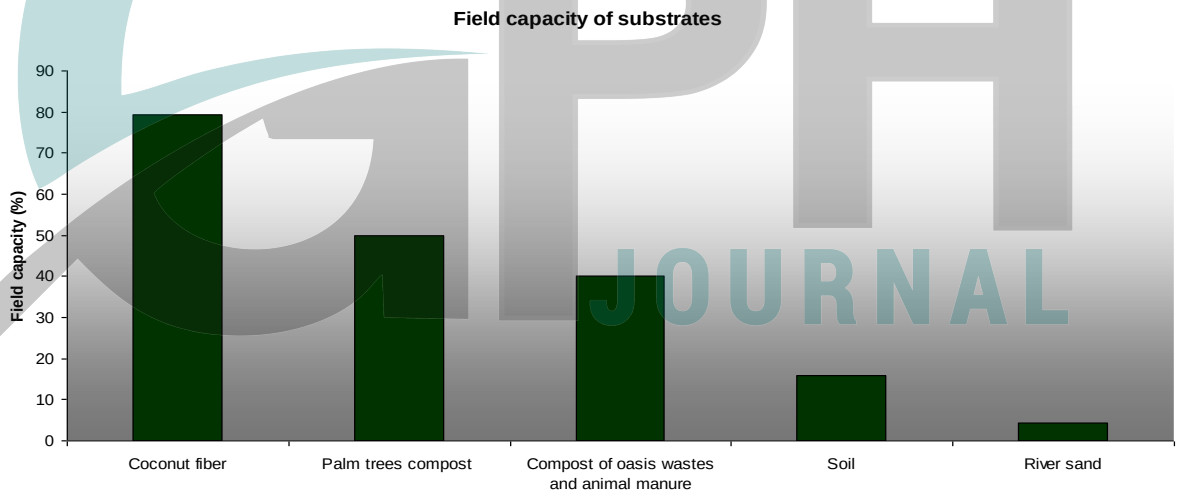

Fig 4: Field capacity of different substrates

No significant differences were found between the pH values of different substrates investigated. The palm trees compost presents the greatest values of pH and electrical conductivity. pH varied from 7.76 to 8.33 (Table 4), these values are higher than the 5.5 to 6.5 considered to be the optimum level for the most greenhouse crops (Abad et *al*., 2001). Significant differences were found between electrical conductivity values of different substrates, which ranged between 1.4 and 18.1 mS/cm.

Table 4: pH and EC of different substrates

	soil	Compost of oasis wastes and animal manure	Palm trees compost	River sand	Coconut fiber
pH	7.83 a	8.16 a	8.33 a	7.87 a	7.76 a
EC (mS/cm)	1.4 d	6.5 c	18.1 a	2.1 d	12 b

TSS (°Brix) content of the fruit was found to differ significantly between substrates. Plants grown on soil and sand produced highest TSS values (Table 4). Whereas, no differences in TSS content were revealed, between organic substrates: Compost of oasis wastes and animal manure, Palm trees compost, Coconut fiber. Higher sugar content improves the quality of tomato fruits (Davies and Hobson 1981).

The pH and the EC of the tomato fruit juice were not significantly different in tomato cultivation with different substrates (Table 5), which is in accordance with Islam et al. (2002). Low pH is associated with high fruit quality (Hobson 1981) and was recorded in Palm trees compost substrate.

Table 5: Effect of different substrates on total soluble solids (°Brix), pH, EC (dS/m) of tomato hybrid 'Cencara' grown under greenhouse

Substrates	TSS	pH	EC
soil	5 a	4,55 a	4,5 a
Compost of oasis wastes and animal manure	4,2 b	4,61 a	4,6 a
Palm trees compost	4,1 b	4,4 a	4.9 a
River Sand	5 a	4,6 a	4,4 a
Coconut fiber	4.2 b	4,56 a	4,3 a

Fruits were classed into three classes according to their weights C1: weight inferior to 80 g; C2: weight ranging between 80 and 100 g; C3: weight superior to 100 g. The plants cultivated in coconut fiber presented the following tomato distribution by three classes C1, C2 and C3: 28%, 48% and 32% respectively. Almost, similar results were found in substrate palm trees compost: 23%, 52% and 28% respectively for three classes C1, C2 and C3. However, in sand and soil,

small tomatoes (C1) decrease to 12%, medium tomatoes (C2) increase to 68% and 72% respectively and C3 decrease to 20% and 16 % respectively (Figure 5).

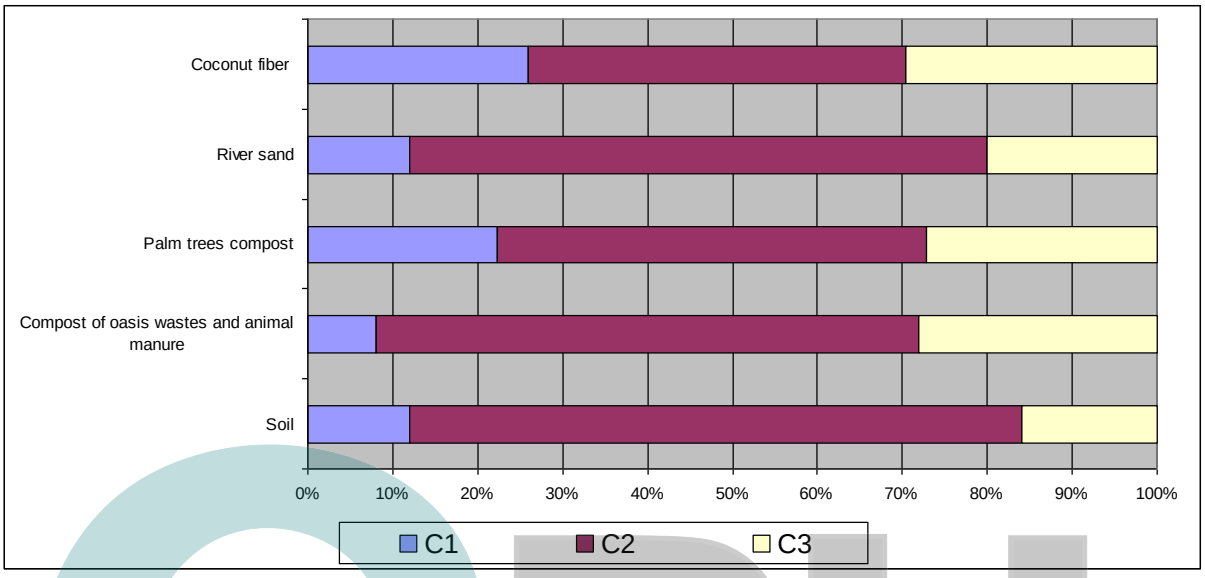

Fig 5: Effect of substrates on caliber of fruits of tomato hybrid 'Cencara' grown under greenhouse

The results of data length on seven occasions, at an interval of two weeks, showed that plant height had a significant difference between treatments at the level of five percent. The plants grown in the coconut fiber substrate were the tallest during the first five measures taken. During the sixth and seventh measures, the tallest plants were produced by tomato cultivated in soil with an average height of 338.2 cm in seventh measure and 382.64 cm when plants were collected. The lowest were those cultivated in sand with an average height of 309.32 cm in seventh measure and 369.64 cm when plants were collected.

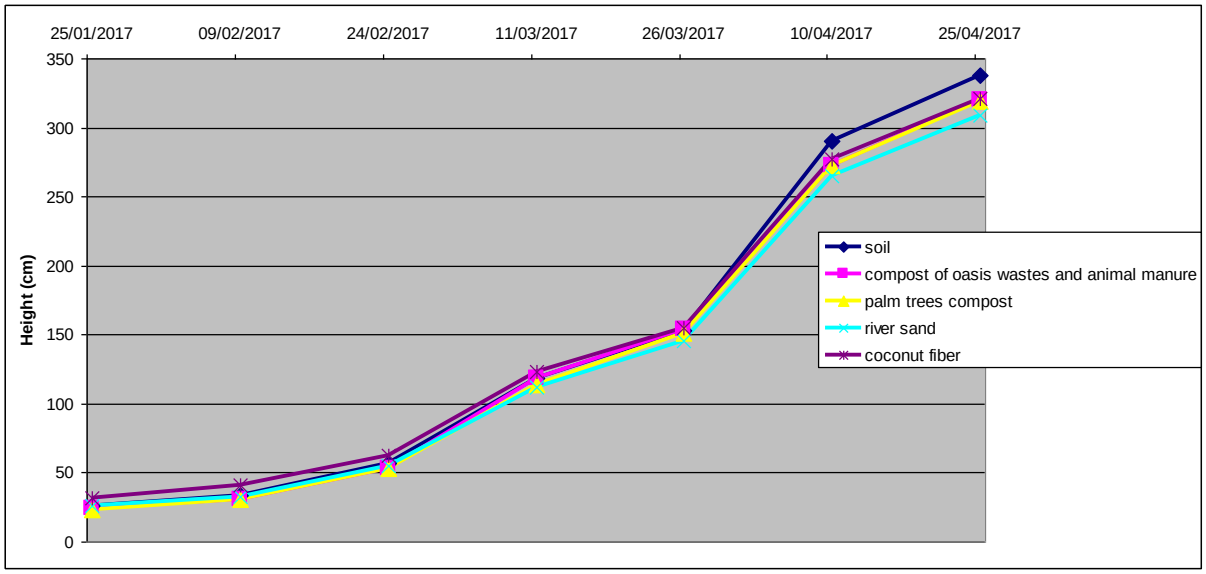

Fig 6: Effect of substrates on height growth rate of tomato hybrid 'Cencara' grown under greenhouse

During the first four measures and the seventh measure, stem diameter varied significantly ($P<0.05$) between treatments (Table 6). But it did not record a significant difference at the fifth and sixth measures. During the seven measures, the most vigorous plants were grown in coconut fiber; with an average stem diameter 19 mm in seventh measure.

Table 6: Effect of substrates on tomato stem diameter during seven measurements

Substrates	Stem diameter (mm)						
	Measurement I	Measurement II	Measurement III	Measurement IV	Measurement V	Measurement VI	Measurement VII
Soil	4.94 b	6.22 b	9.02 b	12.2 ab	14.2 a	16.68 a	17.68 ab
Compost of oasis wastes and animal manure	4.46 bc	5.44 b	8.02 c	11.68 ab	13.8 a	15.96 a	17.38 b
Palm trees compost	4.20 c	5.5 b	8 c	11.16 b	13.72 a	15.96 a	17.94 ab
River	4.9 b	6.3 b	9.02 b	11.64 ab	14 a	15.88 a	17.94 ab

sand							
Coconut fiber	6.46 a	8.38 a	10.42 a	13.1 a	15.4 a	17.16 a	19.02 a

Table 7: Effect of substrates on tomato plant weight during seven measurements

Substrates	Plant height (cm)						
	Measurement I	Measurement II	Measurement III	Measurement IV	Measurement V	Measurement VI	Measurement VII
Soil	26.2 b	33.96 b	57 b	118.84 ab	153.04 a	289.88 a	338.2 a
Compost of oasis wastes and animal manure	24.48 b	30.76 b	52.76 b	118.84 ab	153.64 a	272.92 b	320.56 ab
Palm trees compost	23.36 b	30.44 b	53.64 b	113.88 ab	150.92 a	272.72 b	319.16 ab
River sand	25.84 b	33.08 b	54.92 b	111.64 b	145.68 a	264.88 b	309.32 b
Coconut fiber	31.92 a	41.52 a	62.4 a	123 a	154.88 a	277.28 ab	321.32 ab

The least difference between maximum and minimum temperatures during the study was for Oasis compost at 10 cm deep compared to other media (Table 8). Generally roots in soilless culture are usually exposed daily to large variations in temperature while deep penetrating roots of soil grown plants can escape extreme hot and cold root temperatures (Kafkafi, 2001). Large variation in day and night temperatures may affect several aspects of plant growth, fruit quality and yield (Hurewitz and Janes, 1983; Papadopoulos, 1991). Thus, maintaining of optimum root temperature is the main factor in plant production under soilless culture conditions, and the least temperature variation in Compost of oasis wastes and animal manure substrate (9º C) may reduce the negative effects on tomato yield and quality.

Table 8: Growing media temperature

	Soil	Compost of oasis wastes and animal manure	Palm trees compost	River sand	Coconut fiber
Minimum media temperature (°C)	12.7 c	17 a	16.2 a	12.4 c	14.8 b
Maximum media temperature (°C)	25.2 a	26 a	26 a	25.4 a	26 a

Our results showed that Fruit firmness of full ripe tomato had not any significant difference between treatments at the level of five percent. However, the Fruit firmness of mature green tomato was found to differ significantly between substrates. Compost of oasis wastes and animal manure and palm trees compost recorded the highest values (Table 9).

The data indicated that firmness of tomato fruit was influenced by maturity stage at harvest. The highest value (3.32 kg/cm2) was reported in mature green tomato while the lowest value (1.6 kg/cm^2) was reported in full ripe tomato. Firmness decreased notably with advance in maturity stage of tomato fruit, mature green tomato was noted to be the firmest (Table 9). Fruit firmness is indicative of level of softening of the fruit that can be affected by maturity stage at harvest time. Fruit firmness is related to the susceptibility of tomato fruit to physical damage during harvest and storage. The decrease in fruit firmness with advance in maturity stage may be related to the degradation of polysaccharides

Table 9: Effects of different substrates on fruit firmness (kg/cm^2) of mature green and full ripe tomato

	Soil	Compost of oasis wastes and animal manure	Palm trees compost	River Sand	Coconut fiber
Fruit firmness of full ripe tomato (kg.cm-^{2})	1.6 a	1.81 a	1.9 a	1.67 a	1.72 a

Fruit firmness of mature green tomato ($kg.cm^{-2}$)	2.2 b	3.2 a	3.32 a	2.47 b	2.5 b

DISCUSSION

Comparison of means showed that the treatments had no significant effect on yield. Jensen (1998) research show there are no fundamental differences between the yields of tomatoes grown in different substrates. Halman (2003) data show yield of cherry tomatoes grown in coconut and rockwool was similar. Mohammadi et *al*. (2012) investigated the comparison of Date-Palm wastes and Perlite as culture substrates on growing indices in greenhouse cucumber and reported that Perlite and Date-Palm waste media had similar properties and they had no significant difference on yield and number of cucumber fruit. The effect of substrates include Perlite, Date-Palm peat, Date-Palm peat + Perlite and Coco peat+ Perlite on growing indices of tomato studied by Mohammadi Ghehsareh et *al.* (2011) showed that the yield of tomato fruits had not any significant differences between treatments at 5% level. Our data showed the yields of tomatoes grown in the compost of oasis wastes and animal manure, palm trees compost and coconut fiber were little bit higher than those grown in sand (insignificant differences). Tzortzakis and Economakis (2008) represented that higher yield of tomato fruits was obtained from plants grown in organic media as compared with inorganic media. Hematian et *al.* (2012) investigated the effect of addition of some organic waste to soil on yield and some growth indices of greenhouse cucumber and reported higher yield were obtained from pure palm peat media.

In our study, compost of oasis wastes and animal manure presented the highest total yield. Carmona et *al*. (2012) studied composting of wine industry wastes and their use as a substrate for growing soilless ornamental plants and reported that compost had no limiting characteristics for its use as a medium for the cultivation of ornamental plants in container, and could replace conventional substrates, such as peat and coconut fiber.

Roots of plants developed on Oasis compost have shown superiority through their fresh weight in comparison to those of plants cultivated on other substrates. Superiority of compost concerning this parameter can be attributed to its heat absorbing ability justified by its dark colour, as it was indicated by Yetisir et *al*. (2006) for basaltic tuff.

The results of data length and stem diameter on seven occasions, showed that plant height and diameter had a significant difference between treatments. Our results do not agree with those found by Borji et *al.* (2010), who showed that different substrates (date-palm peat, perlite, cocopeat+date-palm peat, perlite +date-palm peat and cocopeat + perlite) had no significant difference in stem diameter and length of tomato plant.

The plants grown in coconut fiber substrate were the tallest during the first five measures taken. During the sixth and seventh measures, the tallest plants were produced by tomato cultivated in soil. The most vigorous plants were grown in coconut fiber. Tzortzakis and Economakis (2008) found that plants grew faster in organic media compared to inorganic media. In contrast, Böhme et *al*., 2001 and Ikeda et *al*., 2001 found that growth and development of vegetables are enhanced, when plants are grown in inorganic media compared to organic ones. Proper conditions with a view to bulk density and porosity in media caused better support of water and nutrient elements for plant leading to good growth (Olympious, 1992; Kumar and Goh, 1999).

TSS (°Brix) content of the fruit was found to differ significantly between substrates. In accordance with the present study, Traka-Mavrona (2001) recorded significant differences between organic and inorganic substrates in TSS in tomato fruit juice. This contradicts the findings reported by Islam et *al*. (2002).

Conclusions

In conclusion, this experiment demonstrated that:

Length of tomato is enhanced, when plants are grown in soil and coconut fiber compared to sand, compost of oasis wastes and animal manure and palm trees compost. The most vigorous plants were grown in Coconut fiber. The treatments had no significant effect on yield and highest amount of fruit yield related to the compost of oasis wastes and animal manure treatment Local substrates, palm trees compost, sand and especially compost of oasis wastes and animal manure can constitute a promising alternative to the use of the imported ones, such as coconut fiber, perlite...

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