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Full Length Research Paper

Effect of substrate on vegetative growth, quantitative and qualitative production of muskmelon (*Cucumis melo*) conducted in soilless culture

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Greenhouses heated and irrigated by geothermic water, constitute a promoter sector in the South of Tunisia. However, simultaneous salinity of sand and water of irrigation limits amply, the development of this sector. To control salinity, it seems efficient to adopt interesting agricultural techniques like soilless culture. The selection of suitable media is the key that ensures the success of this technique, seeing that the adoption of not standardized one, limits the correct nutrient solution management so the development of plant. The substrate selection must consider technical and economical implications. In this framework, two ubiquitous substrates of the South of Tunisia, sand and compost of dry palms, were compared to the imported media, perlite, for soilless culture of muskmelon (*Cucumis melo*). This study was based on the vegetative growth, quantitative and qualitative production. Results have shown that local substrates have simulated, in relation to perlite, strong and deep roots that permit an effective absorption of nutrients. Subsequently, leaves were larger, their content in fresh and dry matter were higher and stems were taller. This superiority was sustained by superiority of index of growth, NAR. This behavior has reverberated on precocity and yield that were greater on these two media. As regard to external characteristics of fruits, firmness and diameter were higher particularly on compost. With exception of pH, gustative quality was not affected by type of substrate.

Key words: Greenhouse, muskmelon, substrate, vegetative growth, quantitative production, qualitative production.

INTRODUCTION

Nowadays, seeing the increase of human population, an emphasis on higher vegetable production all year round is noted. To response to this demand, sustainable development aims towards upcoming the target of optimizing crop yield by intensifying agriculture (Maloupa, 2000). This intensification conjoined with the shortage of water resources and arable lands can be achieved only through the adoption of promising agricultural practices such as soilless culture. Soilless culture covers all methods and systems of production tool using mineral solution for the plant nutrition with another substrate or support than soil (Resh, 1989; Robin, 1998; Butt et al., 2004; Sheikh, 2006; Gruda, 2009) such as water culture, gravel culture, aeroponics, tube culture and nutriculture (Schwarz, 1994). It can be done on open or closed system (Baas et al., 1995; Papadopoulos et al., 1999).

It was advisable to gradually extend this agricultural practice due to its advantages (Jiang and Yu, 2004; Metin-Sezen et al., 2006; Yetisir et al., 2006). Indeed, it is an efficient tool to overcome problems associated with production factors (Verdonck, 1975; Granqvist, 1981; Olympios, 1992; Abd El-Hady and El-Dardiry, 2006) and create possibility of cultivation with flexibility even in regions where natural growing conditions are hostile (Schwarz, 1994; Morard, 1995; Grillas et al., 2001). The evidence that, this technique helps to surmount soil-borne diseases and pests seeing that, the distribution of

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Table 1. Characteristics of local sand.

Granulometric composition (%)	Gravel	2.7
	Rough sand	46.3
	Fine sand	48.3
	Silt and clay	2.7
pH		8.2
EC (mS/cm)		2.5
Rate of retention of water (%)		26

roots pathogens is drastically minimized (Schwarz, 1994; Choukr-Allah, 2004) has widespread, too, rapidly this practice.

Incontestably, this system of culture ensures an economy of water in relation to conventional soil culture due to decrease of soil evaporation and seepage (Schwarz, 1994; Schröder and Lieth, 2002) and endows an accurate control of the nutritional supply of plants (Resh, 1978; Schwarz, 1994; HO, 2004; Sheikh, 2006; Gruda, 2009). Therefore, this technique allows the use of brackish water (Adams, 1991) namely with the scarcity of good quality of water because of the adjustment of nutrient solution and its permanent replacement. Indeed, improving water use efficiency and the irrigation with available saline water in an economically viable manner, are the main objectives of introducing such technique (Qaryouti et al., 2006). Likewise, among the alternatives to soil sterilization by methyl bromide, soilless culture represents one of the more widely considered possibilities (Ozeker et al., 1999; Maloupa, 2002; Savvas, 2003; Lieten et al., 2004; Giménez et al., 2008; Kaya et al., 2008; Leoni and Ledda, 2004). As well, it protects soil and underground water from pollution caused by pesticides and fertilizers particularly nitrogen (Yetisir et al., 2006). The choice of substrates for soilless cultivation, represents one of the key points to be considered (Leonardi, 2006) due to technical and economical implications (Giuffrida et al., 2008). Indeed, the choice of a not standardised growing media is no guarantee for a correct nutrient solution management. There is no univocal scheme for the choice of the growing media (Leonardi, 2006). But, the knowledge of its characteristics is very important for this selection, seeing that the properties of different materials used as growing substrates, exhibit direct and indirect effects on plant growth and production (Verdonck et al., 1981). These characteristics concern physical, chemical and biological properties. Physical properties concern aeration, drainage and water retention capacity (Blanc, 1987; Lemaire et al., 1989; Cabrera, 2003). Chemical and biological features are indicated, respectively, by not having toxic material and very limited and/or less pathogen and pest (Blanc, 1987).

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 (Haddad, 2007). The soilless culture systems which are currently used in Tunisia, are slanting sand bed and pudding bags. Tunisia is in root of vulgarizing enormously, the use of this practice under these greenhouses, in order to overcome the well known problems of salinity and pathogenic agents that invade this sector (Kouki, 1999). However, it remains limited for big geothermic societies because of the high installation cost compared to soil (material disposal and raising), the use of sophisticated control methods and its requirement of high technical level (Radhouani et al., 2008). The major growing media are imported with a high use of perlite. Nevertheless, several studies have attested that, this growing medium constitutes the most promising and efficient substrate in soilless culture (Grudina et al., 1994; Park et al., 1999), it seems to be of great interest to search locally available and less costly substrates (Verdonck et al., 1981; Klougart, 1983; Abd El-Hady and El-Dardiry, 2006; Abd El-Hady et al., 2006; Giménez et al., 2008; Tzortzakis and Economakis, 2008; Abo-Rezq et al., 2009; Abd El-Hady and Shanan, 2010). To investigate this issue, a trial of a culture of muskmelon conducted under greenhouse, heated and irrigated by geothermic water was carried out. This study aims to test the effects of two local substrates, sand and compost, and imported one, perlite on this plant.

MATERIALS AND METHODS

Location, plant material, and growth conditions

The study was carried out in a 255 m^2 mono tunnel (8.5 x 30 m) covered with a 200 µm polyethylene film, at the experimental field of Institute of Arid Regions (IRA). This greenhouse was heated by geothermic waters. Heating was realized by the circulation of geothermic waters (60°C) in corrugated polypropylene pipes (PPØ 25) placed on the plastic between plant rows. Control of daily temperature occurred by lateral aeration. Transplant took place in early January 2007, at a density of 3 plants/m^2, using the hybrid F1 'Calypso', considered as one of the most representative muskmelon varieties cultivated in Tunisia; seeing its high crop performance and fruit quality. Plants were grown under natural light conditions. They were grown with two stems and pruned above the fifth cluster. An open soilless cultivation system was adopted. Three grown media were considered:

1. Perlite: Perlite used in this study had 90% volume of its expanded particles in 5 to15 mm range, and a very high air-filled porosity of around 60%;
2. Local sand with characteristics represented in Table 1;
3. Local compost formed by fermentation of dry palms with addition of manure (Haddad, 2003; Bouhaouach et al., 2009). The main characteristics of this media are summarized in Table 2.

The adopted system is pudding bags culture system: plastic bags with volume of 33 L and U shape were used as containers with density of three plants per container. They were placed on ground, settled down beforehand and covered by a plastic film. They were disposed on a fine layer of graves. They were perforated to drain excess of water.

Table 2. Characteristics of local compost.

C/N (%)	Organic matter (%)	Total porosity (%)	pH	EC (ms/cm)	Rate of retention of water (%)
27.1	60	62.2	7.64	4.1	31

Table 3. Chemical composition of nutritive solution (%).

	N	K	Ca	Mg	$H_2PO_4^-$	SO_4^{2-}
Water of irrigation	0	1.06	12	7.2	0	14
Norms of fertilization	14.3	6	8.5	2	1.3	2.5
Nutritive solution	14.3	4.94	0	0	1.3	0

Table 4. Composition of nutritive solution regards to stage of development of plants (Huguet et al., 1971).

Stage of growth chemical	Plantation- first fruit set	First fruit set - last fruit set	Last fruit set- start of harvest	Start of harvest- end of harvest
NH_4NO_3	20	100	71.5	94
KNO_3	19	100	73.8	45
$H_2PO_4^-$	17	88.5	80	100
HNO_3	20	100	71.5	94

Nutrient solution management

The nutritive solution was pumped using a pump with 1 atm power, through an open drip irrigation system with one emitter per plant and a flow rate of 4 L/h. This solution was formulated according to the chemical composition of water of irrigation and norms of fertilization of muskmelon (Table 3). The nutritional needs of plants were determined referring to Huguet et al. (1971) (Table 4). Plants were fertilized by fertigation. The plants were irrigated daily 4 to 5 times, depending on the size of the plant and the growing climatic conditions. Additionally, the volume of irrigation water was adjusted to ensure a leaching fraction, sufficient to contain the increase of salt in the substrate (Kempkes and Stanghellini, 2003). To avoid this increase, plants were over watered with a drainage volume equal to about 80% of the supply once a week, with geothermic waters without nutrients. The experiment plan was of a completely randomized design with three replications and each one was represented by 24 plants per row (three rows in the greenhouse).

Data collection and analysis

The experiment was conducted as a randomized complete block design with three replicates. Each experimental unit consisted of 24 plants per line. Evaluation of the effect of substrate on vegetative growth has included steam (average height) and leaves (fresh matter, rate of dry matter and relative content of water). The measures were recorded on the fifth leaf from the top, seeing that it corresponds to a transformation from the state of well to source, as it was indicated by Ouled et al. (2006). Dry matter and leaves' area have served to determine growth indexes: RGR (Relative Rate of Growth) and NAR (Net Assimilation Rate). These measures were done 49, 64 and 79 days after transplantation.

At the end of culture, plants were uprooted and length, fresh and dry weight of roots were measured. Besides, volumes of roots expressed as volume registered on the base of water moved by roots were specified. For each substrate, days preceding harvest were counted. The average number and weight of fruits were determined. Fruits were classed into three classes according to their weights (CTIFL, 1991): C1: weight inferior to 600 g; C2: weight ranging between 600 and 900 g; C3: weight superior to 900 g. Total yield per substrate was determined. Firmness of fruits was estimated by measuring their penetrance. The incidence of substrate on gustative quality was estimated by measuring electrical conductivity, EC, using a conductive meter, pH (by an electronic pH) and soluble solids determined by a refractometer and expressed in °Brix, of juice's fruits. Its titrable acidity was measured by titration of 25 ml of homogenated juice with 0.1 NaOH until pH 8 and reported in percentage of acid content. Statistical analyses were performed using a level of 0.05 (5%) for the ANOVA and Tukey's post hoc tests. Differences between the means of the three substrates were compared, using the least significant difference (LSD). Levels of significance are represented by *($P < 0.05$), ** ($P < 0.01$) and *** ($P < 0.001$) and NS (not significant).

RESULTS AND DISCUSSION

Effect of substrate on vegetative growth

Roots of plants developed on sand and compost have shown a tremendous superiority through their volume and fresh weight ($P < 0.001$) in comparison to those of plants cultivated on perlite (Table 5), due to the enormous development of lateral thin roots (Figure 1). With the local substrates, plants height was statistically similar and significantly greater than the one recorded on perlite: with reference to the latter, plants have reached as at 79 days after transplantation, an average length of stem of around 125.00 cm ; yet, this parameter was about 185.22 and 198.88 cm respectively on sand and compost (Figure 2). This superiority was noted, too, with growth of leaves. Indeed, local substrates have presented similarly, fifth leaves with a fresh matter of 1.45 g and an average area

Table 5. Effect of substrates on vegetative growth, quantitative and qualitative production.

		Perlite	Sand	Compost	Level of significance
Roots	Length (cm)	27 a ± 1.13	28.33 a ± 1.42	32.66 a ± 1.72	NS
	Volume (ml)	27.33 b ± 0.65	41.66 a ± 0.65	49.66 a ± 1.17	**
	Fresh weight (g)	31.23 b ± 0.77	61 a ± 0.79	62 a ± 0.92	***
	Dry weight (g)	2.7 b ± 0.68	5.03 a ± 1.07	4.8 a ± 0.67	**
Leaves	Surface (cm^2)	31.83 b ± 0.54	40.5 a ± 0.61	41.83 a ± 0.85	*
	Fresh matter (g)	1.01 b ± 0.07	1.33 a ± 0.11	1.58 a ± 0.17	*
	Rate of dry matter (%)	14. 51 a ± 0.04	16.29 a ± 0.04	16.68 a ± 0.08	NS
	Content of water (%)	83.89 a ± 0.03	83.39 a ± 0.02	81.51 a ± 0.04	NS
Quantitative Production	Days before harvest	91	90	88	-
	Fruits/plant	5.33 b	6.32 a	6.28 a	**
	Kg/fruit	0.41b	0.51 ab	0.65 a	**
	Total production (Kg/plant)	2.21 c	3.24 b	4.11 a	***
Qualitative production	Penetrance (cm)	0.15 a ± 0.048	0.12 a ± 0.044	0.04 b± 0.042	***
	Diameter (cm)	7.66 b ± 0.61	10.56 a ± 0.48	10.42 a ± 0.14	*
	pH	6.66 b ±0.02	6.87 a ±0.09	6.98 a ± 0.08	*
	EC (mS/cm)	7.18 a ± 0.40	7.51 a ± 0.52	6.94 a ± 0.32	NS
	IR (°Brix)	10.1 a ± 0.80	10.8 a ± 1.60	11.8 a ± 0.65	NS
	Acidity (%)	1.40 a ± 0.02	1.19 a ± 0.14	1.17 a ± 0.13	NS

Values followed by the same letters within each line are statistically similar according to test of Newman and Keuls at $P \leq 0.05$. Levels of significance are represented by * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ and NS, not significant.

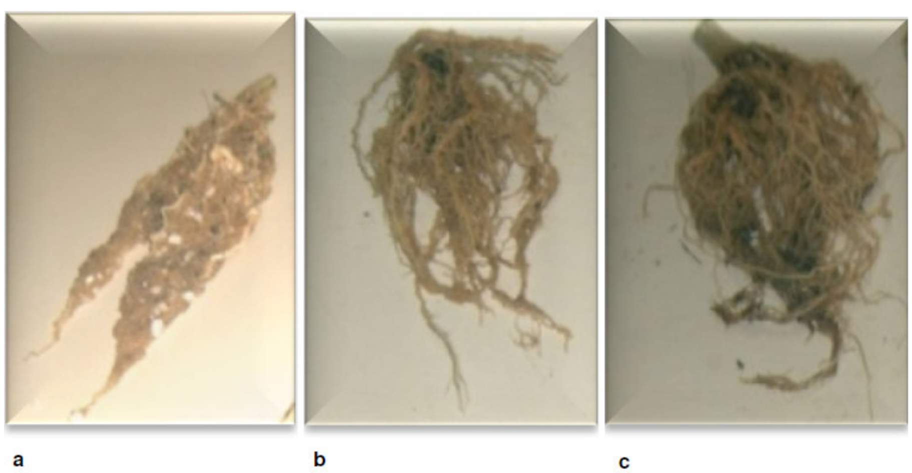

Figure 1. Roots on perlite (a) sand (b) and compost (c).

of 41.65 cm^2. However, on perlite, growth of leaves was limited to a fresh matter of 1.01 g and an expansion of 31.83 cm^2. Rate of dry matter of leaves for the three treatments were statistically similar (Table 5).

Although their similar rate of growth, RGR, (Figure 3) substrates have shown a conspicuous difference concerning their net assimilation rate (NAR). For the last parameter, values were negative on three substrates, yet this negativity was more drastic on perlite (Figure 4).

Effect of substrate on quantitative production

Harvest of fruits had begun on compost, 88 days after transplantation with superiority of 2 and 3 days respectively, in relation to sand and perlite (Table 5).

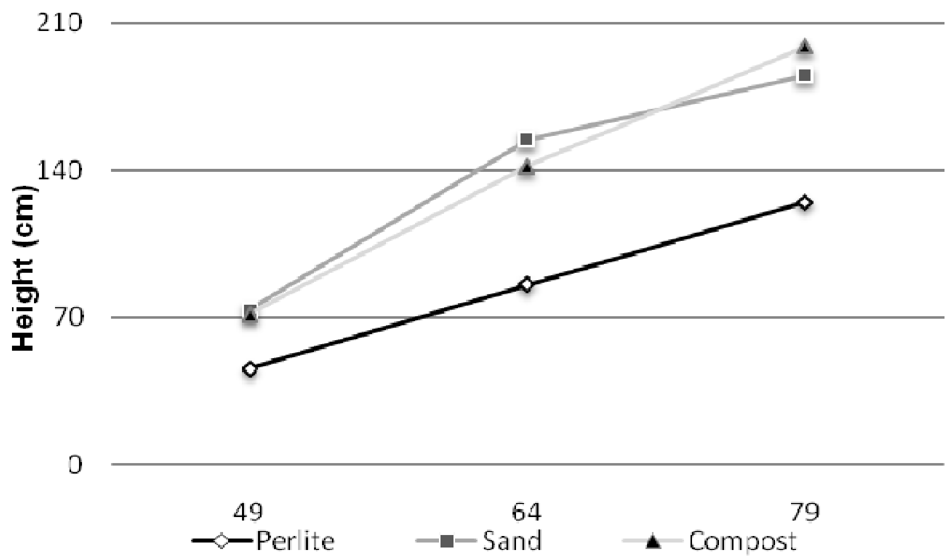

Figure 2. Effect of substrates on the rate of growth (cm/day).

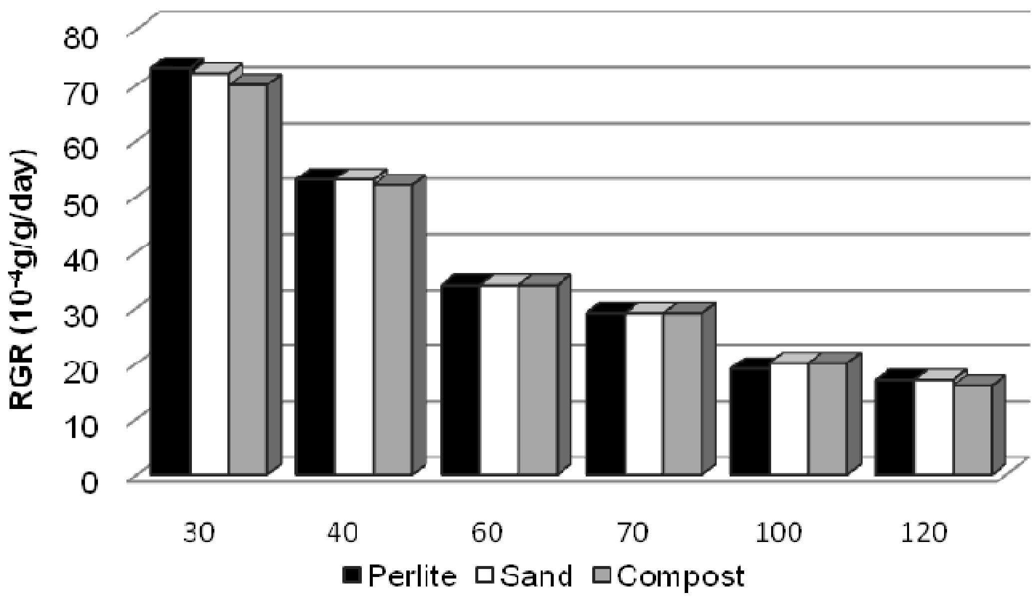

Figure 3. Effect of substrates on relative rate of growth, RGR, (10^{-4} g/g/day).

Plants cultivated on sand and compost had formed towards 6 fruits with an average weight of 0.58 Kg. This effect of two ubiquitous media was higher than one or of perlite, where each plant had formed 5.3 fruits with a small weight around 0.41 Kg (Table 5). All the same, total production was better on local substrates than on perlite. This superiority was about 66.28%. Additionally, these two growing media have enthused production of fruits with marketable weight. Indeed, on sand and compost, this class was represented respectively by 43.64 and 22.44% of total production, but for plants cultivated on perlite, this class constitutes only % of their all production (Figure 5).

Effect of substrate on qualitative production

The most important, firmness, deducted from penetrance of fruit's pericarp, was remarked on compost (Table 5). Fruits harvested on sand and compost were larger (important diameter) than those collected on perlite. Measures have revealed that, the effect of substrate on

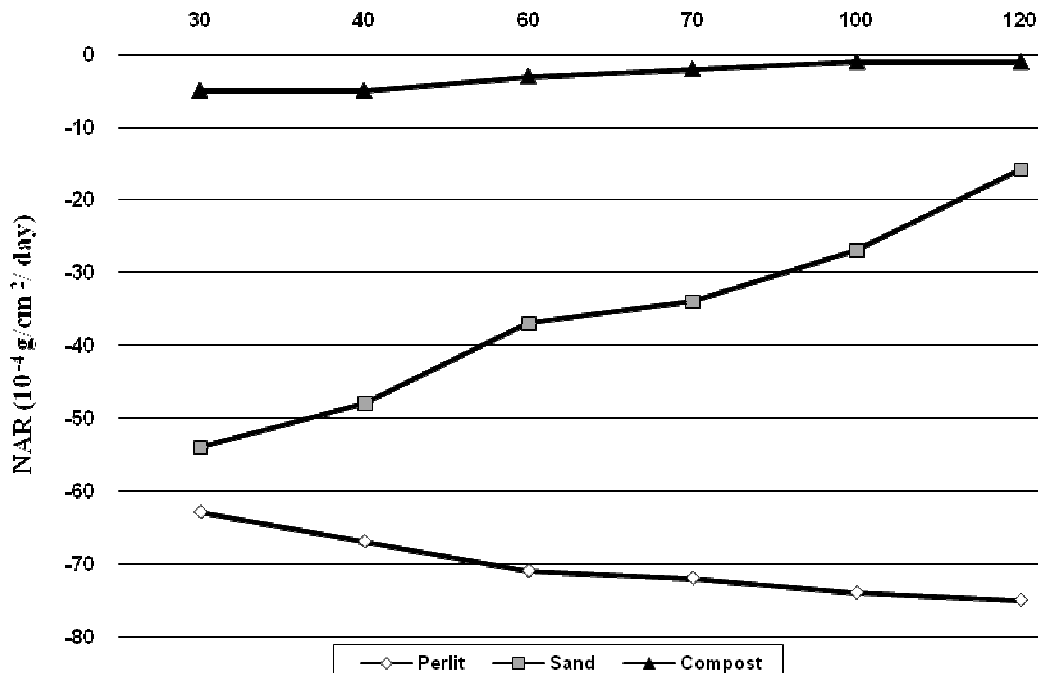

Figure 4. Effect of substrates on net rate of growth, NAR, (10^{-4} g/cm^2/day).

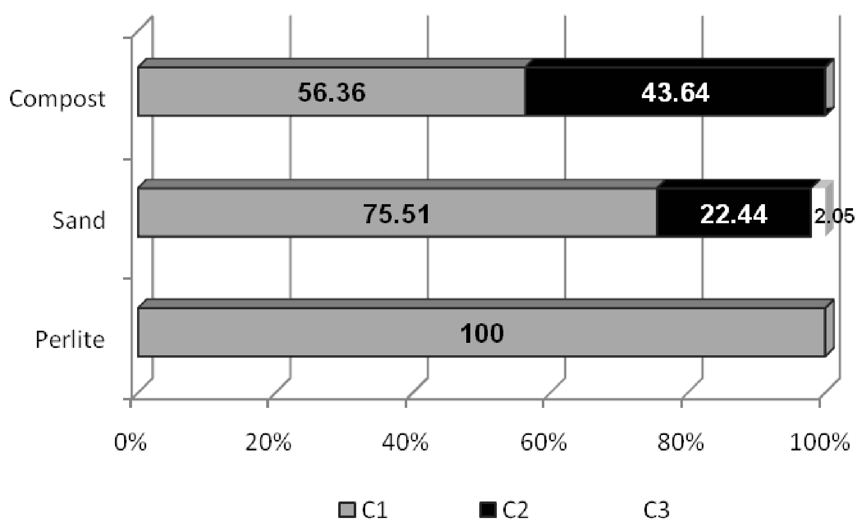

Figure 5. Effect of substrates on caliber of fruits.

gustative quality was similar (Table 6). With exception, pH was higher on sand than on the two other substrates.

DISCUSSION

In the lights of the results of this study, it was seen that local substrates, sand and especially compost can constitute a promising alternative to the use of imported media, such as perlite. Indeed, these substrates have promoted remarkably vegetative growth of plants. This behavior may be attributed to the great growth of roots, represented by their great fresh and dry weights and volume. Moreover, thin roots were dominant on their morphology. The dominance of such roots can be explicated by the high holding water capacity of the two local substrates. Thus, assimilation of nutrients was efficient, seeing that these roots were effective in absorption of brut sap ingredients, as it was affirmed by Daaaloul et al. (2001).

Consequently, leaves were larger and richer in fresh matter and stem was taller. The weak effect of perlite, on the height of plant, compared with sand was indicated too for tomatoes by Haddad (2007). The lowest effect of perlite on vegetative growth can be due to the high electrical conductivity of its nutrient solution (Xu et al., 1997).

Superiority of growth on sand and compost, in relation to perlite was confirmed by the net assimilation rate, NAR. Indeed, on this medium was recorded the most negativity of this parameter. This negativity may infer that, fifth leaves presented a physiological state of well, as it was indicated by Marcelis et al. (1998) and Loveys et al. (2002). This result confirms the faster vegetative growth of plants cultivated on local substrates, seeing that negative values of this parameter indicates a lengthiness of this growth, as it was attested by Fahrurrozi (2000) for muskmelon. Difference in vegetative growth has reverberated on precocity which was better on local substrates than on perlite, seeing their hasty vegetative growth. Superiority of compost concerning this parameter can be attributed to its heat absorbing ability justified by its dark color, as it was indicated by Yetisir et al. (2006) for basaltic tuff. A part the slight enhancement of precocity by local substrates in relation to perlite, quantitative production was considerably promoted.

This finding corroborated the one of Yetisir et al. (2006) elaborated between sand and perlite. It seems that, promising growth of leaves in terms of area and fresh matter was beneficial for production of heavy fruits. Furthermore, fruits with marketable weight were higher on these two substrates. Concerning qualitative production, fruits harvested on local media, especially compost, were firmer and larger than those formed on perlite. However, Haddad et al. (2003) have sustained, for tomatoes, a similarity between these substrates. The superiority of sand in relation to perlite was evidenced, too, by Yetisir et al. (2006) for watermelon. Gustative quality was unaffected by type of substrate. This remark was consistent with previous studies of Haddad et al. (2003) and Haddad (2007) for tomatoes. Yetisir et al. (2006) noted similar total soluble solids for watermelon cultivated on sand and perlite.

Conclusion

In the South of Tunisia, few years after the use of geothermal waters in protected cultures, decrease of soil fertility and increase in soil salinity, associated to the incurrence of soil-born diseases, have rapidly developed and limited amply both the growth and the productivity of crops. To overcome these constraints, a local soilless system culture was developed. This work compared two local substrates, sand and compost, to perlite. Results have shown that, local grown media have revealed promising performance: plants grew faster, produced earlier and formed more fruits with marketable yields. Nevertheless, it was noted at the end of culture that, compost and particularly sand have subside. This disadvantage can be prevailed over by their mixing, to reward their mutual deficiencies.

REFERENCES

Abd El-Hady M, El-Dardiry EI (2006). Improving Hydrophysical Properties Quality of Compost. J. Appl. Sci. Res., 2(12): 1137-1141.

Abd El-Hady M, Shaaban SM, El-Dardiry EI (2006). Effect of Hydro-physical Improvement of Substrates on Cucumber Plant Growth. J. Appl. Sci. Res., 2(12): 1185-1190.

Abd El-Hady M, Shanan N (2010). Enhancement growth characters of Pothos plants (Epipremnum Aureum Lind L.) grown in different improved pot media. Int. J. Acad. Res., 2(2): 89-97.

Abo-Rezq H, Albaho M, Thomas B. (2009). Effect of Sand in Growing Media on Selected Plant Species. Eur. J. Sci. Res., 26(4): 618-623.

Adams P (1991). Effects of increasing the salinity of the nutrient solution with major nutrients or sodium chloride on the yield, quality and composition of tomatoes grown in rockwool. J. Horticult. Sci., 66: 201-207.

Baas R, Nijssen HMC, Van Den Berg TJM, Warmenhoven MG (1995). Yield and quality of carnation (Dianthus caryophyllus L.) and gerbera (Gerbera jamesoniiL.) in a closed nutrient system as affected by sodium chloride. Sci. Hort., 61(1): 273-284.

Blanc D (1987). Les cultures hors sols. Ouvrage collectif. INRA. Paris, p.478.

Bouahaouach H, Marc HC, Kouki K (2009). Compostage et valorisation des déchets oasiens pour l'amélioration des sols et de la productivité. Symposium international AGRUMED : Gestion des Ressources en Eau et en Sol et Durabilité des systèmes de Cultures en Zone Méditerranéenne. Rabat, IAV Hassan II. 14-16 Mai 2009.

Butt SJ, Varis S, Al-Haq MI (2004). Improvement of sensory attributes of tomatoes (Lycopersicon esculentum Mill) through hydroponics. Agric. Biol., 6(2): 388-392.

Cabrera RI (2003). Fundamentals of container media management. Part 1. Physical properties, The State Univ. of New Jersy Agric. Exp. Station.

Choukr-Allah R. (2004). Protected cultures in Marocco: New trends and developments. international work shop: "The production in the greenhouse after era of the methyl bromide" Comiso, Italy. 1-3 Apr 2004. CTIFL. 1991. Le melon, p. 295.

Daaloul A, Bchini H, Sayar R. (2001). Variabilité génétique de quelques paramètres du système racinaire du blé dur (Triticum durum) sous deux régimes hydriques. Biodivers. int., 129: 25-31.

Fahrurrozi A (|2000). Effect of mulch / mini-tunnel and thermal-water tube combination on daily dioxide concentration and early growth of musk melons. Thèse de doctorat. Department of plant science. Macdonald. Campus of Mc Gill University. Monterall, Quebec, Canada, p. 138.

Giménez G, Andriolo JL, Janisch D, Rodrigo G (2008). Closed soilless growing system for producing strawberry bare root transplants and runner tips. Pesq. agropec. Bras., 43(12): 1757-1761.

Giuffrida F, Leonardi C, Marfà O. 2008. Substrate reuse in tomato soilless cultivation. Acta Hort., p. 801, ISHS. 2008.

Granqvist G. (1981). Recent experiences in the use of substrates for vegetables production under glass in Sweden. Acta Hortic., 126: 262-264.

Grillas S, Lucas M, Bardopoulou E, Sarafopoulos S (2001). Perlite based soilless culture systems: Current commercial applications and prospects. Acta Hort., 548: 105-113.

Gruda N (2009). Do soilless culture systems have an influence on product quality of vegetables. J. Appl. Bot. Food Quality, 82: 141-147.

Grudina R, Fadda N, Chessa F, Leoni S, Serra G, Tononi F, Leoni S. (1994). Two years of watermelon cultivation in soilless culture. Act Horticult., 361: 574-577.

Haddad M. (2003). Exploitation des eaux géothermiques du Sud tunisien pour la culture de la tomate (Lycopersicon esculentum. Mill). Thèse de doctorat de biologie, p. 132

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. J. Food Agric. Environ., 5(2): 175-178.

Haddad M, Boukhriss M, Mougou A (2003). Growth and quality of tomato plants grown in sand and perlite by use of geothermal water. International Symposium on Managing Greenhouse Crops in Saline Environment. Pisa. Italy. 9-12 July 2003.

HO LC (2004). The contribution of plant physiology in glasshouse tomato soilless culture. Acta Hort., 648: 19-25. HUGUET.

Jiang WJ, Yu HJ (2004). Current situation and perspectives of protected horticulture in china. International work shop:" The production in the greenhouse after era of the methyl bromide". Comiso, Italy1-3 Apr. 2004.

Kaya S, Caturano E, Tuzel Y, Leonardi C (2008). Response of tomato plants to organic nutrition in soilless culture. J. Food Agricult. Environ., 6(2): 303-305.

Kempkes F, Stanghellini C (2003). Modelling salt accumulation in a closed system: A tool for management with irrigation water of poor quality. Acta Hort., 641: 143-148.

Kouki K (1999). Protected cultivation in Tunisia. Soilless culture: Prospects and challenges. Proceeding of the first Meeting of the FAO Thematic Working Group of soilless Culture. 2 Septembre 1999. Halkidiki, Grèce.

Klougart A (1983). Substrates and nutrient flow. Acta Hort., 150: 297-313.

Lemaire F, Dartigues A, Rivieère LM, Charpentier S (1989). Cultures en pots et en conteneurs. Principes agronomiques et applications. Edition INRA. Paris et PHM. Revue horticole, p. 181.

Leonardi C (2006). Substrates. 26-30. ECOPONICS-SOP project, pp. 27-30.

Leoni S, Ledda L (2004). The consequences of the methyl bromide ban on vegetable protected crops in sardinia. International work shop: "The production in the greenhouse after era of the methyl bromide". Comiso, Italy, 1-3 Apr. 2004.

Lieten F, Longuesserre J, Baruzzi G, Lopezmedina J, Navatel JC, Krueger E, Matala V, Paroussi G (2004). Recent situation of strawberry substrate culture in Europe. Acta Horticult., 649: 193-196.

Loveys BR, Schurwater F, Pons TL, Fitter AH, Atkin OK (2002). The relative importance of photosynthesis and respiration in determining growth rate. Plant cell Environ., 25(1): 975-998.

Maloupa E (2000). Alternative crops and growing systems for vegetables under protected cultivation in Mediterranean conditions. National Ag. Research Foundation of Greece. 4 Oct 2000.

Maloupa E (2002). Hydroponic systems. In Savvas, D. and Passam, H.(eds). Hydroponic Production of Vegetables and Ornamentals. Embryo Publications, Greece,

Marcelis LFM, Heuvelink E, Goudrian J (1998). Modelling biomass production and yield of horticultural crops: A review. Sci. Horticult., 74 (1): 83-111.

Metin-Sezen A, Celic S, Yazar G, Yalcim A, Mendi Y, Sahinler S, Tekin S, Gencel B (2006). Effects of drip irrigation management and different soilless culture on yield and quality of tomato grown in a plastic house. Pakistan J. Biol. Sci., 9(4): 766-771.

Morard P (1995). Les cultures végétales hors sol. I. N. P. T, France, p. 303.

Olympious CM (1992). Soilless media under protected cultivation rockwool, peat, perlite and other substrates. Acta Hort., 401: 443-451.

Ould Djeh TK, Dali N, Bettaieb T, Ben Salah A (2006). Influence métabolique du CO2 atmosphérique sur la tomate cultivée en milieu saumâtre. John Libbey Eurotext. Cahiers d'études et de recherches francophones / Agricultures, 15 (5): 441-447.

Özeker E, Eltezr Z, Tüzel Y, Gül A, Önal K, Tanrýsever A (1999). Investigations on the effects of different growing media on the yield and quality of strawberries grown in vertical bags. Acta Hort., 486: 409-414.

Papadopoulos AP, Hao X, Tu JC, Zheng J (1999). Tomato production in open or closed rockwool culture systems with NFT or rockwool nutrient feedings. Acta Hort., 481: 89-96.

Park SG, Lee BS, Chung SJ (1999). Effect of substrates on growth and fruit quality of "Mudeungsan" watermelon grown in hydroponics. J. Korean Soc. For Hort. Sci., 40: 419-424.

Qaryouti MM, Qawasmi W, Hamdan H, Edwan M (2006). Influence of NaCl salinity stress on yield, plant water uptake and drainage water of tomato grown in soilless culture. ISHS International Symposium on Protected Culture in a Mild-Winter Climate. Advances in soil and soilless cultivation under protected environment. February 19-24, 2006. AGADIR, MOROCCO.

Radhouani A, El Bekkay M, Ferchichi A (2008). The actual situation of the geothermic sector in the South of Tunisia. International Symposium of Biotechnology. Sfax – Tunisia May 4th – 8th, 2008.

Resh HM (1978). Hydroponic Food Production. A definitive guidebook of soilness food growth methods. Woodbridge Press Publishing Company, pp. 10-34.

Resh HM (1989). Hydroponics foodproduction. Woodbridge Press publishing company. Santa Barbara, California 93160, U.S.A., pp. 462.

Robin P (1998). Horticulture sans sol : Histoire Et Actualité. Cahiers d'économie et sociologie rurales, n° 46-47.

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

Schröder FG, Lieth JH (2002). Irrigation Control in Hydrophonics. In.'Hydrophonic Production of Vegetables and Ornementals'. Ed. by D.Savvas and H.Passam. Embryo Publications Athens, Greece, pp. 263-298.

Schwarz M (1994). Soilless culture management. Springer-Verlag. 196 pp.

Sheikh BA (2006). Hydroponics: Key to sustain agriculture in water stressed and urban environment. Pak. J. Agri., Agril. Eng. Vet. Sc., 22(2): 53-57.

Tzortzakis NG, Economakis CD (2008). Impacts of the substrate medium on tomato yield and fruit quality in soilless cultivation. Hort. Sci. (Prague), 35(2): 83-89

Verdonck O (1975). Horticultural substrates. Wageningen,International Agricultural Centre, p. 88.

Verdonck O, De Vleeschauwer D, De Boodt M (1981). The influence of the substrate to plant growth. Acta Hort., 126: 251-258.

Xu HL, Gautier L, Cosselin A. (1997). Greenhouses tomato photosynthetic acclimation to water deficit and response to salt accumulation in the substrate. Japan Soc. Hort. Sci., 65(4): 777-784.

Yetisir H, Sari N, Aktas H, Karaman C, Abak K (2006). Effects of different substrates on plants growth, yield and quality of watermelon grown in soilless culture. American-Eurasian J. Agric. Environ. Sci., 1(2): 113-118.