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Research Article

Date palm compost versus peat and perlite: a comparative study on germination and plant development of muskmelon and tomato

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This research was carried out in the experimental site of the Arid and Oasian cultures Laboratory of the Institute of Arid Regions, Medenine, Tunisia. It aims at studying the effects of compost on seed germination patterns, seedling growth, and plant development of muskmelon and tomato under greenhouse conditions. Three growth media were used: compost of date palm wastes and two reference media (peat and perlite). The results showed that compost presented a promising threshold of both maturity and stability, which is related to its neutral pH, C : N ratio, greater humic acid vs fulvic acid, and low values of chlorophyll-type compounds. Seeds of muskmelon and tomato germinated at varying liquid compost extract concentrations and muskmelon reached higher germination index values even at the pure extract solution (100%). Moreover, seeds of both species germinated relatively faster in peat than in compost and an overall delay in germination was observed, with a more pronounced reduction on tomato germination percentage. Produced seedlings have attained a similar vigour index among media (p <0.05). Compost of date palm was more suitable for muskmelon stem elongation and leaf-enlarging capacity than perlite. However, the gustative quality of fruits was not significantly affected by the medium-types. Thus, it is concluded the promoising effect of compost of date palm as potting medium and substrate in soilless culture under greenhouse conditions unless a pertinent choice of cultures.

Keywords: compost, stability, maturity, germination, greenhouse, soilless culture

1 Introduction

Worldwide, the increase in food requirements has stimulated agrochemicals inputs (Dayo-Olagbende et al., 2018). In order to permit a sustainable crop production system, a great interest was given to organic agriculture (Olojugba & Opeyemi, 2020). It is a production system excluding the use of synthetic products (Angadi et al., 2017) yet emphasizing the adoption of eco-friendly practices such as composting (Gastol et al., 2011; Islam et al., 2017).

Composting process is considered as a promising technique of toxic compounds' conversion into innocuous end products instead of their landfill input, dumping, and/or incineration (Lazcano et al., 2009). Therefore, it combines the recovery of valuable resources with environmental protection (Islam et al., 2017; Neher et al., 2015). Several studies affirmed that compost's amendment enhances soil properties (Ch'ng et al., 2014; Trupiano et al., 2017) and contributes to preventing plants from diseases (Khan et al., 2017). Besides, it can be used as potting media in nursery (Unal, 2015) and in soilless culture system (Neher et al., 2015). The principal requirements for the compost to be safely used are a suitable threshold of both stability and maturity which imply, respectively, stable organic matter content and absence of phytotoxic compounds, virulent pathogens, or viable seeds (Bernal et al., 1998; Neher et al., 2015).

In southern Tunisia, date palm (*Phoenix dactylifera* L.) is one of the most cultivated trees producing huge amounts of waste. This waste is largely managed by composting especially due to the fact that this region suffers from continuous soil degradation. Under greenhouses, this constraint is alleviated, among others, by soilless culture relying on the use of sandy desert and/or perlite. While the first medium is too heavy and subsides as it gets older, perlite is expensive and presents problems of management in post-production. Thus, exploration of relatively inexpensive, locally available and more

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environmentally friendly substitutes such as compost based on date palm waste is of great interest (Haddad, 2007), particularly under greenhouses.

Limited information is available on the integrated use of organic media under greenhouses heated by geothermal water, the present study was undertaken to determine the response of tomato and muskmelon to compost. For this purpose, potting experiments were performed to determine: (i) how the compost of date palm affects seed germination patterns, seedling growth, and fruiting quality. (ii) if there are any metabolically related changes in response to soilless cultivation by using compost. Thus, muskmelon and tomato seeds were germinated at varying compost extract concentrations and plants grown from seeds in three medium types including compost and two reference ones (peat and perlite), and germination requirements, morpho-physiological parameters and biochemical traits were analysed.

2 Material and methods

The experiment was carried out at the research site of the Arid and Oasian Cultures Laboratory of the Institute of Arid Regions, Medenine (Eastern-South of Tunisia).

2.1 Substrates

The research employed commercial compost of date palm (CP) obtained from the association of Chenini oases' protection. It is produced in a specific composting process referring to the method of Bouhouach et al. (2009). Briefly, compost was prepared by mixing dry wastes of date palm and ovine manure.

Peat and perlite were employed as reference media.

2.2 Compost analyses

pH and electrical conductivity (EC) of compost were measured, respectively, by potentiometry (pH meter Eutech Instruments) and a conductivity meter (Cond 510, XS Instruments) on compost: water suspension. For total nitrogen determination, a modified Kjeldahl method was used. Total organic carbon was measured according to the Colorimetry method (ISO 14235). Available phosphorus was determined calorimetrically in sulpho-molybdic acid system. The content of Na, K, Ca and Mg were determined referring to Haddad (2007). Both polyphenol, lignin, humic and fulvic acids contents were measured as reported by Radhouani et al. (2012), the humification index was determined as indicated by Zbytniewski and Buszewski (2005), and the decomposition of chlorophyll-type compounds was estimated by the assay of light absorption of acetone extracts of compost.

Physical characterization consisted of determination of the moisture content, bulk density, particle density, water retention capacity, and total space as the procedures described by Verdonck and Gabriëls (1992). The enumeration of total, fungal and bacterial flora was realized as reported by Radhouani et al. (2012).

The extraction of the micro-organisms was carried out on 5 g of compost mixed with 45 ml of 0.1 M buffer phosphate and 0.05% Tween 80. Cultivable total microflora, actinomycetes, and the fungal microflora were analysed on standard plate LPGA, Pochon and Tardieux and malt's extract. Calculations were done in triplicate by performing quantitative determinations based on colony forming units (CFU). All results were expressed as log CFU.g^{-1} DW.

2.3 Experimental design and layout

Compost phytotoxicity was assessed through the germination index (GI%) of muskmelon (*Cucumis melo*) and tomato (*Solanum lycopersicum*) seeds. Six different solutions were used: sterile deionized water, as control solution, and solutions containing 25, 50, 75 and 100% extract of compost. Solutions were added to Petri dishes containing 5 sterile seeds. Germination percentage and seedlings' root length were recorded after 5 days of incubation according to Tiquia and Tam (1998). This index was assessed as follows:

$$GI\% = (GsLs)/(GcLc) \times 100 \qquad (1)$$

where:

Gs and *Ls* – are, respectively, seed germination and root elongation (mm) for the samples; *Gc* and *Lc* –the corresponding values for controls (Trupiano et al., 2017). The test was repeated in triplicate.

Seeds were sown into cell plug trays containing peat and compost. The treatments were laid out in a completely randomized design. Germination was performed in an air-conditioned room at the temperature of 27 ±1 °C and the relative humidity of 90-95%. The number of germinated seeds was recorded 5, 10, 15 and 20 days after sowing (Tiquia & Tam, 1998). The cumulative percentage of germination (%) was determined. The mean germination time (MGT) was calculated referring to the procedure of Alvarado et al. (1987). The needed time to get 50% germination (T_{50}) was calculated according to Farooq et al. (2005). Damping off disease incidence of infected seedlings was calculated as described by Rahim et al. (2014).

Twenty days after sowing, the number of leaves of seedlings was counted; shoot height and root lengths were measured, mutual shoot and root's dry matter were weighted, and their ratio was calculated. The vigour index was determined according to the International Seed Testing Association (1996).

For soilless culture experience, one-month-old tomato seedlings (cv. Romana) were transplanted into plastic pots (5 L) filled with compost and perlite. Plants were conducted in glasshouse under a controlled water regime, temperatures ranging between 12 and 25 °C, and natural day length corresponding to winter-spring season. For muskmelon, growth media were placed in white plastic containers with volume of 33 L and U shape. They were conducted under plastic greenhouses. The nutrient solution was formulated according to the chemical composition of irrigation water, norms of fertilization of each culture, and stage of development. It is of open system's type.

Plant morphological data were collected weekly by measuring stem height (cm) and girth (cm) 80 days after transplantation; surface leaf area (cm^2), the rate of dry matter and specific leaf area (SLA) were calculated 30 days after transplantation. At the end of culture, plants were uprooted, and dry weights of roots were measured. Days preceding maturity of the first fruit were counted. The average weight of fruits was determined, too. Gustative quality of produced fruits was evaluated via measurement of pH, EC, IR, acidity, and the IR/acidity ratio.

2.4 Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) using Statistica for Windows, version 9. The Duncan's Multiple Range Test (DMRT) was carried out to determine if significant differences (p <0.05) occurred between individual treatments.

3 Results and discussion

3.1 Characterization of date's palm compost

The finding of neutral pH of compost was similar to those of Forster et al. (1993), Ofosu-Budu et al. (2010), and Unal (2015). The content of nitrogen of 1.13% aligned with works of Francou (2003) who reported content oscillating between 1 and 4%. The C : N value of 15.23 reflected a net mineralization referring to Ch'ng et al. (2014). In previous studies, better values fluctuated between 10 and 30 (Francou, 2003). Moreover, Abdel-Razzak et al. (2018) have reported that composts with a C : N ratio ranging from 12 : 1 to 25 : 1 are ideal for nursery plant production. This N limitation seems to result in decomposing less of the easily available C by thermophilic bacteria and leaving more organic matter for fungal decomposition during the curing phase. Thus, a predominance of fungi flora with several 61 10^6CFU.g^{-1} DM has characterized the pile of compost (Table 1).

Synthetic and transformational activities of these microorganisms result in production of 1.23 10^{-3} g.g^{-1} DM of phenolic compounds and 4.93 unit of lignin. This attribution was indicated by Gill and Al-Shankiti

Table 1 Chemical, physical, and biological properties of both compost of date palm (CP) and peat (P)

Parameter		CP	P
pH		7.53	6.74
EC (dS.m^{-1})		4.83	1.22
OM (%)		32.84	61.85
N (%)		1.13	0.60
C : N		15.23	26.92
Mineral composition (% DM)	Na	0.52	0.18
	K	0.46	0.53
	Ca + Mg	3.23	2.87
	Cl	0.16	0.04
Phenolic compounds (g.g^{-1} DM)		1.23 10^{-3} a	0.094 10^{-3} b
A665		0.027	–
Lignin		4.93	–
Humification (% DM)	HA	9.41	14.57
	FA	7.1	9.3
	HI	6.98	9.11
H (% DM)		31.42	62.87
Porosity (% DM)		46.83	84.24
Bulk density (g.m^{-1})		0.42 10^{-2}	0.26 10^{-2}
Real density (g.m^{-1})		0.79 10^{-2}	1.65 10^{-2}
Retention of water (l.l^{-1})		0.35	0.43
Air capacity (% V/V)		19	35.00
Total flora (10^{10} CFU.g^{-1} DM)		101	–
Fungi (10^6 CFU.g^{-1}DM)		61	–
Bacteria (10^3 CFU.g^{-1} DM)		47	–

EC – electrical conductivity, OM – organic matter, HA – humic acid, FA – fulvic aid, HI – humification index

(2015). Referring to Zbytniewski and Buszewski (2005), higher content of humic acid (9.41% DM) in comparison with this of fulvic one (7.1% DM) is in favour of compost's maturity. In addition, humification index greater than 5 (6.98) reflected a complete compost maturation as reported by Radhouani et al. (2012) for compost of green wastes. These authors have reported that low index of decomposition of chlorophyllous compounds, as in the case of the studied compost, may provide a good level of maturity, too.

3.2 Germination on compost's extract

The germination index, GI, declined significantly (F = 163.58***) for both species as the compost extract concentrations intensified (Fig. 1). This negative correlation was confirmed by R^2 of 0.97 for both species. This effect was found by Abdel-Razzak et al. (2018) for tomato, cucumber, and summer squash when adding higher quantities of tomato waste compost to potting media.

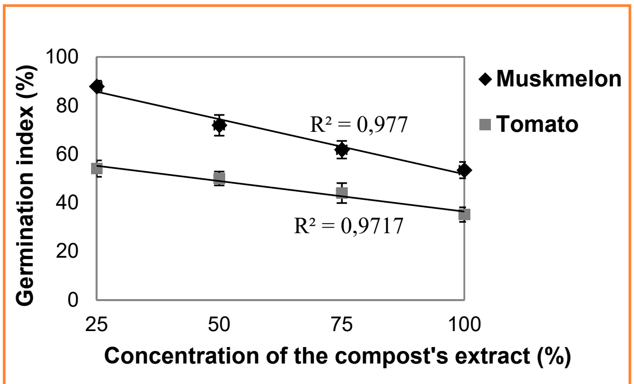

Figure 1 Changes in germination index of muskmelon and tomato at varying compost water extract concentrations (25, 50, 75 or 100%)
Data represent mean ±SE, n = 5

The results were in agreement with studies of Sanchez-Monedero et al. (1999) when using sewage sludge, poultry manure, pig slurry, olive mill wastewater, city refuse and the lingo-cellulosic cotton waste, maize straw and sweet sorghum bagasse composts' extracts. This reduction seems to be the most drastic one for tomato attaining a value of 35.15% with the solution of pure compost's extract. This selective effect was reported by Bernal et al. (1998). Abdel-Razzak et al. (2018) have indicated that it might be a direct consequence of genus-related genotypic effects when comparing cucumber and summer squash tomato's germination.

Zucconi et al. (1985) have reported that a germination index lesser than 50% reflects a lack of maturity of compost. Thus, biological evaluation may provide an acceptable threshold of maturity of compost showing stable chemical and microbiological characteristics with the potential to be used in agriculture without the risk of toxicity and even the lower value recorded for the tomato. This finding can be attributed to the more effective suppression of seed germination and radical elongation of seeds of dicotyledonous species such as tomato by the water compost extract and its sensitivity to the higher electrical conductivity (Lazcano et al., 2009; Ofosu-Budu et al., 2010).

3.3 Direct germination in compost

Among the treatments, the quickest germination was recorded for muskmelon sown in peat (Fig. 2).

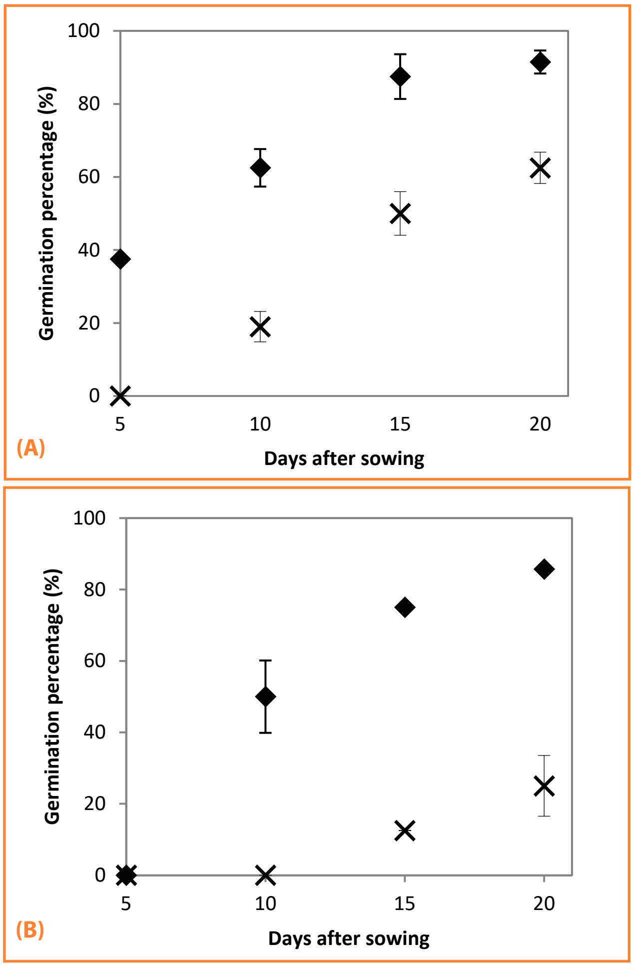

Figure 2 Changes in germination percentage of (A) muskmelon and (B) tomato sown in compost (CP) or peat (P) after 5, 10, 15 and 20 days of sowing
Data represent mean ±SE, n = 5

The delay of germination on compost was recorded by Abdel-Razzak et al. (2018) for tomato, hot pepper, cucumber, and summer squash with higher proportion of tomato waste compost. The lower performance of compost in terms of cumulative germination percentage

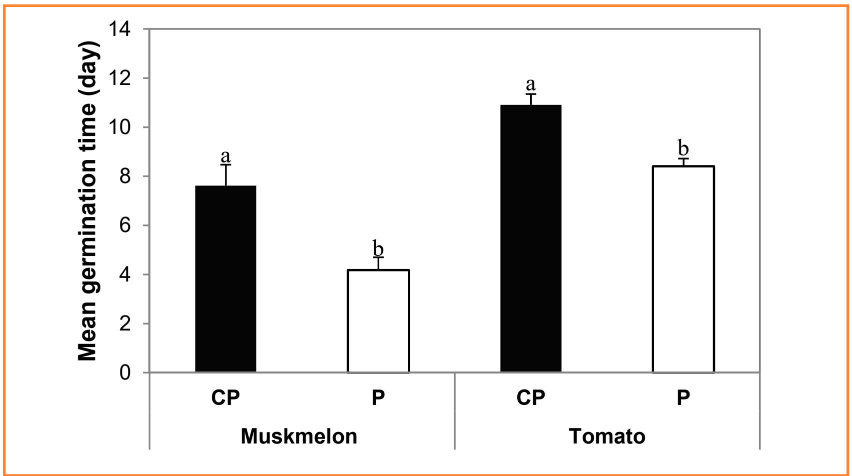

Figure 3 Changes in mean germination time (MGT, days) of seeds of muskmelon and tomato sown in compost (C) or in peat (P)
Data represent mean ±SE, *n* = 5
For each species, different letters above bars are significantly different at *P* <0.05 according to Duncan test

was observed by Herrera et al. (2008), too, on tomato sown in municipal solid waste compost. This attitude resulted from the delay on germination's stimulation as justifies the mean germination time (Fig. 3) and T_{50} values which were of 12.59 and 6.97 days for compost of date palms and peat, respectively (F = 8.74*).

The damping infected seedlings were of 4.1 and 6.2% for muskmelon and tomato, respectively. The delay of seed germination in compost as compared to peat is in accordance with works of Herrera et al. (2008) and Zaller (2007) for municipal solid wastes compost and vermi-compost, respectively. Faster stimulation of the germination's process in peat might stem from its promising total porosity (Table 1) that ensures better water-holding capacity (Abdel-Razzak et al., 2018) and aeration for seeds (Cai et al., 2010; Martin & Brathwaite, 2012).

However, the delay of germination in compost can be attributed to its higher electrical conductivity as explained by Abdel-Razzak et al. (2018) when adding great proportion of tomato waste compost to potting media. Cai et al. (2010), Herrera et al. (2008) and Medina et al. (2009) have confirmed the relationship. Indeed, Unal (2015) reported a suitable value between 2 and 4 $dS.m^{-1}$. The alleviation of this effect can be attributed to the content of Ca^{2+} + Mg^{2+} and humic compounds which help seedlings to tolerate salt stress (Cai et al., 2010) and increase cell membrane permeability, cell division, and cellular enlargement (Gill & Al-Shankiti, 2015), respectively.

3.4 Seedlings' growth

Referring to Table 2 showing the data recorded on seedlings' growth as affected by potting medium, it seems that peat displayed significantly (p <0.001) higher shoot/root ratio. This effect corroborated works of Keeling et al. (1994); Lazcano et al. (2009); Martin & Brathwaite (2012), Unal (2015) and Zaller (2007) for compost of digested slurry of cow manure, vermicompost, cow manure compost, compost of spent mushroom and this of refuse derived, respectively. In contrast, Medina et al. (2009) have noticed lower aerial biomass of tomato and pepper cultivated in peat with respect to those grown in spent mushroom substrate. Ghehsareh et al. (2011) have reported similar effects of white peat and wood fibre substrate for tomato.

Peat has stimulated the elongation of roots by 1.5 and two times for muskmelon and tomato, respectively, in comparison with compost (Table 2). This result contrasted with the work of Unal (2015) on tomato seedlings grown on peat and spent mushroom's compost. This author explained difference between potting media by their acidity specifying that high pH values can impair this development, while Ch'ng et al. (2014), working on maize plants, attributed medium's effect to

Table 2 Changes in some characteristics of tomato and muskmelon seedlings as affected by potting media

Species	Muskmelon		Tomato	
Substrate	**CP**	**P**	**CP**	**P**
Height (m)	0.30 ±0.006a	0.27 ±0.001b	0.29 ±0.01a	0.24 ±0.009b
Shoot dry weight (g)	0.23 ±0.002a	0.21 ±0.001b	0.21 ±0.002a	0.19 ±0.001b
Shoot/Root DW ratio (%)	2.92 ±0.034b	4.07 ±0.098a	2.02 ±0.76b	3.38 ±0.91a
Roots' length (m)	0.06 ±0.001b	0.08 ±0.008a	0.05 ±0.002b	0.09 ±0.002a
Vigour index (%)	28.56 ±2.18a	26.26 ±1.11a	19.39 ±3.94a	21.67 ±1.78a

For each species, means within a row followed by the same letter are not significantly different at the *P* = 0.05 level for the substrate according to the Duncan test. Data represent mean ±SE, *n* = 5 its porosity. In opposition, compost was more suitable for stem elongation, and dry matter's accumulation at the aerial part was more important at compost. Produced muskmelon and tomato seedlings on the two potting media showed statistically similar vigour index (p <0.05) (Table 2).

3.5 Compost's impact in soilless culture system

80 days after transplantation, the compost of date palms was more suitable for muskmelon's stem elongation in correlation with findings of Afriyie et al. (2017) for radish. For tomato, superiority was in favour of perlite (Fig. 4A) in contrast to results of Borji et al. (2010) and Ghulam et al. (2002) who found similar effects of compost of date palm and this of pine bark, respectively, with respect to perlite. Angadi et al. (2017) have noticed longer tomato plants when using organic manure.

For both species, the growth substrate did not result in significant (P = 0.05) effect in plant stem girth (Fig. 4B). This trend was obtained by Borji et al. (2010) on tomato, whereas Ghulam et al. (2002) have noted that tomato plants grown in pine bark's compost reached higher diameter values than those grown in perlite.

In the same context, the results of higher leaf surface area noted on compost for the two horticultural species (Table 3) were noted in previous works of Ghulam et al. (2002) for tomato by comparing compost of pine bark and perlite. Whilst no significant difference was observed for muskmelon's leaf dry mass among media, in tomato, this parameter was higher in perlite (30.22 g) than compost (21.94 g).

Furthermore, the leaves of muskmelon were thicker (low SLA) on compost (1.28 $m^2.g^{-1}$) than those in perlite (153.74 $cm^2.g^{-1}$). Ch'ng et al. (2014) explained this superiority, for compost and biochar, by their richness on functional groups (COOH, phenolic, alcoholic OH and C = O) which served as exchange sites for the crops nutrients. In contrast, leaves of tomato showed higher SLA in compost (142.2 $cm^2.g^{-1}$) than in perlite (111.33 $cm^2.g^{-1}$) (Table 4). Lower surface area seems to be the cause of thick leaves as a positive correlation between them was

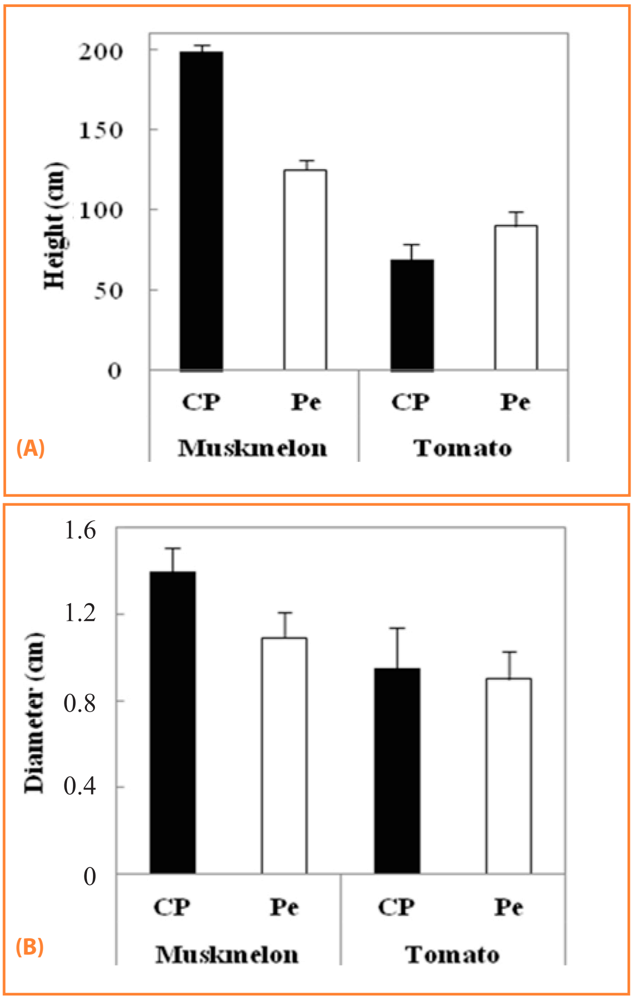

Figure 4 Changes in (A) height (cm) and (B) diameter (m) of muskmelon and tomato plants grown in compost (CP) or in perlite (Pe)
Data represent mean ± SE, n = 5
Different letters indicate significant differences between substrates at P <0.05 according to the Duncan test

established by Herrera et al. (2008). Both species showed higher root dry mass when grown in compost than in perlite (data not shown).

Maturity of muskmelon fruits was three-days earlier in compost than in perlite. This pattern was also marked for tomato. Similar results were found by Tzortzakis and

Table 3 Changes in leaf parameters of muskmelon and tomato plants grown in compost of date palms (CP) and perlite (Pe)

Species	**Muskmelon**		**Tomato**	
Substrate	**CP**	**Pe**	**CP**	**Pe**
Leaf area (m^2)	0.41 ±0.008a	0.31 ±0.005b	0.35 ±0.002a	0.24 ±0.029b
Dry mass (%)	16.68 ±0.08a	14.51 ±0.04a	21.94 ±2.03b	30.22 ±1.43a
Specific leaf area ($m^2.g^{-1}$)	1.28 ±0.01b	1.53 ±0.02a	1.42 ±0.01a	1.11 ±0.03b

For each species, means within a row followed by the same letter are not significantly different at the P = 0.05 level for the substrate according to the Duncan test. Data represent mean ±SE, n = 5

Table 4 Effect of media on gustative quality of muskmelon and tomato fruits.

Parameter	Muskmelon		Tomato	
	CP	Pe	CP	Pe
pH	6.98 ±0.08a	6.66 ±0.02a	4.16 ±0.31a	4.31 ±0.17a
EC (dS.m^{-1})	6.94 ±0.32a	7.18 ±0.4a	7.16 ±0.33a	7.27 ±0.22a
RI (° Brix)	11.8 ±0.65a	10.1 ±0.8a	7 ±0.01a	7.8 ±0.03a
Acidity (%)	1.17 ±0.13a	1.4 ±0.02a	13.62 ±0,31a	14.01a
RI/acidity	10.08 ±0.05a	7.21 ±0.021b	3 ±0.13a	3 ±0.13a

For each species, means within a row followed by the same letter are not significantly different at the $P = 0.05$ level for the substrate according to the Duncan test. Data represent mean ± SE, $n = 5$

Economakis (2005) who noted that plants grew faster in organic media as compared to inorganic ones. In contrast, Olle et al. (2012) reported that cucumber plants developed quicker in perlite or rockwool as compared to coconut fibre.

It should be noted that the heaviest fruits were produced by plants grown in compost and it was even more significant in case of muskmelon. A similar result was obtained by Tzortzakis and Economakis (2005) with compost of maize waste. In contrast, Borji et al. (2010) and Ghehsareh et al. (2011) concluded a significant superiority of perlite with respect to compost of date palms. Such superiority of organic media in comparison to inorganic one was reported by Olle et al. (2012) for seven tomato cultivars grown in coir straw in comparison to rockwool hence it was invalidated by Gąstol et al. (2011) when comparing organic and conventional crops. Higher effect of compost could be explained by the correlation between the fruit size and its degree of hydration (Ghehsareh et al., 2011). Indeed, it was shown that compost enhanced the nutrients availability (Olojugba & Opeyemi, 2020) and improved the plant capability of more nutrients' uptake from the surrounding soil (Olle et al., 2012). These effects were indicated for radish, tomato, and maize, respectively, by Afriyie et al. (2017) and Khan et al. (2017). In the same framework, Islam et al. (2017) have affirmed higher fruits weight of tomato grown in compost and vermin-compost regarding inorganic fertilizers. Indeed, soil fertility affects the movement and uptake of nutrients by roots, and their utilization within plants (Ch'ng et al., 2014).

The data related to qualitative attributes display significant variation among treatments. The greater refractrometric index of tomato fruits produced in perlite was in agreement with works of Borji et al. (2010) but in opposition to results reported by Ghehsareh et al. (2011) who found higher soluble solids of tomato fruits grown in cocopeat in relation to those cultivated in perlite. Gastol et al. (2011) found higher effect of organic media for pear, blackcurrant, beetroot, and celery, and a lower effect for apple and carrot in regarding to conventional ones. For both crops, fruit taste was not affected by the type of growth medium (Table 4). On the contrary, Olle et al. (2012) reported that vegetables grown in organic media could be tastier than those grown in inorganic ones.

4 Conclusion

Positive effects of the only adoption of date palm compost on the germination and plant development were noted in the current research. These effects were similar to or better than those of the used conventional media: peat and perlite. Our results confirmed the beneficial use of both solid and liquid forms of compost for horticultural crops such as muskmelon and tomato.

Thus, considering low cost and great availability of date-palm compost in the south of Tunisia, it appears that it can be employed under geothermal greenhouses. However, further studies and research on alleviation of its salinity should be prepared in order to enhance its effectiveness and avoid environmental risks.

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