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Assessment of the potential of two local composts for seeds germination and vegetable production

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Abstract - Composting is becoming an environmental technique of producing promising organic substrates. In this framework, two local Tunisian composts; compost of date palms (CP) and this of green wastes (CW) were compared to peat and perlite respectively concerning germination and plant growth's attitudes. Two germination experiences of direct sowing and use of compost's water extract applied on muskmelon, tomato and barley seeds suggest that the two composts, namely this of green wastes, can serve as potting media without risks of toxicity. Indeed, they permit the germination of seeds in a rate statistically similar to this of peat even a delay in the process's stimulation which it is reduced with time. Moreover, with a concentration of 100 % compost's extract, the germination index overlaps 50 % that represents the limit of toxicity.
Regarding plant growth's performance, the two composts have permitted the greatest foliar expansion, accumulation of the dry matter yet lower SLA reflecting their thickness.

Keywords: Compost, stability, maturity, germination, plant growth

1. Introduction

In Tunisian nursery, peat is widely used as the potting media despite its expensiveness. Moreover, soilless culture systems are, predominantly, based on artificial substrates. This situation rekindled the search of alternatives within the local, available, renewable and low cost one (Radhouani et al. 2011). Moreover, in an attempt of recycling solid wastes using environmental friendly methods, namely composting, various organic products were formed and reintegrated in husbandry (Bouhouach et al. 2009). Several studies have indicated that various sources and forms of compost can be used effectively as organic support medium and fertilizer source (Perez-Murcia et al. 2006; Bustamante et al. 2010). Likewise, compost displayed a suppressing soil-borne diseases effect (Martin and Brathwaite, 2012).
The principal requirements for compost to be safely used are stability and maturity that refer, respectively, to the microbial biomass activity's level and the plant growth's potential or phytotoxicity (Bernal et al. 2009). Owing to the heterogenic standards of compost quality in the International legislation, numerous analytical methods are adopted. Broadly, these methods are classified into physical (odor, temperature), chemical (C/N ratio, cation exchange capacity, nitrification), microbiological (respiration analysis), spectroscopic (NMR and infrared methods), chromatographic (sephadex fractionation) and biological (germination test, plant growth). It is advisable to employ a compilation of the aforementioned methods (Zmora-Nahuma et al. 2007). Indeed, phytotoxins don't present a permanent state and are produced solely in specific stages of decomposition added to that they lean to be swiftly inactivated and plants' sensitivity tends to be transient (Zucconi et al. 1985). Based on all the previous considerations, this study aims to: i): assess the suitability of two local composts as potting media during germination using muskmelon (*Cucumis melo* L.), tomato (*Solanum* l*ycopersicum* L.) and barley (*Hordeum vulgare* L.) seeds and ii): evaluate their aptness as growing media for greenhouse tomato grown in soilless culture system.

2. Material and methods

2. 1. Growing media

Two composts were considered: compost of date palm (CP) produced referring to the method described by Bouhouach et al. (2009) and this of pure green wastes (CW) gathered from the experimental area of the Dry Lands and Oasiann Cropping Laboratory, Institute of Arid Regions, Medenine as described by Radhouani et al. (2012). Peat and perlite were adopted as references.

2. 2. Media's analyze

Composts were chemically characterized by determining their pH, electrical conductivity (EC), Na, P, K, Ca and Mg using the water extracts 1:5. The content of organic matter was determined by ignition referring to the method of Changa et al. (2003). Nitrogen content, total organic carbon and the content in polyphenols were determined referring to the method described by Bustamante et al. (2008). Physically, they were evaluated by determining their humidity (H), bulk (BD) and particle density (PD), retention of water, total pore space (TPS) according to Verdonck and Gabriëls (1992). The composition on lignin, humic and fulvic acids were determined according to the protocols cited by Albrecht (2007). The humification index was evaluated referring to Zbytniewski and Buszewski (2005). The decomposition on chlorophyll-type compounds (mainly chlorophyll a, chlorophyll b, pheophytin, chlorophyllide, and pheophorbide) was determined by the assay of light absorption of acetone extracts of compost referring to Rajbanshi and Inubushi (1998). The same analyzes was done for peat.

2. 3. Germination trials

The attitude of composts as potting media was evaluated using local Tunisian muskmelon (*Cucumis melo*), tomato (*Solanum lycopersicon*) and barley (*Hordeum vulgare*) seeds. Two experiments were run.

2. 3. 1. Direct sowing

Seeds were sown into cell plug trays having a volume of 17 cm^3 filled with media. The treatments growing media * species; were established in a completely-randomized design with three replicates per treatment (one tray per replication). Germination was performed in an air-conditioned room at a temperature of 27 ± 1 °C and a relative humidity of 90-95%. The number of germinated seeds was recorded at 5, 10, 15 and 20 days after sowing as recommended by Tiquia and Tam (1998). The cumulative percentage of germination (%) (Number of germinated seeds relative to the total number of sown ones), and the rate of germination (%) (Number of germinated seeds at a specific period with respect to the total germinated seeds during the experiment, were calculated. Besides, the mean germination time (MGT) was calculated referring to the equation of Alvarado et al. (1987):

$$\mathrm{MGT} = \frac{\Sigma \mathrm{Ti} \times \mathrm{Ni}}{\Sigma \mathrm{Ni}}$$, where Ni is the number of newly germinated seeds at time Ti

Twenty days after sowing, seedlings' numbers of leaves were counted; shoot height and root lengths were measured, mutual shoot and root's dry matter were weighted and their ratio was calculated. The vigor index was calculated according to ISTA (1996) as following:

$$\text{Seedling Vigor Index (SVI)} = [\frac{\text{Seedling length (cm)} \times \text{Germination percentage (\%)}}{100}]$$

2. 3. 2. Germination on compost's extract

This experiment adopts the germination test settled by Zucconi et al. (1985). Referring to this test, the compost's aqueous extract was prepared by shaking the fresh sample with dionized water at 1:10 (w/v). Serial dilutions of the resulted supernatant with sterile distilled water (SDW) to yield 0, 25, 50, 75 and 100 % were prepared to quantify the strength of phytotoxicity hence the degree of immaturity. Five seeds were placed on filter paper in the bottom of 9 cm diameter petri dishes. The paper was moistened with 2.5 ml of a compost aqueous extract. The dish was sealed with parafilm, to minimize water loss, and placed in an incubator at temperature of 25°C ±1. 2.5 ml of distilled water was considered as control treatment. The test was run in triplicate. 5 days after dark incubation, the numbers of germinated seeds as well as the length of their roots were recorded. Seeds were reckoned germinated when the radical length was at least 2 mm. Relative seed germination, relative root growth and germination index were calculated according to further equations indicated by Tiquia and Tam (1998):

$$\text{Relative seed germination (\%)} = \frac{\textit{Number of seed germinated in the extract}}{\textit{Number of seeds germinated in the control}} * 100$$

$$\text{Relative root elongation (\%)} = \frac{\textit{Mean root elongation in the extract}}{\textit{Mean root elongation in the control}} * 100$$

$$\text{Germination index (\%)} = \frac{(\%\,\textit{Seed germination}) * (\%\,\textit{Root elongation})}{100\%}$$

2. 4. Growing trial

Seedlings of tomato cv “Romana” provided by “Grow Tunisia” society were transplanted in greenhouse on 02/03/2012 adopting an open soilless culture system using the two composts and perlite as treatment control. Plants were irrigated by geothermic water and their fertilization was carried out referring to the composition of water of irrigation and the needs of plant. Plants were run in one stem. One month after transplantation, the stem length and diameter were recorded. The surface area and the leaves’ dry matter content were measured. Photosynthetic rate (A, µmol $CO_2.m^{-2}.s^{-1}$), transpiration rate (E, mol $H_2O.m^{-2}.s^{-1}$) and stomatal conductance (G_s, $mol.m^{-2}.s^{-1}$) were measured on the fifth mature leaf from the top by a portable photosynthesis system as it was recommended by Radhouani et al. (2011). Five plants from each substrate treatment were randomly chosen to measure these parameters between 10:00 and 12:00.

2. 5. Statistical analysis

Statistical analyses were carried out using STATISTICA software. The results were expressed as mean values. The significance of the differences the means of the treatments was assessed using the Duncan post hoc multiple comparison procedure at $P < 0.05$.

3. Results

3. 1. Chemical and hydrophysical characterization of composts

Excepting pH, the three media present dissimilarity in their properties. Indeed, the compost of date palms presents the greatest values of phenolic compounds, nitrogen and electrical conductivity owing to its higher content on mineral elements. Hence, it is the most power substrate on organic matter that the highest value was noted for peat. This last medium was characterized by premium hydrophysical properties. The compost of green wastes showed superiority on lignin’s content (Table 1).

Table 1. Chemical and physical charcaterization of Compost of dry palms (CP), compost of green wastes (CW) and peat.

Parameters		CP	CW	P
Chemical properties				
pH		7.53^{a}	7.15^{a}	6.74^{a}
EC (mS/cm)		7.83^{a}	4.61^{b}	1.22^{c}
%OM		32.84^{c}	40.19^{b}	61.85^{a}
N		1.13^{a}	0.87^{ab}	0.6^{b}
C/N		15.23^{b}	24.21^{a}	26.92^{a}
Mineral composition (%DM)	**Na**	0.52^{a}	0.13^{b}	0.18^{b}
	K	0.46^{a}	0.15^{b}	0.53^{a}
	Ca+Mg	3.23^{a}	1.2^{c}	2.87^{b}
	Cl	0.16^{a}	0.017^{c}	0.04^{b}
Phenolic compounds (mgg/gDM)		1.23^{a}	0.82^{b}	0.094^{c}
A_{665}		0.027^{b}	0.04^{a}	-
Lignin		4.93	6 .36	-
Humification (% DM)	**HA**	9.41^{a}	6.88^{b}	-
	FA	7.1^{a}	5.7^{b}	-
	HI	6.98^{a}	6.35^{a}	-
Hydro-physical properties				
H (% DM)		31.42^{c}	46.19^{b}	62.87^{a}
Porosity (% dry matter)		46.83^{c}	68.36^{b}	84.24^{a}
Bulk density ($g.cm^{-3}$)		0.42^{a}	0.31^{b}	0.26^{b}
Real density ($g.cm^{-3}$)		0.79^{b}	0.87^{b}	1.65^{a}
Retention of water ($ml.l^{-1}$)		352^{b}	391^{b}	430^{a}
Air capacity (%V/V)		19^{c}	27^{b}	35^{a}

3. 2. Media effect on seed germination

3. 2. 1. Direct sowing

Five days after sowing, germination was only observed on peat (for muskmelon and barley) and compost of green wastes for barley (Figure 1).

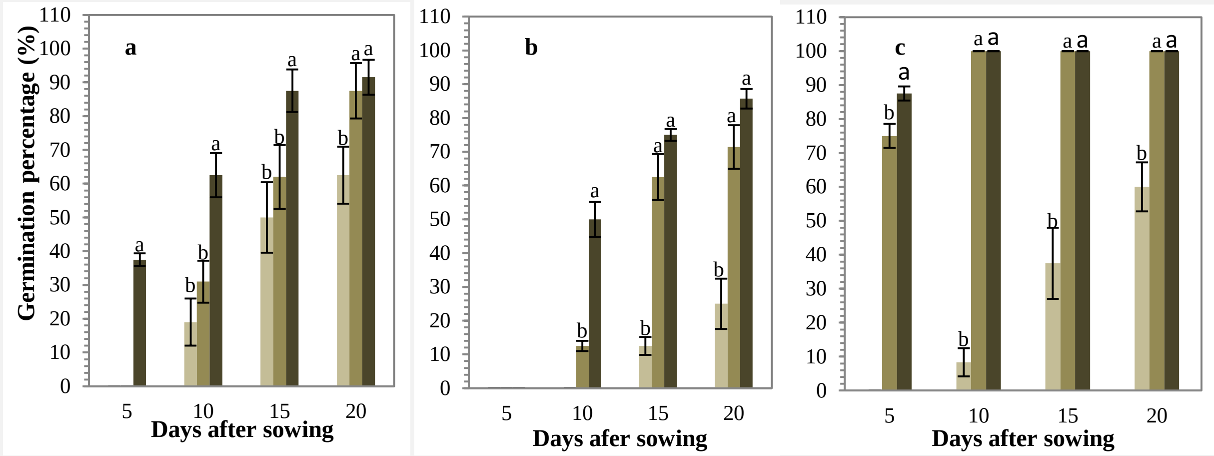

Figure 1. Seeds' germination percentage of muskmelon (a), tomato (b) and barley (c) respectively on compost of date palms, CP, (■), compost of green wastes, CW, (■) and peat, P, (■) throughout 5, 10, 15 and 20 days after sowing.

Vertical bars represent the standard error (*n* = 5). For each seed, values recorded on the three media at the same time and followed by the same letter are statistically similar referring to the test of Duncan at 5%.

The aforementioned treatments have shown the least mean germination times (Figure 2).

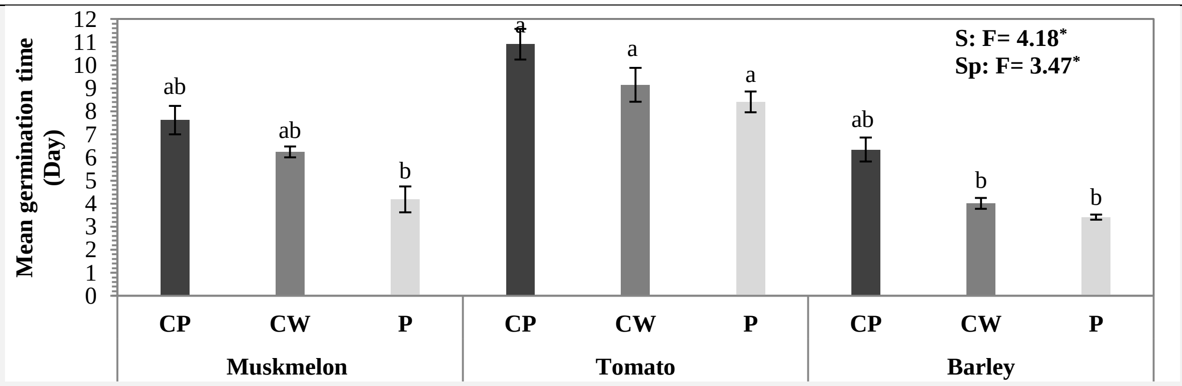

Figure 2. Mean germination time of muskmelon, tomato and barley respectively on compost of date palms (CP), compost of green wastes (CW) and peat (P).

Vertical bars represent the standard error (*n* = 5). Average values followed by similar letter are statistically homogenous referring to the test of Duncan at 5%. The effect of medium (M), species (S) and their interaction M*S was estimated by both F-values and level of significance (* *P* <0.05, ** *P* <0.01, *** *P* <0.001).

Other treatments have started the germination with a delay that was the most drastic for tomato grown on compost of date palms. From the 15nd day onwards, the discrepancy between media was allayed namely between peat and the compost of green wastes (Figure 1).

3. 2. 2. Germination on compost's extract

For the three species, the increase of the concentration of compost's extract has diminished the germination index. This effect was affirmed by the statistical significance of F values of concentration (Figure 3 a) and the regression's coefficient, R^2, comprised between 0.97 and 0.99. The same effect was noted for the two others germination's parameters that the root elongation (Figure 3 b) was more hampered than the relative seed germination (Figure 3 a).

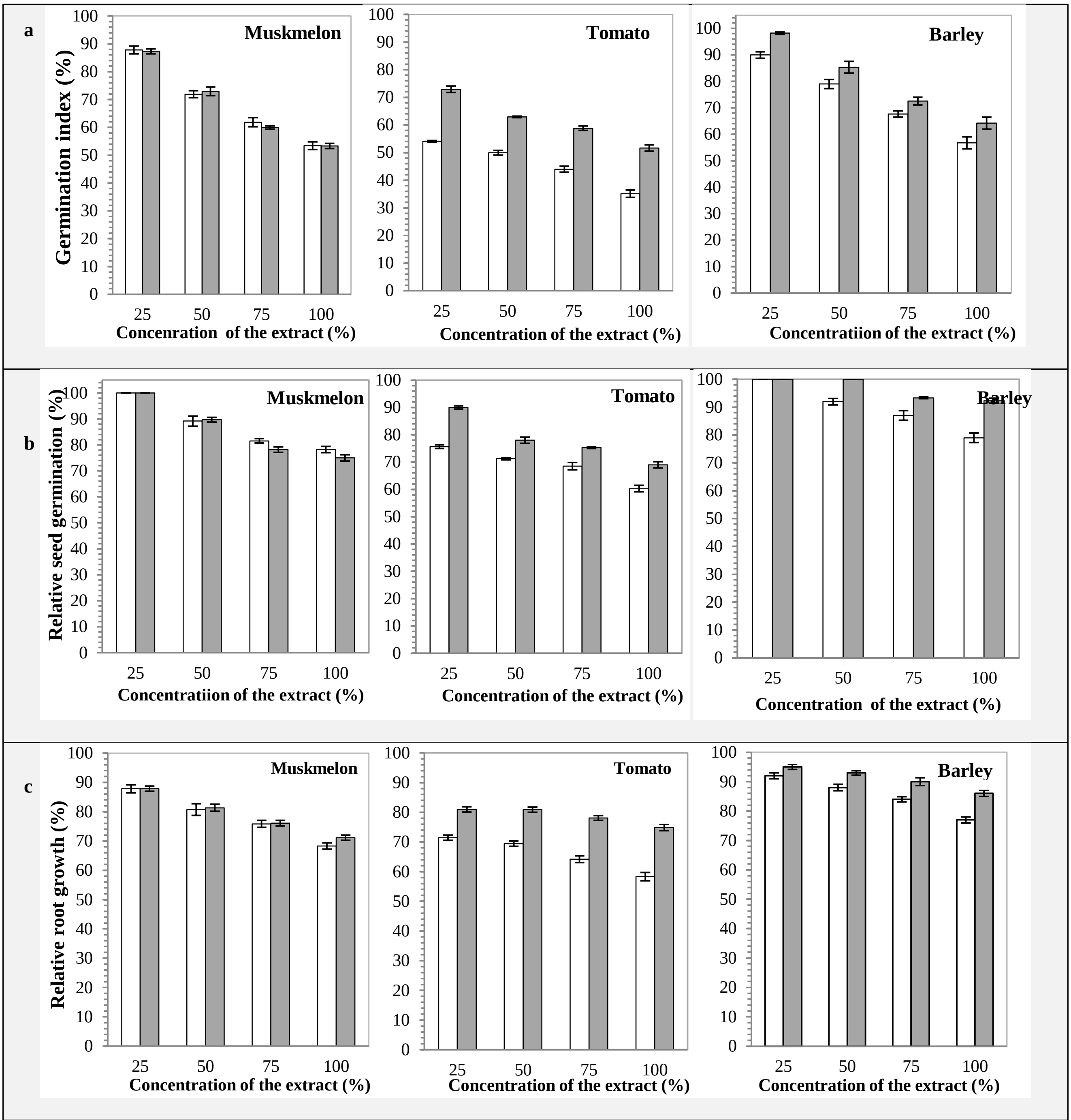

Figure 3. Germination index (a), relative seed germination (b) and relative root growth (c) responses to increasing concentration of compost's extract of green wastes (□) and this of dry palms (□).

Vertical bars represent the standard error (n = 5).

For the three seeds, the reduction of the germination's parameters was more drastic for compost of dry palms than this of green wastes. The discrepancy was perceived among seeds too. Indeed, barley showed the best attitude by establishing, for 100% of the compost extract, a germination index higher than 50% that represents the toxicity limit as postulated by Zucconi et al. (1985). However, tomato's germination was the most impaired by the increment of the concentration of the compost's extract (Figure 3).

3. 3. Growing trial

Data illustrated in Table 2 showed that the adopted substrates have a similar effect on the stem's diameter. Excepting this parameter, a discrepancy was remarked for the elongation of the plants in favor of perlite. Moreover, for the leaves' growth, the two composts namely this of dry palms stimulated the foliar expansion and the accumulation of the dry matter. However, leaves of plants grown in perlite had lower surface area yet greater content in dry matter and lower SLA reflecting their thickness. This substrate has privileged the assimilation rate, gas exchange and the synthesis of chlorophyll pigments hence it impairs the transpiration rate.

Table 2. Tomato growth attitude on compost of dry palms (CP), compost, of green wastes (CW) and perlite (Pe).

	CP	CW	Pe
Plant height (cm)	$60.6^{b}\pm 2.01$	$69.8^{ab}\pm1.15$	$75.13^{a}\pm 1.22$
Stem diameter (cm)	$0.55^{a}\pm 0.18$	$0.6^{a}\pm 0.39$	$0.56^{a}\pm 0.14$
Leaf area (cm^2)	$35.68^{a}\pm 2.1$	$29.64^{ab}\pm 1.87$	$24.97^{b}\pm 2.97$
Leaf dry matter percentage (%)	$21.94^{b}\pm 2.03$	$16.85^{c}\pm 1.28$	$30.22^{a}\pm 1.43$
SLA (cm^2/g)	$142.2^{b}\pm 0.85$	$156.89^{a}\pm 1.11$	111.33^{c} (2.73)
Ch a ($mg.g^{-1}$ fresh matter)	$1.22^{b}\pm 0.032$	$0.98^{c}\pm 0.038$	$1.53^{a}\pm 0.22$
Ch b ($mg.g^{-1}$ fresh matter)	$0.89^{b}\pm 0.045$	$0.52^{c}\pm 0.024$	$1.13^{a}\pm 0.54$
Carotenes ($mg.g^{-1}$ fresh matter)	$0.32^{b}\pm 0.063$	$0.33^{b}\pm 0.024$	$0.54^{a}\pm 0.087$
A (µmol $CO_2.m^{-2}.s^{-1}$)	$10.84^{b}\pm 1.05$	$12.71^{a}\pm 0.76$	$15.03^{a}\pm 0{,}006$
G_s (mol CO_2. $m^{-2}.s^{-1}$)	$0.16^{c}\pm 0.002$	$0.25^{b}\pm 0.022$	$0.33^{a}\pm 0.014$
E (mol CO_2. $m^{-2}.s^{-1}$)	$3.66^{b}\pm 0.13$	$6.11^{a}\pm 0.37$	$2.14^{c}\pm 0.65$

For each parameter, values followed by the same letter are statistically similar referring to the test of Duncan at 5%.

4. Discussion

Referring to Cai et al. (2010), the three substrates seem to be suitable for using as potting media owing to their pH values comprising between 6 and 8. The two composts presented promising levels of both maturity and stability deduced from their C/N ratios varied from 15 to 25 as confirmed by Rosen et al. (1993). Moreover, their H_A/F_A ratios greater than 1 and humification indexes higher than 5 reveal, respectively, advanced humification and maturity referring to Zbytniewski and Buszewski (2005). Their lower indexes of decomposition of chlorophyllous compounds, interpreted from their A_{665} values, postulate a good decomposition as reported by Rajbanshi and Inubushi (1998).

Peat has faster induced the seeds' germination in comparing to the two composts and tended to swiftly accomplish this process. Indeed, for the three species seeds sown in peat, the greatest portion of germination was implemented all through the first ten days after sowing period (data not shown). The faster germination of peat comparing with this of composts was established versus vermicompost by Zaller (2007) for tomato cv. *Rheinlands Ruhm* and Herrera et al. (2008) for tomato sown in municipal solid waste compost. This behavior can be explained by its promising hydrophysical properties (Table 1) as bulk density, total porosity and readily available water which favored considerably this process (Cai et al. 2010; Martin and Brathwaite 2012). However, Martin and Brathwaite (2012) have reported the similarity of peat with compost for tomato and watermelon sown in yard trimming-grass clipping compost.

From the 15^{nd} days after sowing onwards, the composts, namely this of green wastes, have presented a germination percentage statistically similar to this of peat. Thus, it seems that the superiority of peat was due to a delay of germination on composts rather than its hindrance as it was adopted by Keeling et al. (1994) in justifying the superiority of peat regarding the refuse derived compost. As the same, the induction of germination delay without affecting the final germination percentage was reported by Perez-Murcia et al. (2006) for lettuce grown in household waste compost and by Herrera et al. (2008) for tomato cultivated in municipal solid waste compost. This delay can be explained by their higher electrical conductivity (Table 1) which impairs germination *via* its osmotic stress and nutritional disorder as it was reported by Herrera et al. (2008) and Cai et al. (2010). This explanation is confirmed by the least germination percentage recorded for tomato (Fig 1) seeing its salt sensitivity namely in the seedling stage as it was reported by Medina *et al*. (2009). These last authors have found, even, a curtailment of the germination percentage for tomato and pepper grown in spent mushroom compost having higher electrical conductivity. The mitigation with time of the germination's hindrance, namely for the compost of green wastes, can be justified by their significant content on $Ca^2 + Mg^2$ (Table 1) that help plants to tolerate salt stress as it was mentioned by Cai et al. (2010). Moreover, it can be explained by an adaptation of seeds to salinity as it was noted by Zucconi et al. (1985). In addition, their great contents on polyphenols (Table 1) can lessen, too, the germination as it was enunciated by Zucconi et al. (1985).

The reduction of germination without being hindered reflects low levels of toxicity as it was indicated by Tiquia and Tam (1998) and Teaca and Bodîrlau (2008). The lesser sensitivity of seeds germination in relation to the root elongation agrees with findings of Teaca and Bodîrlau (2008). The stronger lessening of the germination index by the compost of date palms than this of green wastes can be attributed to its higher

electrical conductivity (Table 1) as reported by Perez-Murcia et al. (2006). The best performance of barley could be attributed to its higher food reserves (root crop) that contribute to enhance its behavior regarding salinity and toxicity in relation to leafy plants with lower food reserves such as tomato (Cheung et al. 1989). Indeed, referring to the limit of compost's toxicity settled by Zucconi et al. (1985), tomato seed germination seems being damaged by higher concentration of compost's extract. Moreover, Khan et al. (2007) have indicated that the water-compost extract has a more effective suppression of seed germination and radical elongation of dicotyledonous species, such as tomato, than monocotyledonous ones like barley.
The similarity of the effect of perlite in relation to the two composts concerning the stem's diameter was indicated by Borji et al. (2010) too regarding to two date-palm substrates (one produced without fermentation period; another formed further to fermentation one). The works of these authors confirmed the aforementioned superiority of perlite concerning the height of the plants and justified it by its better aeration that enhances the root oxygen demand and eventually permits more absorption of water and nutrients. This result agrees the findings of Radhouani et al. (2011) for muskmelon plants cultivated on perlite and compost of dry palms. These last authors found for muskmelon, too, the inferiority of perlite's effect on surface area regarding this of compost of dry palms. This lower surface area is the cause of thick leaves on perlite. Indeed, Herrera et al. (2008) have established a positive correlation between the surface area and thickness. This thickness seems being attributed to lower transpiration rate and higher assimilation one which is favored by higher gas exchange, and expressed by greater content in chlorophyll pigments. The best assimilation rate of perlite in relation to composts can be justified by its higher availability of water (due to its promise hydrophysical properties especially porosity) as it was proved by Nguyen et al. (2012).

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