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ORIGINAL RESEARCH

Application of different doses of compost as a substitution of the commercial substrate in nursery for pepper and tomato seedlings

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Abstract

Purpose The decreasing number of peatlands has driven the search for new cultivation substrates. The aim of this study was to evaluate the use of different composts as growing media in the production of vegetable seedlings (pepper and tomato).

Method Composts were produced from: discarded carrots (ZC), fats (FC), and biosolids (BC) from the dairy industry. They were used as peat substitutes in different doses depending on the germinating species: control (CS-commercial substrate) and three growing media prepared with perlite: 25, 35, and 45% of ZC, FC, and BC for pepper seedlings and 40, 55 and 70% of ZC, FC, and BC for tomato seedlings. When the plants were ready for transplantation they were harvested and the data were collected to assess the development of the seedlings in the different growth media.

Results The obtained results suggest the possibility of total substitution of the CS by ZC, FC, and BC to produce pepper and tomato plants in commercial nurseries. The plants cultivated with composts presented higher concentrations of total dry matter compared to the controls. Photosynthetic pigments were affected by the presence of FC and BC, whereas TSP concentration was favored by BC.

Conclusion Ours results suggest that it is feasible to perform a total substitution of commercial substrates with composts of different origins and compositions for the production of pepper and tomato plants in commercial nurseries.

Keywords Compost, Growing Media, Tomato, Pepper, Nursery

Introduction

One of the fundamental pillars on seedlings production at seedbeds is the use of good quality substrates, since both during germination and the first stages of development the seedlings are sensitive to different environmental factors such as water, air and nutrients supply (Zhang et al. 2020). The substrates usually used to produce vegetable seedlings are *sphagnum* peat, coconut fiber, perlite,

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and vermiculite to promote aeration and humidity. Costs of these materials are a limitation as well as the fact that peat is a non-renewable natural resource, whose exploitation and commercialization causes the destruction of peatlands (Nocentini et al. 2021). In addition, peatlands are protected, so their use should be gradually reduced. In this way, in the last years, attempts were made looking for sustainable alternatives that are environmentally friendly and that allow the restoration of deteriorated soils, such as the reuse of organic wastes in the formulation of growing substrates (Manca et al. 2020; Bustamante et al. 2021; Nocentini et al. 2021; Przemieniecki et al. 2021). Numerous studies have been reported on the possible use of various wastes of urban, agro-industrial or agricultural origin as substrates to replace peat in the production of vegetable seedlings (Fiasconaro et al. 2015; De Corato 2020a; Stewart-Wade 2020 a, b).

The most frequently detected problems related to the use of compost as growing medium for vegetable plantlets comprises the presence of organic phytotoxins, high electric conductivity (EC) due to the incidence of elevated concentrations of soluble salts, excess of ammonium and deprived physical properties caused by low aeration or reduced water retention capacity (Pascual et al. 2018; Stewart-Wade 2020 a, b; Bustamante et al. 2021). However, vegetable discards and animal manures are appropriate materials for producing suitable composts and subsequently can be used for agricultural purposes (Afonso et al. 2021; Shafique et al. 2021). Likewise, the recycling of organic wastes leads to a decrease in the volume of wastes disposed in sanitary landfills (Gavilanes-Terán et al. 2017; Rashid and Shahzad 2021).

The final disposal of organic wastes in landfills generates methane gas that can contribute to the greenhouse effect and causes odor and leachate problems. The disadvantages of this conventional method of final disposal have prompted the agricultural, industrial and waste management sectors to work on sustainable solutions to manage this biodegradable waste with reduced pollution (Chia et al. 2020). In this regard, composting technologies can constitute a viable and ecologically friendly alternative for putrescible organic wastes management in emerging countries, due to its economic, rapid and easy execution (Rashid and Shahzad 2021). Composting can play a key role in the bioeconomy towards the best environmental sustainability by transforming agro-wastes into profitable resources (De Corato 2020a). Furthermore, reusing organic wastes by composting could be even more economical than landfilling, if municipalities take into account the true environmental cost of waste disposal rather than recycling (Keng et al. 2020). In addition, with this process, a product of high added value is obtained that can be securely utilized as a soil restorer or, if its quality is high enough, as a substitute (partial or total) for peat in germination and seedbed growth. The application of good quality organic amendments could be considered as an adequate strategy to raise the carbon content and improve soil fertility and productivity, simultaneously contributing to the reduction of greenhouse gas emissions related to wastes (Sujatha et al. 2021). Furthermore, organic farming is also an effective tool to manufacture good quality agricultural products. In the last years, many studies have shown that soil amendment with compost increased soil fertility, microbial activity, pathogens' suppression and plant growth of different crops (Milinković et al. 2019; De Corato 2020a,b; Ortega et al. 2020; Sujatha et al. 2021).

Production of vegetables in trays is a practice commonly used by horticultural producers, with the aim of obtaining fast and uniform seedling emergence under suitable growth conditions. Cultivation from seedlings has many advantages including earlier harvest and a more efficient use of resources such as land, time, seeds, herbicides, among others (Pascual et al. 2018). There is a wide range of published research works that study the partial replacement of peat with different composts as growing media in seedbeds. For instance, Herrera et al. (2008) used different doses of municipal solid waste compost in tomato germination, and then mixed this component with peat in order to prepare appropriate substrates for tomato seedlings. Carmona et al. (2012) applied de-alcoholised grapevine marc and grape stalk as a partial substitute of peat for growing lettuce, tomato, pepper, and melon. They concluded that these composts lacked of phytotoxic behavior or nitrogen immobilization. Moreover, chemical properties of compost and their partial mixtures with peat did not seem to be restraining factors for their use as growing medium. Likewise, Gavilanes-Terán et al. (2017) and Jara-Samaniego et al. (2017) published satisfactory results regarding the partial replacement of peat with compost obtained from organic residue in the cultivation of tomato, pepper and courgette. Also, Fiasconaro et al. (2015) showed that using fat compost for the growth and development of nursery-produced pepper plantlets produced seedlings resistant to transplantation with good fruit production. In all the exposed cases, the highest replacement dose consisted in using up to 75% of compost. Shafique et al. (2021) used different doses of vermi-compost on seed germination and development of Tagetes erectus. They obtained satisfactory results using 20% of compost for seed germination and 35% for plant growth and flowering. Finally, they concluded that vermi-compost could be used as bio-fertilizer for marigold production. Afonso et al. (2021) evaluated the mixture of hop leaves with cow manure for producing a stable compost that can be used in horticultural crops, irrespective of the proportion of raw materials. Bhunia et al. (2021) evaluated the organic amendment from slaughterhouse waste residues (manure, blood, rumen) obtaining favorable results in the yield of the pepper crop. Likewise, the yield of amaranth amended with slaughterhouse waste doubled the yield of the control. They concluded that recycled slaughterhouse wastes promoted healthy growth of plants and abundance of soil beneficial microbes. It is important to highlight that those multiple studies have evaluated the use of different organic residues as possible substitutes for peat. However, the information available on the utilization of carrot residues compost, as well as composts obtained from residues of the dairy industry (fats and biosolids) as an alternative for the total replacement of peat for the production of horticultural crops in nurseries is still scarce. Consequently, the objective of this research was to evaluate the use of different composts as the sole growing substrate in the production of vegetable seedlings. The physical-chemical quality of the organic amendments produced from different wastes (discarded carrots, and fats and biosolids from the dairy industry) was determined. The characterized residues were used to grow two horticultural species (tomato and pepper). The main characteristics of the horticultural species such as foliar pigments and primary metabolites were studied to evaluate their growth and development in the different selected substrates.

Material and methods

Composts obtaining and characterization

The three studied composts were obtained from the aerobic co-processing of: (i) carrot wastes from a packing plant located in Santa Rosa de Calchines (Santa Fe province, Argentina) where the selected carrots were washed and packed, and those that were not complied with the market requirements were discarded, (ii) fats from a Dissolved Air Flotation process (DAF) and (iii) biosolids, both were obtained from a local dairy industry in Rafaela (Santa Fe province, Argentina). The composting process was performed in windrows using green grass and wood chips as the base mixture, and carrot waste (ZC), fats (FC) and biosolids (BC) as co-substrates. The proportions of co-substrates: wood chips: green grass were 54%: 28%: 18% (w/w/w). The composting process lasted 2 months for ZC and 6 months for FC and BC until the utilization of the organic amendment. During the thermophilic period, the windrows were homogenized manually. The thermal stability was reached after 12 days for ZC and after 20 days for FC and BC. During the composting process, moisture was kept in the optimal range for microbial metabolism (55-60%) (Ceglie et al. 2015). All composting processes were performed at room temperature ranging between 15°C and 25°C.

The main properties of carrot compost (ZC), fat compost (FC), biosolids compost (BC), and the commercial substrate (CS) are shown in Table 1. The pH and electrical conductivity (EC) were measured following Chan et al. (2016) with modifications. Determinations were made in an aqueous solution (1:10 w/v) using a HACH multimeter (Hach HQ30d). Nitrogen content was determined in dried samples by using the Kjeldahl method. Potassium (K), Magnesium (Mg), Calcium (Ca) and Sodium (Na) were extracted using HCl and HNO_3 following the methodology proposed by Alaboudi et al. (2018) and then analyzed by atomic absorption spectrometry (Perkin Elmer AAnalyst 800). Organic matter (OM) was determined according to Eid et al. (2019) by dry combustion at 550°C during 4 hours. The total organic carbon was determined from OM using a correlation factor (Barrington et al. 2002). Phytotoxicity test on the different composts consisted in a germination test utilizing radish (*Raphanus sativus* L.) seeds. The seeds were placed in Petri dishes with 7 ml of ZC, FC and BC extract or CS extract and germinated in the dark for 5 days at 25°C. The germination index (GI) was calculated as follows (Zucconi et al. 1981; Fiasconaro et al. 2019):

$$GI(\%) = \frac{RSG \times RRG}{100} \quad (1)$$

$$RSG(\%) = \frac{Number\ of\ seeds\ germinate\ in\ treatment}{Number\ of\ seed\ germinate\ in\ control} \times 100 \quad (2)$$

$$RRG(\%) = \frac{Average\ root\ length\ of\ seedling\ in\ treatment}{Average\ root\ length\ of\ seedling\ in\ control} \times 100 \quad (3)$$

Table 1 Properties of the studied composts

Parameter	CS	ZC	FC	BC
pH	6.25±0.12c	8.26±0.10a	7.45±0.11b	6.51±0.12c
EC (dS m^{-1})	0.61±0.04c	4.43±0.10a	3.72±0.08b	3.58±0.08b
$N_{kjeldhal}$ (%)	0.92±0.01b	2.36±0.04a	2.35±0.03a	2.28±0.06a
K (g kg^{-1})	12.5±3.02c	623.66±15.01b	775.40±19.21b	966.60±15.62a
Mg (g kg^{-1})	2.22±0.94d	4.76±1.52c	187.10±7.69b	271.10±4.25a
Na (g kg^{-1})	4.01±0.9c	40.95±2.47b	83.80±3.05a	84.30 ± 5.87a
C (%)	25.41±1.10b	34.27±3.45a	32.70±4.57a	26.56±1.05b
OM (%)	45.73±3.57b	61.7±4.58a	58.87±5.69a	47.80±1.98b
C/N	27.62±0.9a	14.52±1.22b	13.91±1.77b	11.65±0.15b
GI (%)	165.04±9.25a	112.85±12.57b	133.9±10.25b	88.95±5.26c

Carrot compost (ZC), fat compost (FC), biosolids compost (BC) and the commercial substrate (CS). Values are means (n=3) ± standard error (S.E.).

Experimental design

An experiment was designed to evaluate the use of carrot compost (ZC), fat compost (FC) and biosolids compost (BC) as nursery amendment on pepper and tomato seedlings. For the pepper experiment, the three composts were mixed with perlite at different proportions: 25%, 35%, and 45% (w/w). For the tomato experiment, the percentages were 40%, 55%, and 70% (w/w). The control treatment consisted of a commercial substrate (CS). The different doses of compost used in this study were calculated based on the tolerance to salinity of the plant species, taking into account the optimal EC for growth and yield and the EC of the growth substrate. Cultivated tomato is considered as a moderately sensitive crop to salinity, able to tolerate electrical conductivities up to 2.5 dS m^{-1} without affecting growth and yield (Gómez-Bellot et al. 2021). Dissimilarly, pepper has a threshold value for soil salinity (EC) of 1.5 dS m^{-1} (Özdemir et al. 2016). Three trays of 36 cells were used for each treatment. One seed per cell was sowed and the trays were distributed randomly in three blocks. Irrigation was done with tap water and no fertilizer was applied. The growth-period lasted 45 days. The experiment was carried out under greenhouse conditions. Data were analyzed by groups of nine plants per treatment.

Plant determinations

The emergence of pepper and tomato plants was examined on alternate days. Seedlings were counted 20 days after sowing following the results published by Herrera et al. (2008). Rates of emergence were calculated using a modified Timson's emergence velocity index (Al-Ansari and Ksiksi 2016). The plants were harvested when the seedlings reached the commercial transplanting size (45 days). After the harvest, the height of the seedlings, stem diameter, dry and fresh weight of the different organs were determined (Fiasconaro et al. 2015). The specific leaf area (SLA) and leaf area ratio (LAR) were calculated as the ratio of the leaf area to leaf dry matter (DM), and the ratio of the leaf area to plant DM, respectively. Leaf samples of each plant were stored at -80°C until analysis.

Chlorophylls, total soluble sugars (TSS) and total soluble proteins (TSP) were quantified following Fiasconaro et al. (2019). Leaf chlorophylls were extracted in 95% (v/v) ethanol and their concentration was quantified in a spectrophotometer (Perkin Elmer Lambda 35. UV/VIS, Spectrometer). Calculations were made using the equations of Lichtenthaler (1987). TSP were analyzed by the protein dye-binding method using bovine serum albumin as a standard. TSS in leaves and roots were analyzed by reacting 0.25 ml of the extracts with 3 ml of freshly prepared anthrone solution and placing it in boiling water for 10 minutes. After cooling, the absorbance at 620 nm was determined spectrophotometrically.

Statistical analysis

Statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS) (SPSS Inc., Chicago, IL, USA) version 15.0 for Windows. Means± standard errors (S.E.) were calculated. All data were subjected to a two-factor analysis of variance (ANOVA) to assess the main effect of the factors plant species (S) and treatment (T) and the interaction between them (S×T). When ANOVA was statistically significant ($P<0.05$), the differences among groups were tested with a Duncan test post-hoc test. Results were considered statistically significant if $P<0.05$.

Results and discussion

Compost properties and germination assay

Table 1 shows the different properties of the substrates used as growth media: fat compost (FC), carrot compost (ZC), biosolids compost (BC) and commercial substrate (CS). It is observed that the pH values of CS and BC are slightly acidic (6.25±0.12 and 6.51±0.12, respectively), while ZC and FC present basic pH (8.26±0.10 and 7.45±0.11, respectively). This parameter is important because it affects the mobility and availability of nutrients. Even though different authors affirm that it is not possible to establish the ideal qualities of the substrates for the cultivation of horticultural species since each plant shows their optimum pH value (Pascual et al. 2018; Roehrdanz et al. 2019), it is known that the ideal pH ranges between 5.2 and 7 (slightly acidic). The EC of the three composts used as growth medium (ZC 4.43±0.10 dS m^{-1}, FC 3.72±0.08 dS m^{-1} and BC 3.58±0.08 dS m^{-1}) was notably higher than the control (CS 0.61±0.04 dS m^{-1}), in accordance with the results published by Herrera et al. (2008). The findings suggest that this fact only affected the germination and growth of the seedlings that received BC as substrate. The N content was higher in ZC, FC and BC than in the control substrate (CS). The same behavior was observed when analyzing the concentrations of K, Mg and Na in the organic amendments. However, the differences found in OM between the studied growth media (CS, ZC, FC, BC) showed only a slight difference. The C/N ratio is widely used as an indicator of the maturity and stability of organic matter. All the composts used (ZC, FC, BC) presented a low C/N ratio, indicating a good state of maturity and stability. This observation coincides with the low C/N ratio values found in the municipal solid waste compost presented by Herrera et al. (2008). Massa et al. (2018) found that, when compared to peat, the incorporation of compost from different origins and in different concentrations in the growing media presented a lower C/N value. C/N ratios below 20 are considered appropriate for the production of nursery plants, while values above 30 could exhibit phytotoxic effects (Zucconi et al. 1981; Pascual et al. 2018).

Among the parameters analyzed to evaluate the phytotoxicity of composts, the GI is the most frequently used, it is also directly associated with the maturity of the compost. GI values higher than 80% suggest that the substrate is free of phytotoxins, and it could be considered fully mature. On the other hand, composts with GI values lower than 60% would indicate an incomplete stabilization and its application could be harmful to the crop (Zucconi et al. 1981). The outcomes of the germination test (Table 1) show that the highest germination index was that of CS (165.4%), the lower percentages being those of ZC (112.85%) and BC (88.95%). Likewise, all the germination rates indicated the absence of potentially toxic and harmful substances for germination. The composts studied (ZC, FC, BC) presented GI values higher than those reported by Zucconi et al. (1981) as optimal. This would suggest that the organic amendments used in this study lacked substances that could harm the germination and correct development of the roots of the seedlings.

When the germination percentages of pepper and tomato plantlets were evaluated, significant differences were observed on the treatments modified with biosolids compost (BC) when compared to the rest of the treatments (Table 2). Said treatment presented the lowest values of germination percentage. In Table 2, the ANOVA analysis of two factors shows significant differences between species ($P<0.05$) in the percentage of germination as well as among the applied treatments ($P<0.001$). Furthermore, it could be observed that there is a significant difference in the interaction between species and treatments, which could imply that each species has a particular response to the applied treatment ($P<0.01$). This is shown graphically in Fig. 1, where the application of BC decreases the germination percentage of pepper and tomato in direct response to the increasing dose.

On the other hand, in the ZC and FC treatments, no significant differences were observed, the germination percentage being similar between the different applied doses of both composts on pepper and tomato. In both cultivated species, pepper and tomato seedlings, significantly lower emergence rates were observed in the treatments where BC was applied (3.45 plants day $^{-1}$ for pepper and 2.09 plants day^{-1} for tomato) (Table 2). Different studies indicated that low pH and EC improve germination conditions in nurseries (Herrera et al. 2008; Pascual et al. 2018). Nevertheless, our data show that, although BC was the amendment with the lowest pH and EC, the germination percentage and emergence index were lower than those exhibited by the other composts tested. The high concentration of K in the BC (966.60±15.62 g kg^{-1}) substrate could explain this result (Table 1), because it would delay the imbibition time of the seedlings (Ruttanaruangboworn et al. 2017). This observation is in accordance with other studies (Mininni et al. 2013; Gavilanes-Terán et al. 2017; Jara-Samaniego et al. 2017), showing that high concentrations of salts were responsible for the low germination percentages and seedling development delay of different crop species, such as tomato and pepper.

Table 2 Germination characteristics from pepper and tomato seedlings grown in perlite amended with different composts

Variables	**Rate of emergence (n°. plants day^{-1})**	**Germination (%)**
Pepper		
CS	4.51±0.1a	90.3±1.39a
ZC	4.61±0.21a	92.1±4.16a
FC	4.35±0.25a	87.0±4.96a
BC	3.45±0.5b	69.0±10.10b
Tomato		
CS	4.17±0.31a	83.3±6.36a
ZC	4.51±0.05a	90.3±0.92a
FC	4.33±0.20a	86.6±4.1a
BC	2.09±0.55b	41.7±11.0b
ANOVA		
Species (S)	*	*
Treatment (T)	***	***
S×T	**	**

Carrot compost (ZC), fat compost (FC), biosolids compost (BC). A commercial substrate (CS) was used as a control treatment.Values represent means±S.E (n=27). For each plant species, the data of all doses have been joined evaluating the effect of the compost type as the main factor. Within columns and plant species, means followed by the same letter do not differ significantly (P≥0.05) according to Duncan's test. Significance of the analysis of variance (ANOVA): *P<0.05; **P<0.01; ***P<0.001; ns, not significant (P≥0.05).

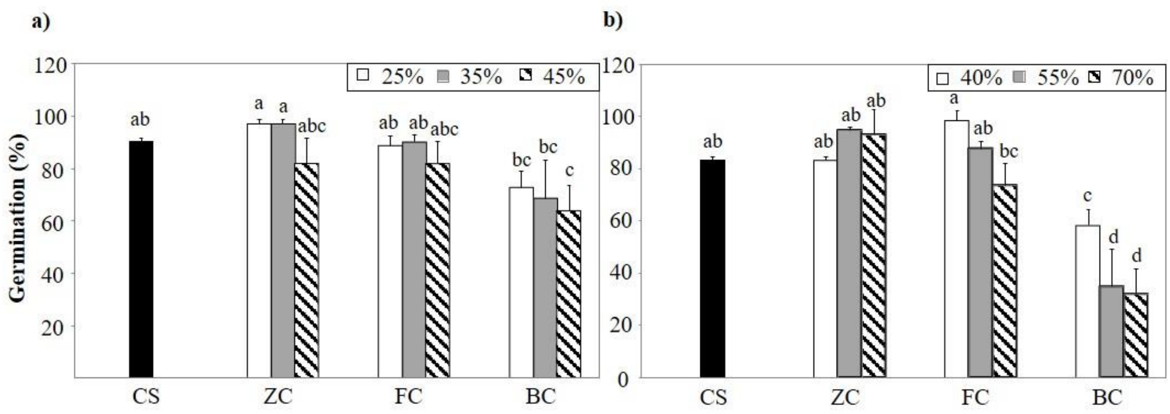

Fig. 1 Percentage of germination of a) pepper and b) tomato seedlings grown in perlite amended with different doses of compost

Carrot compost (ZC), fat compost (FC) and biosolids compost (BC). A commercial substrate (CS) was used as a control treatment. Values are means ±S.E. (n=9). Bars topped by the same letter do not differ significantly (P≥0.05) according to Duncan's test.

Use of different composts as nursery amendment on pepper and tomato seedling

Growth and some leaf characteristics

One of the purposes of any mixture of substrates used to produce horticultural seedlings is to obtain good plant quality during the shortest period and at the lowest production costs possible (Pascual et al. 2018). The effect of compost amendments on plant growth characteristics is shown in Table 3. Results show that all composts tested improved plant DM production, being this effect higher in plants grown with BC. Pepper seedlings cultivated with BC reached a production of 0.6 g plant^{-1} DM, while tomato seedlings produced 0.40 g plant^{-1} DM. The significance in the interaction term of the factors (species and treatment) indicates that the effects of different composts on root growth, plant DM and root/aerial part ratio (R/AP) differed by species. In pepper, the leaf area was increased by the application of ZC and BC, whereas in tomato, a positive effect was only detected in BC amended plants. Overall, the impact of composts was higher on leaf area than in plant DM, which resulted in a reduction on the leaf area ratio (LAR). The LAR index represents the relationship between the photosynthetic and the respiratory parts of the plant. This parameter is also used to evaluate the resistance of seedlings at the time of transplantation (Herrera et al. 2008). The specific leaf area (SLA) index symbolizes the relative proportion of assimilator tissues to the conductor and mechanical tissues. This index evaluates the resistance to transplant stress, which is intensified as the SLA declines, suggesting higher susceptibility to the transplant of pepper grown under BC media (Herrera et al. 2008). Our results of both indexes in pepper plants grown in FC coincide with that published by Fiasconaro et al. (2015). Likewise, they are in concordance with Herrera et al. (2008), the addition of carrot compost (ZC) did not produce significant differences in SLA of the pepper and tomato seedlings.

Table 3 Plant growth of pepper and tomato seedlings grown in perlite amended with different composts

Variables	Leaf area (cm^2 $plant^{-1}$)	Plant DM (g $plant^{-1}$)	Root DM (g $plant^{-1}$)	R/AP (g g^{-1})	SLA (cm^2 g^{-1} DM)	LAR (cm^2 mg^{-1} DM)
Pepper						
CS	42.81±5.45 c	0.12±0.012c	0.14±0.00b	1.16±0.15a	776.1±30.15a	0.048±0.01 b
ZC	64.1±4.31b	0.21±0.02b	0.04±0.00c	0.31±0.07b	817.0±33.39a	0.076±0.01a
FC	38.3±4.04c	0.30±0.03b	0.16±0.01b	1.39±0.19a	805.3±57.39a	0.034±0.00c
BC	81.7±9.35a	0.60±0.06a	0.25±0.01 a	1.08±0.20a	739.0±45.16b	0.025±0.00c
Tomato						
CS	21.7±3.54c	0.12±0.02c	0.02±0.00b	0.37±0.11b	411.5±15.45b	0.102±0.01a
ZC	64.1±4.31b	0.17±0.01bc	0.03±0.00b	0.26±0.05b	817.0±33.39a	0.077±0.01b
FC	53.2±3.91b	0.21±0.02b	0.02±0.00b	0.10±0.01c	812.9±76.43a	0.029±0.00c
BC	91.5±12.54a	0.40±0.05a	0.14±0.01a	0.56±0.08a	787.4±48.54a	0.030±0.001c
ANOVA						
Species (S)	ns	***	***	***	ns	**
Treatment (T)	***	***	***	***	**	***
S×T	ns	**	***	***	**	**

Carrot compost (ZC), fat compost (FC), biosolids compost (BC). A commercial substrate (CS) was used as a control treatment.

Values represent means S.E (n=27). For each plant species, the data of all doses have been joined evaluating the effect of the compost as the main factor. Within columns and plant species, means followed by the same letter do not differ significantly (P≥0.05) according to Duncan's test. Significance of the analysis of variance (ANOVA): **P<0.01; ***P<0.001; ns, not significant (P≥0.05). DM: dry matter; R/AP: root/aerial part; SLA: specific leaf area; LAR: leaf area ratio.

The influence of the doses applied to plant growth significantly differed according to the compost and plant species studied (Fig. 2). Increasing doses of ZC reduced leaf area and plant DM and increased LAR similarly in both species. However, increasing doses of FC affected in a different way in each plant, stimulating plant DM with low R/AP in pepper, and increasing leaf area in tomato (from 37 to 78 cm^2 $plant^{-1}$). Also, increasing doses of BC enhanced leaf area and plant DM with low R/AP in pepper, whereas an opposite effect on the plant DM was detected in tomato plants. Plant DM values varied from 0.47 to 0.63 g $plant^{-1}$ for pepper, and from 0.52 to 0.33 g $plant^{-1}$ for tomato seedlings, when the doses were increased. In this case, the stimulating effect of BC on plant DM has been reduced when increasing the doses applied. Coinciding with other authors (Gavilanes-Terán et al. 2017; Jara-Samaniego et al. 2017), we have found an increase in tomato and pepper plants biomass production in the different treatments when using compost as the main component of the germination substrate. This fact could be attributed to the greater content of nutrients in the different composts (Table 1). St. Martin et al. (2014) applied two types of compost (banana leaf compost and grass trimmings compost) as partial substitutes in seedlings of pepper and tomato. Conversely, they found that the dry weight of root, stem, leaf and total dry matter of both pepper and tomato were lower in plants grown in compost substrate than those that grew in the control (commercial substrate). Bernal-Vicente et al. (2008) demonstrated that citrus composts amendments produced significantly higher melon plant weights than the control. These differences could be ascribed to the increased nutrients content of this substrate in comparison with the control treatment (peat).

The effect of compost amendments on leaf pigments and primary metabolites is exhibited in Table 4. Results show that all composts tested reduced the concentration of chlorophyll and carotenoids in leaves of both plant species. The ratio chlorophylls/carotenoids evidenced the selective effects of composts in the pigment composition of leaves of each species (S×T, $P<0.001$). In fact, chlorophyll content was more affected than carotenoids in pepper plants grown under FC amendments, but the opposite trend was detected in BC-treated tomato plants. The content of total chlorophylls in leaves is directly influenced by the increase of nutrients in the substrate (Khan et al. 2019; Zhang et al. 2021). In our case, a decrease in the concentration of total chlorophylls can be seen in the leaves of plants treated with compost (Table 4, Fig. 3). Likewise, significant effects are observed in the interaction of the species used and the compost applied (S x T, $P<0.01$). The composts studied here contained K and N in concentrations higher than the control, which would exhibit problems related to the availability of the above mentioned nutrients or to their absorption by the plants. Nitrogen favors the absorption of Mg, which influences the synthesis of chlorophyll (Ahmed et al. 2020; Farhat et al. 2016). Thus, one of the most significant factors that could indicate the efficiency of fertilization by nitrogen is the content of photosynthetic pigments in the leaves (Bassi et al. 2018). Carmona et al. (2012) reported that the concentrations of chlorophylls in the vegetables grown with compost (a mixture of dealcoholized vine pomace and grape stem) were greater or equal than in those grown in peat. In our case, this statement was partially reflected since this coincides with those observed in ZC for tomato, but that was not the case for FC and BC treatments (Table 4).

Concerning total soluble sugars, BC and FC application produced significant increases in their concentration whereas ZC reduced the content of sugars in leaves of pepper and tomato. Finally, the concentration of total soluble proteins was reduced by FC and BC applications in pepper seedlings, but no significant changes were detected in tomato. The influence of the applied compost doses on leaf composition is presented in Fig. 3. Overall, increasing doses of ZC did not modify leaf characteristics of pepper and tomato plants. However, plants showed significant reductions in the concentration of total soluble sugars when grown with increasing doses of FC. In the case of BC, increasing doses of this amendment augmented the concentration of total soluble sugars in pepper leaves, but no significant variations were detected in the case of tomato. The foliar concentrations of both primary metabolites showed substantial differences in plants grown in ZC, which could indicate a possible nutritional deficiency. Concentrations of Total chlorophylls, TSS and TSP could be strongly related to fertilization (Khan et al. 2019; Abrile et al. 2021; Zhang et al. 2021). The decrease in the concentrations of these organic molecules is correlated to the degree of inhibition of photosynthesis as a consequence of deficient nutrition.

Gavilanes-Terán et al. (2017) stated that the emergence of tomato and pepper seedlings exhibited a depletion of approximately 50% in most of the growing media, possibly due to the high salinity of these substrates. According to Fiasconaro et al. (2015), the application of compost produced improvements in the quality of pepper seedlings. Stages of germination, growth and transplantation can be directly affected by different soil conditions such as temperature, water content, and oxygen availability. These three stages of horticultural species development and growth are crucial when evaluating the yield and production of the crops (Finch-Savage and Bassel 2016; Pascual et al. 2018).

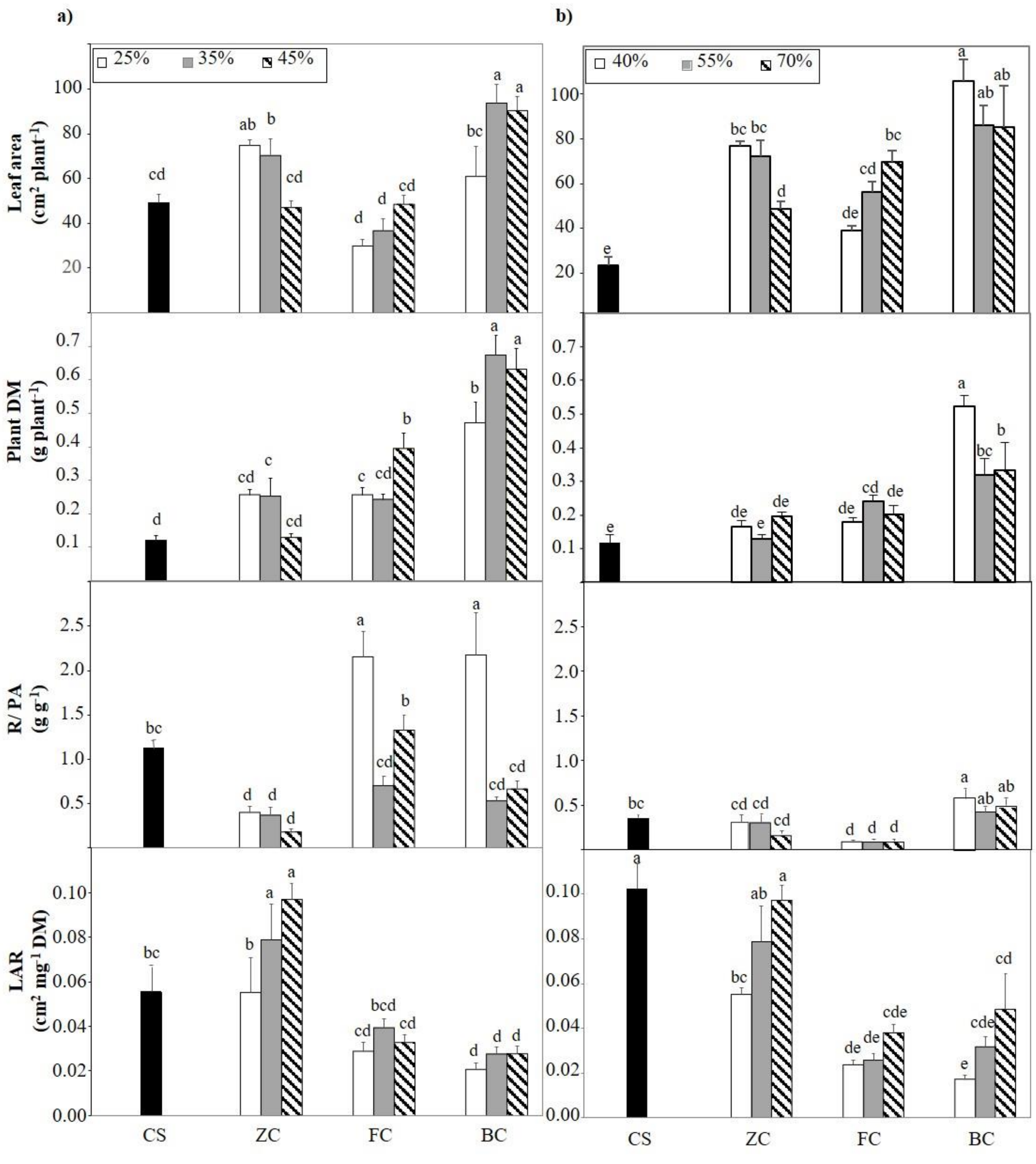

Fig. 2 Some plant growth parameters of a) pepper and b) tomato seedlings grown in perlite amended with different doses of compost

Carrot compost (ZC), fat compost (FC) and biosolids compost (BC). A commercial substrate (CS) was used as a control treatment. Values are means ±S.E. (n=9). Bars topped by the same letter do not differ significantly (P≥0.05) according to Duncan's test.

Conclusion

The formulation of the growing substrate in seedbeds results in the fundamental importance for the germination, growth and subsequent transplantation of the crops**.** Our experiments confirmed that the use of composts obtained from putrescible organic wastes such as carrot discards, fats and biosolids from the dairy industry are a sustainable and economically viable alternative to the use of peat as growing substrate in greenhouse horticultural crops. The use of this type of product would allow the reduction of costs in commercial substrates and fertilizers due to its nutritional effects. Our results suggest that it is possible to perform the total substitution of the commercial substrate (based on peat) with composts of different origins and compositions for the production of pepper and tomato plants in commercial nurseries. Likewise, this study shows that it is necessary to improve some aspects of the obtained product (such as the salt content) to optimize horticultural production of pepper and tomato plantlets. It is important to highlight that for the ZC treatment, a continuous experiment was carried out in pots until fruits harvest, obtaining particularly good results (Fiasconaro et al. 2019). It is considered important to continue this line of research in order to optimize the process of obtaining high quality composts from industrial organic wastes with the purpose of finding the optimal doses to be used as organic amendments.

Table 4 Leaf pigments and primary metabolites of pepper and tomato seedlings grown in perlite amended with different composts

	Total chlorophylls (mg g^{-1} DM)	**Total carotenoids (mg g^{-1} DM)**	**Chlorophylls/ carotenoids (mg mg^{-1})**	**Total soluble sugars (mg g^{-1} DM)**	**Total soluble proteins (mg g^{-1} DM)**
Pepper					
CS	31.33±3.85 a	4.94±0.63a	6.44±0.06a	20.03±7.18c	13.68±3.91 a
ZC	27.68±4.58b	5.01±0.78a	5.50±0.06b	29.74±4.43bc	7.52±6.68b
FC	13.02±1.91c	2.77±0.36b	4.96±0.13c	63.49±12.97ab	14.01±2.01a
BC	16.53±2.29c	3.39±0.69b	5.26±0.16bc	72.83±19.57a	19.81±5.84a
Tomato					
CS	15.18±3.8c	1.95±0.63b	7.78±0.06a	24.02±6.45b	1.32±4.31c
ZC	27.68±4.58a	5.74±0.78a	7.15±0.06ab	26.88±6.53b	5.81±6.70b
FC	18.39±2.53b	2.32±0.52b	6.39±0.58b	60.13±8.23a	10.47±3.02a
BC	21.25±2.21b	2.98±0.31b	7.10±0.09ab	52.56±7.76a	11.70±3.58a
ANOVA					
Species (S)	ns	ns	***	ns	***
Treatment (T)	***	***	**	***	***
S×T	ns	ns	ns	ns	*

Carrot compost (ZC), fat compost (FC), biosolids compost (BC). A commercial substrate (CS) was used as a control treatment.

Values represent means± S.E. (n=27). For each plant species, the data of all doses have been joined evaluating the effect of the compost as the main factor. Within columns and plant species, means followed by the same letter do not differ significantly (P≥0.05) according to Duncan's test. The significance of the analysis of variance (ANOVA): *P<0.05; **P<0.01; ***P<0.001; ns, not significant (P≥0.05). DM: dry matter.

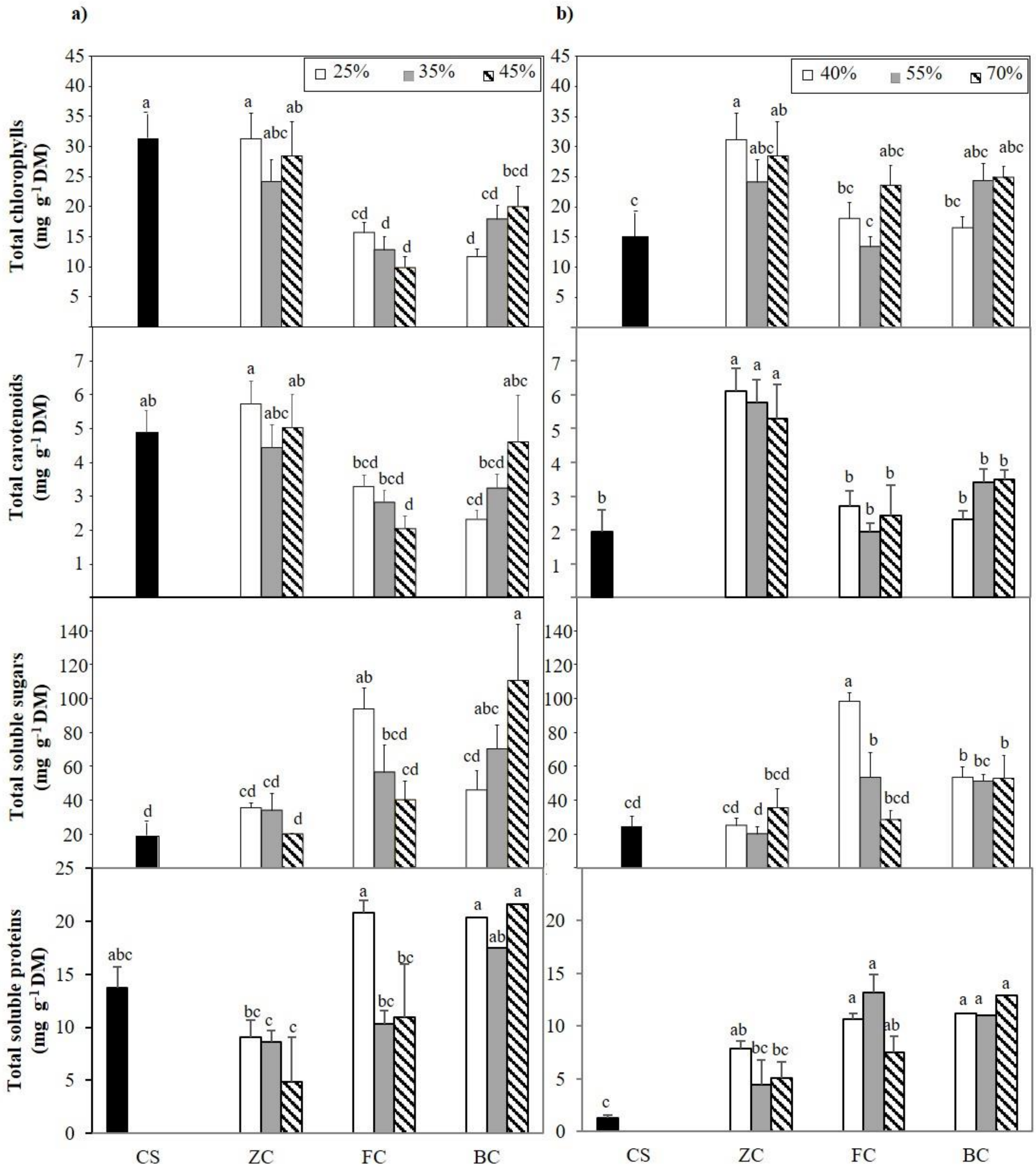

Fig. 3 Leaf pigments and primary metabolites from a) pepper and b) tomato seedlings grown in perlite amended with different doses of compost

Carrot compost (ZC), fat compost (FC) and biosolids compost (BC). A commercial substrate (CS) was used as a control treatment. Values are means± S.E. (n=9). Bars topped by the same letter do not differ significantly (P≥0.05) according to Duncan's test.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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