Evaluation of municipal solid waste compost and/or fertigation as peat substituent for pepper seedlings production

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Abstract

The performance of pepper (*Capsicum annuum* L. cv P14) seed germination and seedling growth using municipal solid waste compost (MSWC) in various proportions was evaluated in nurseries studies. MSWC extracts (10^{-0} up to 10^{-6} dilutions) were evaluated for seed priming/germination in Petri dishes. The MSWC extracts at 10^{-1}–10^{-6} showed similar seedling germination whereas extracts at 10^{-1}–10^{-3} accelerated root radical length compared to the control treatment. However, pure extracts (at 10^{-0}) almost failed seed germination. Under nursery conditions, six substrates prepared from commercial peat MSWC and were further assessed in conjunction with the nutrient application as basic fertilizer (BF) or hydro fertilizer (HF). Seedling growth/development parameters were assessed. The addition of MSWC into peat inhibited seed emergence with increased in the mean germination time, while fertigation accelerated seed emergence at 15% addition of MSWC. Addition of > 30% MSWC reduced seedling height, leaf number and fresh weight. BF and HF increased fresh weight in seedlings grown in 15% MSWC. Leaf Chlorophyll a and total carotenoids content decreased in > 60% MSWC into the peat. The greatest leaf photosynthetic rate were found with the application of HF, while higher leaf stomatal conductance and leaf internal CO_2 concentration were found in plants grown in without fertilizers for both 15% and 45% of MSWC addition. The K content decreased, Na content increased while P content did not differ with MSWC addition. Fertigation improved the seedlings nutritive status. No visual phytotoxicity was observed macroscopically. Low content (15-30%) of MSWC may act as alternative substitute to peat with more positive effects observed if nutrients are provided through HF rather than BF.

Keywords: compost; municipal solid waste; peat; growth; pepper; seed emergence

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Introduction

Recently, growing plants under nursery conditions is an important part of the agricultural industry, and has expanded progressively. Therefore, nursery stock is produced in containers due to market demands and numerous production advantages including greater production per surface unit, faster plant growth, higher plant quality, and lack of dependence on arable land [1]. One of the main challenges of horticultural nurseries is to produce seedlings of high quality with target morphological and physiological features that guarantee crop success and productivity after transplanting. Development of an altered above- and below ground plant morphology during this stage can have consequences for plant growth and health in the field. Survival of newly-planted seedlings is largely dependent on the rapid extension of roots, which reestablish root-soil contact and absorb water to replenish water loss due to transpiration [2]. The morphology of the root system determines the amount of soil that can be exploited by the plants and will therefore influence the uptake of nutrients and water. Similarly, an adequate development of the aerial parts of the plant will determine an efficient photosynthesis and gas exchange as well as the plant susceptibility to attacks by sucking or chewing insects (e.g. leaf thickness).

In Southern Europe, peat usage is the main substrate component for production of seedlings in containers is widely expanded. However, peat is imported from Northern and Central Europe and recently has become more expensive as well as its properties more variable. The need to recycle wastes and increasing environmental pressures against peat extraction leads to an increasing interest in the feasibility of substituting peat by organic wastes and by-products. It is important to look for good quality and locally available low cost substitutes for peat. Several media as potential alternatives have been identified [3-5], and composts derived by different organic materials have proved to be promising [6], attracting researchers interest as well as public acceptances. The use of compost can be an important tool to control soil nutrition status [6-7] and soil-borne pathogens [8]. Certain groups of microorganisms (bacteria and fungi) present in compost produce metabolites, such as siderophores and antibiotics, with specific suppressive activity against soil-borne pathogens: among these compost bacteria, species of *Pseudomonas* and *Bacillus* are very important [8]. However, the use of compost as a substrate component may cause some problems as a consequence of its high salt content [9-10], unsuitable physical properties and variable composition and quality [11]. There is a need to determine the correct amounts of composts to use to improve plant growth [12-13]. Castillo et al. [9] reported that mixtures of compost with perlite may be used as substrates without the need for additional mineral fertilizer, occasionally.

The use of municipal solid waste (MSWC) or sewage sludge composts in agriculture has been increasingly promoted by environmental agencies, preventing landfill disposal and contributing soil organic matter restoration [14]. Benefits of soil application of compost have been attributed to improvement of physical properties; that is, increased water infiltration, water-holding capacity, aeration and permeability, reduction of disease incidence, weed control, or improvement of soil fertility [15]. Therefore, MSWC is suggested that it can be used in agricultural production as an organic soil additive when applied in field, improving soil physicochemical properties, increasing water retention as well as supply with considerable amount of essential nutrients [16-17]. Municipal solid waste as organic material, is approximately 60-90% biodegradable and might be used as a bulking material to absorb excess water, and supply a useful raw product for the horticulture industry [18]. Herrera et al. [19] reported that urban waste compost can be used for tomato (*Solanum lycopersicum* L.) transplant production whereas Avramidou et al. [20] also reported that MSWC can be used for growing media for an energy plant production, such as rapeseed. Pepper (*Capsicum annuum* L.) is also crop that can be started as transplants [18]. However, little information is available regarding the use of MSWC as a peat alternative for nursery production of horticultural crops [13, 21-22]. For each particular compost it is necessary to identify the best amounts for a particular plant growth as there is no one standard growing medium recommended for all container crops under all growing conditions.

Another issue that is of concern, is the fact that MSWC are often characterized by high values of trace elements and heavy metals, due to the inadequate separation of biodegradable fractions from non-degradable or inert materials [23], whereas several studies indicated increased accumulation of Cu, Pb, and Zn in plant tissues [23-24]. Heavy metals are posing great threat to human health. However, trace elements accumulation in plant tissues depends on element availability, which in turn is affected by composting method, soil properties, and plant species/cultivar. Other factors that end-users should consider include increases in soil electrical conductivity (EC) and changes in pH and nitrogen availability [14-15].

A previous study showed that the growth and development of nursery-produced tomato seedlings using a peat+MSWC mixture was similar to that obtained with the standard peat mixture [9], while melon, marigold and basil seedling production benefited with the adding of MSWC into peat [21-22]. The present study sought to evaluate the effect of varying the proportion of MSWC mixed with conventional peat substrates, as a growth medium in the nursery production of pepper seedlings.

2. Material and Methods

2.1 Seed and municipal solid waste compost source

Seeds of pepper (*Capsicum annuum* L. cv P14) were purchased from Agrimore (Agrimore SA, Thessaloniki, Greece) company. Municipal solid waste compost punctuated by Inter-Municipal Enterprise for the Management of Solid Wastes, based in Chania, Greece. The compost used was made from the organic fraction of source separated urban waste and was arranged in piles of 5 m wide of 2.5 m high of 45 m long, which were regularly turned and watered over a 5-6 months period to ensure appropriate composting conditions (turned windrow system). This material was then passed through a densimetric table and a 15 mm trommel screen to remove the largest particles. Almost 60% of compost consisted of particles less than 4 mm size, was considered not appropriate regarding physical properties. Therefore, compost physicochemical and nutritional parameters were measured. The main physicochemical characteristics (in dry weight: dwt) of compost had been described previously [21]. In details the characteristics of compost were pH: 7.7; EC: 17.9 dS/m (1:2.5 v/v); ash content 50.1% dwt; organic matter: 49.9% dwt; organic carbon: 27.2% dwt; N: 1.9% dwt; ratio C/N: 7.1; and total content of P: 164 μg/g; K: 727 μg/g; Na: 403 μg/g, with low levels for heavy metal content.

2.2 MSWC extracts and germination studies *in vitro*

The MSWC extracts were obtained by using a 2 L capacity plastic container, which was filled with MSWC:water (1:1.5) and was shaking for 24 h at ambient temperature. The EC and pH of MSWC extract were evaluated. A series dilutions (MSWC:water at 10^{-0} up to 10^{-6} dilutions) for the MSWC extract was done in the ratios of: 1:0, 1:10, 1:100, 1:1000, 1:10000, 1:100000. For germination tests, air-dried pepper seeds were placed in Petri dishes with filter paper (four replicates/treatment, 25 seeds/replicate) in a completely randomized design under laboratory conditions (average temperatures: 24.2 ± 1.9 ^{o}C max, 21.1 ± 2.1 ^{o}C min) and monitored daily. Filter papers were moistened daily using aliquots (~ 5 mL) of diluted MSWC extract for the six treatments.

Plates moisturised with de-ionized H_2O were used as control treatment. Seeds were considered germinated upon radicle emergence. Mean shoot and root length was evaluated on the eighth day.

2.3 Germination and plant growth studies in nursery tests

A mix of commercial compost peat (Professional peat, Gebr. Brill Substrate GmbH & Co.KG, Georgsdorf, Germany), perlite (Perloflor, Protectivo EPE, Athens, Greece) and MSWC were used in different ratio to create six treatments which were (% v/v): 1) peat:MSWC (100:0) as control, 2) peat:MSWC (85:15), 3) peat:MSWC (70:30), 4) peat:MSWC (55:45), 5) peat:MSWC (40:60) and 6) peat:MSWC (0:100). In order to examine the impact solely of fertigation in seedlings development, a low MSWC (15%) and a high (45%) MSWC content were evaluated in combination with or without fertigation. Thus, additionally to the previous mixtures, four treatments were created 7) peat:MSWC (85:15) with basic fertilizer (BF), 8) peat:MSWC (55:45) with BF, 9) peat:MSWC (85:15) with weekly hydro fertilizer (HF), 10) peat:MSWC (55:45) with HF. BF applied (1.5 kg/m^3) once during the mixtures preparation with 4 times stirrings, before sowing and HF (20-20-20) applied on a weekly basis as nutrient solution of EC 1.8 dS/m. In each substrate medium was added 10% (v/v) of perlite for adequate substrate aeration and drainage.

Pepper seeds were sown (0.5 cm depth; 1.0-1.5 cm between seeds) in plastic seedling trays (5 seeds per module; 4 modules per replication; 5 replications per treatment, 40 cm^3module capacity) on top of the surface of the each medium. The experiment was carried out in a completely randomized design in an unheated glasshouse (temperature: 25.2 ± 5.9 ^{o}C max, 15.2 ± 4.8 ^{o}C min; RH (%): 92.8 ± 1.3 max, 74.6 ± 4.5 min) with alternate-day watering by mist system (initially with 1 min/ 2 h and then up to 1 min/ 5 h).

Over the seedling growth-period in the nursery, no fertilizer was applied; seedling nutritional requirements were thus met entirely by the substrates. Daily observations recorded for seed germination (seeds recorded as emerged when the hypocotyls appeared above substrate medium surface). After 13-days pepper seedlings were thinned to single plant, maintaining 4-5 cm distance among seedlings. Mean germination time (MGT) was calculated as follows [21]:

$$t=\frac{\Sigma ni.ti}{\Sigma n} \text{ (days)}$$

where: t = mean germination time, ti = given time interval, ni = number of germinated seeds during a given time interval, n = total number of germinated seeds.

Seedling growth was assessed by harvesting six individuals/treatment after 28 days. Seedlings were harvested above substrate, the leaf number and height (cm) per seedling were measured from substrate surface, stem diameter (mm) was measured below the cotyledon node, upper fresh weight (g), total dry matter content (%), content (μg/g fresh weight) of chlorophyll a (Chla), chlorophyll b (Chlb) and total carotenoids (Car) determined according to Porra [25]. Leaf fluorescence was determined (chlorophyll fluoremeter, opti-sciences OS-30p, UK) and leaf photosynthetic rate (*p*n), the stomatal conductance (*g*s) and the internal leaf concentration of CO_2 (*C*i) were measured using a portable infra-red gas analyser (model Li-6200, Li-Cor, Inc., Lincoln, Nebr.). Measurements were carried out between 9:00-11:00 a.m., the leaf temperature within the chamber was 28 ± 2 °C, the photosynthetic photon flux density of 1300 μmol/m^2/s at the ambient CO_2 concentration. The Li 6200 was equipped with a leaf chamber with constant area inserts (6.0 cm^2). All gas-exchange measurements were started 3 h after the onset of the photoperiod and were replicated in six plants of each treatment and on two fully expanded, healthy, sun-exposed leaves per plant.

Leaf elemental analysis for potassium-K, phosphorus-P, sodium-Na and nitrogen-N was determined at the end of the experiments. After a hydrochloric acid digestion of the plant sample ash, nutrients analysis for K and Na (photometric; JENWAY, PEP-7 Jenway, Dunmow, UK), P (spectrophotometric; Pye Unicam Hitachi U-1100, Tokyo, Japan) was determined while total N determined by Kjeldahl method.

2.4 Statistical analysis

The experiments were carried out twice. Percentage data were log-transformed before analysis. Data were tested for normality, and then subjected to analysis of variance (ANOVA). Significant differences between mean values were determined using Duncan’s Multiple Range test following one-way ANOVA. Statistical analyses were performed using SPSS (SPSS Inc., Chicago, Ill.).

3. Results and discussion

3.1 Seed germination and emergence time *in vitro*

The C/N ratio is widely used as an indicator of the maturity and stability of organic matter. The compost used in the present study was of good quality with a C/N ratio of 7.1. This low value of C/N ratio in MSWC suggested that compost was stable and mature as indicated by Davidson et al. [26] who reported that composts with a C/N ratio of less than 20 are ideal for nursery plant production. Ratios above 30 may be unstable, as organic matter decomposition is taking place, and due to the toxic minerals (i.e. NH_4^+) production, it might cause plant death [27]. Field studies with MSW, derived from household garbage, horticultural waste, and other organic sources, when applied as soil amendments, have shown that improper MSW maturity can retard germination in direct-seeded crops [28].

Examining pepper seed germination with the MSWC extracts application, seeds first germinated after two days whereas the final germination was obtained before eight days (Fig. 1). The MSWC extracts at 10^{-1}–10^{-6} showed similar seedling germination compared with the control treatment (water) (Fig. 1A). However, pure extracts (at 10^{-0}) lead to almost failed seed germination, which implicated the sensitivity to pepper seeds to salts as is directly related to the high EC and pH values of MSWC extract (EC: 11.21 dS/m; pH: 6.87). Extracts at 10^{-1}–10^{-3} and at 10^{-1} accelerated root radical and shoot length, respectively, compared to the control treatment (Fig. 1B), while pure MSWC extract almost failed germination (Fig. 2).

In previous studies, it was reported that there was no inhibition of germination in case of cucumber seeds in relation to the control treatment when MSWC:water extracts used [Pal and Bhattacharyya 2003], being in accordance with the present findings, probably due to the similar values of EC in both experiments. Recent finding revealed that MSWC may enhance melon seed germination at 10^{-2}-10^{-6} extract concentrations [22], and highlights the importance of the developed seed priming techniques [29]. Similar findings observed in previous studies when olive-mill wastes extracts were used for seed priming procedure in lettuce and radish [4]. Indeed, root length and shoot length suppressed when cucumber seeds were treated with 1:7.5 MSWC:water extracts [30]. The stimulatory effects due to MSWC extract on seed germination may help early seed germination, providing a higher competitive ability [31] and reducing mortality.

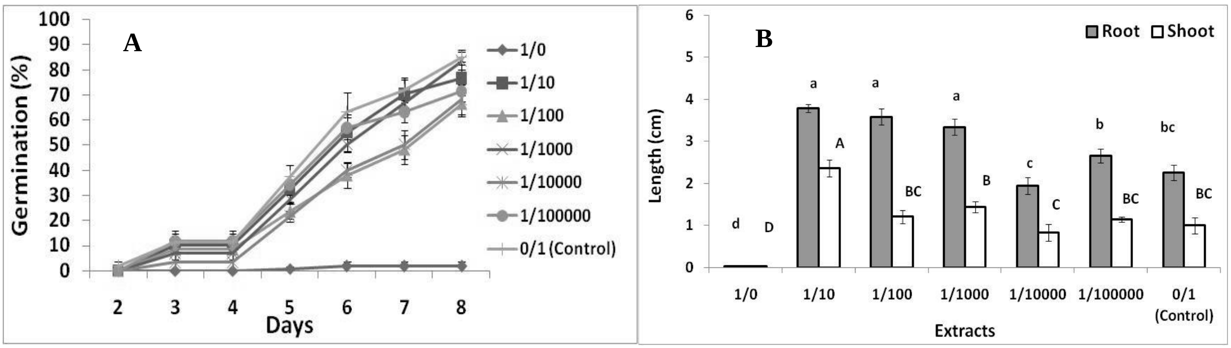


Figure 1. Effects of municipal solid waste compost extracts at concentrations (10^0–10^{-6}) on (A) cumulative seed germination and (B) on shoot and root length of pepper *in vitro*. Values represent mean (±SE) of measurements made on four Petri dishes (25 seeds and five radicles/dish) per treatment. Mean values followed by the same letter do not differ significantly at P=0.05 according to Duncan's MRT.

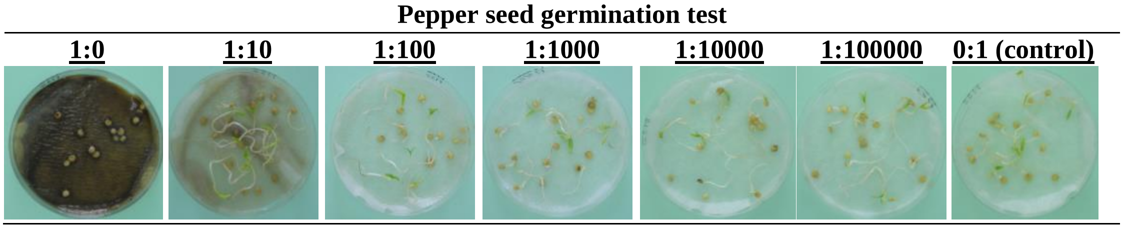


Figure 2. Seed germination test using MSWC extracts at different ratios.

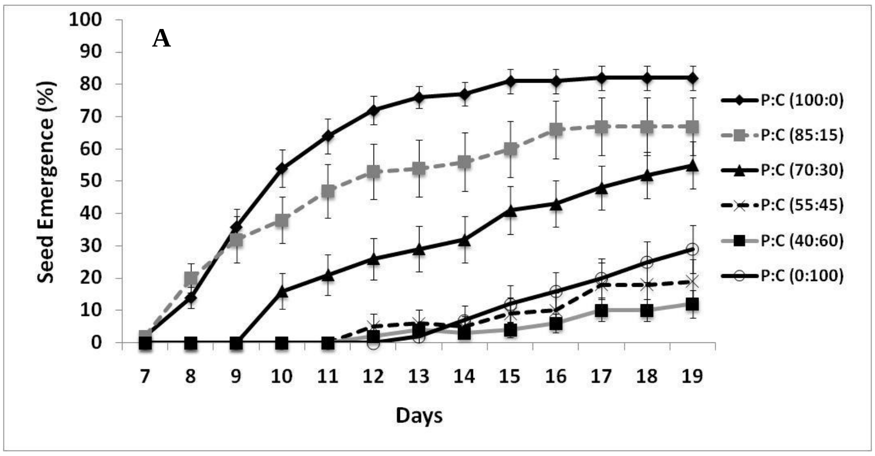
3.2 *In vivo* seed germination and emergence time

The inconsistency in vegetable seedling emergence with the different lots of MSWC could be of great concern to the commercial transplant grower. Delayed emergence can result in uneven plant growth within the tray, and a subsequent reduction in whole tray quality. Retarded emergence may also reduce the number of marketable plants within the tray, requiring over seeding insuring production numbers in accordance with the customer's order.

In the present study, the first germination observed after seven days of sowing while the first true-leaf emerged after 12 days. The MSWC content used into the mixtures as well as the fertigation affected seed germination/emergence (Fig. 3A,B and Fig. 4). The addition of MSWC into the substrate inhibited seed emergence with more pronounced inhibition as MSCW increased into the media. Similar findings were observed in melon seedling production with MSWC in different ratio [22]. In previous studies in basil and marigold, Tzortzakis et al. [21] found that seed emergence was increased in low MSWC (i.e. 15-30%) and this effect did not persist throughout the seedling growth. The application of > 45% MSWC, decreased up to 75% seed emergence (Fig. 3A and Fig. 5). Examining the impact of fertigation, seed emergence was increased when low (15%) MSWC used with BF, while HF did not affect the emergence (Fig. 3B). This beneficial effect of BF in relation to HF or no-fertigation was also evident even at 45% MSWC content. Therefore, when higher (45%) MSWC content used, the weekly fertigation (HF) did not improve seed emergence, adequately, and this is probably due to the high EC value as a result of the higher MSWC content and/or added fertigation (Fig. 3B).

The application of MSWC in different ratios as well as the application of fertilizer affected seed MGT (Mean Germination Time) (Fig. 5A,B). Thus, increased MSWC content (at 30% and >45%) into the peat resulted in MGT increment (up to 3 and 5 days delay, respectively) which is in accordance with previous studies employing MSWC in melon seeds emergence [22]. The addition of fertilizers into the peat with MSWC content did not affect the seed germination/emergence time, supporting the improved nutrition on MSWC itself, and therefore, additional nutrients did not result in any improvement regarding seed emergence. The stimulation of several pre-sowing treatments (hydropriming; halopriming; osmopriming, thermopriming; solid matrix priming and biopriming as reported by Ashraf and Foolad [29] of seed comparing with untreated seeds might be due to altered physiology of embryos and activation of enzymes, so that developmental processes occur more rapidly after sowing [32] and this is possible with the seed germination under MSWC-fertigation enrichment.

Despite the fact that there is no single, ideal growth medium for nursery production for horticultural crops [33], most greenhouse-grown species display better growth at slight acid pH values (5.2–7.0); peat mixtures approached these values but MSWC did not. Thus, further exploitation is needed, in order to identify the type of fertilizer used into the mixtures as it is well known that application may increase (i.e. potassium nitrate) or decrease (i.e. ammonium nitrate) the pH of a medium. As with pH levels, the highest initial substrate EC values were recorded for mixtures containing MSWC. Ribeiro et al. [12] reported that substrates with high EC values reduce water retention, negatively affecting the imbibing process and may delay seed emergence rates, which actually reflected the findings of the present study.



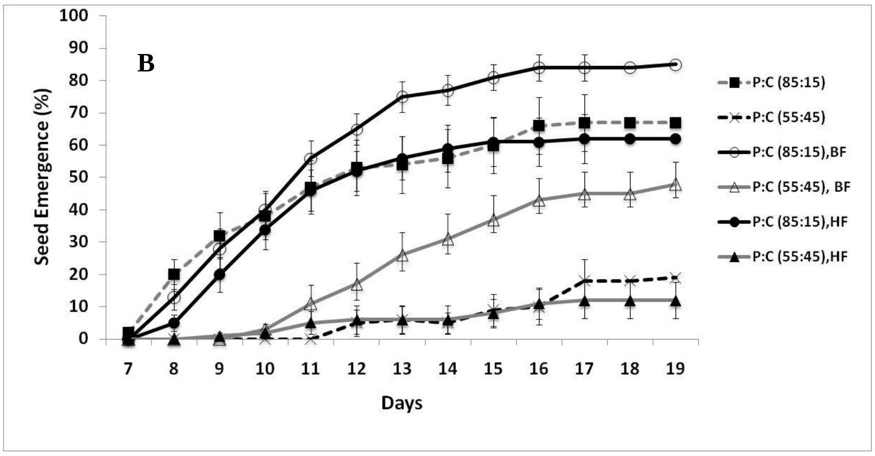


Figure 3. Influence of (A) substrate medium (commercial peat-P, municipal solid waste compost-C) and/or (B) fertigation (basic fertilization-BF, hydro fertilization-HF) on cumulative seedling emergence of pepper seeds germinated in greenhouse nursery. Values represent mean (± SE) of measurements made on 5 independent replication (4 wells per replication; 5 seeds per well) per treatment. Mean values followed by the same letter do not differ significantly at P=0.05 according to Duncan's MRT.

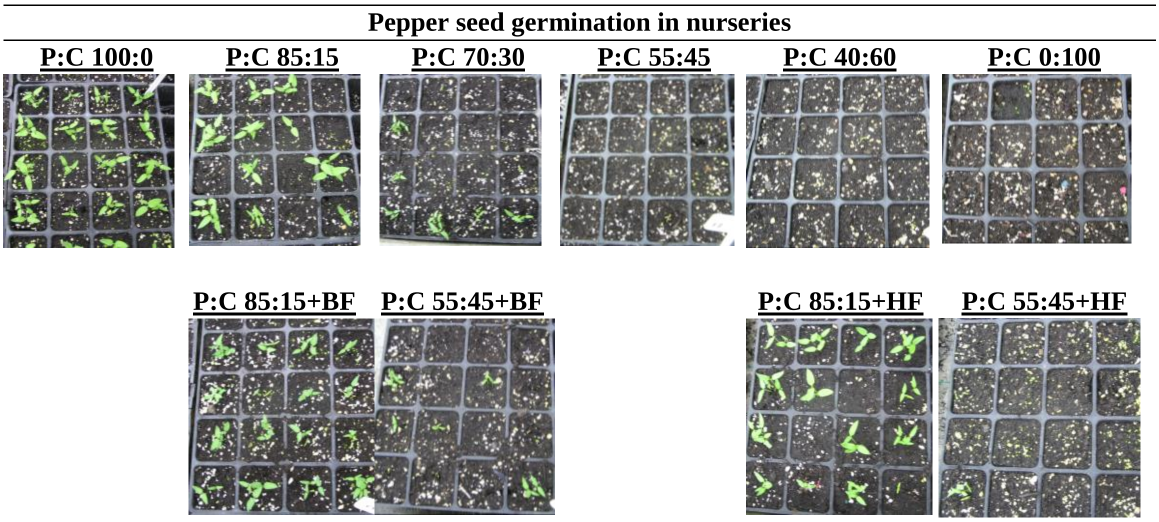


Figure 4. Influence of substrate medium (commercial peat-P, municipal solid waste compost-C) and/or fertigation (basic fertilization-BF, hydro fertilization-HF) on pepper seedling emergence.

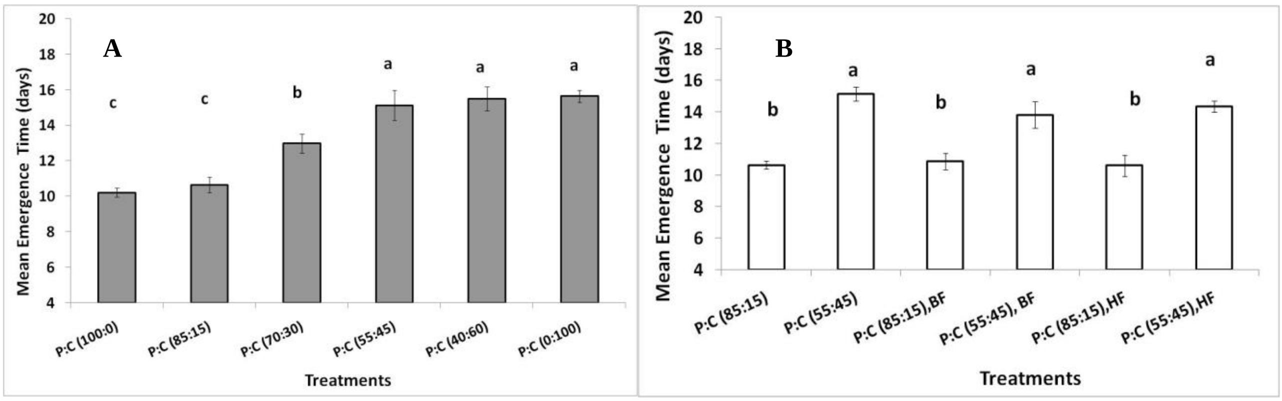


Figure 5. Mean emergence time for pepper in (A) different substrate medium (commercial peat-P, municipal solid waste compost-C) and/or (B) fertigation (basic fertilization-BF, hydro fertilization-HF) under nursery condition. Values represent mean (±SE) of measurements made on 5 replication (4 wells per replication; 5 seeds

per well) per treatment. Mean values followed by the same letter do not differ significantly at P=0.05 according to Duncan's MRT.

3.3 Seedling growth *in vivo*

The impact of fertigation and/or substrate medium on pepper seedling growth is presented in Table 1. Analyses of variance showed that the addition of >30% MSWC in commercial peat significantly decreased (up to 70%) seedling height, whereas the adding of > 45% MSWC decreased the number of leaves produced up to 44%, compared to seedlings grown in control treatment (peat-based substrate). Therefore, the decrease in plant growth parameters recorded in plants grown in >30% of MSWC reflected plant biomass reduction of 46%. Dry matter content was greater in seedlings grown in >60% MSWC. The addition of BF and HF seems to benefit plant growth and biomass only in low (i.e. 15%) MSCW content, as fresh weight in seedlings grown in 15% MSWC was increased. These findings are in agreement with previous studies in cucumber and melon seedlings [18, 22] whereas MSWC increased EC as well as N immobilization and/or decreased N mineralization that were responsible for inhibited growth by constraining N availability in tomato and lettuce crops [17]. Thus, seedlings grown in the MSWC mixtures at high ratios displayed poorer quality and suitability for transplanting, possible due to increased EC and/or change in medium physicochemical properties. Similar findings were observed when compost of high pH and EC was used in tomato seedlings, causing plant damage at the root level and subsequent plant mortality [1]. Seedling resistance to transplant stress is directly related to dry matter content, which improves seedling establishment in the soil or growth substrate [34].

Table 1. Impact of fertigation (basic fertilization-BF, hydro fertilization-HF) and substrate medium (commercial peat-P, municipal solid waste compost-C) on seedling height (cm/plant), number of leaf produced, stem diameter (mm), fresh weight (g/plant), dry matter content (%) on pepper seedlings grown in the nursery.

Mixtures	Height	Leaf No	Stem diameter	Fresh weight	Dry matter
P:C (100:0)	13.60 ^{a,Y}	4.16 ^{a}	2.20 ^{ab}	4.63 ^{a}	8.34 ^{b}
P:C (85:15)	12.60 ^{a,AB}	4.01 ^{a,ABC}	2.41 ^{a,ABC}	4.05 ^{a,B}	7.95 ^{b,B}
P:C (70:30)	9.70 ^{b}	4.00 ^{a}	2.11 ^{ab}	4.20 ^{a}	8.22 ^{b}
P:C (55:45)	4.71 ^{c,C}	2.33 ^{b,D}	2.02 ^{ab,BC}	2.63 ^{b,C}	8.52 ^{b,B}
P:C (40:60)	4.05 ^{c}	2.66 ^{b}	1.86 ^{ab}	2.50 ^{b}	9.01 ^{ab}
P:C (0:100)	4.96 ^{c}	2.83 ^{b}	1.77 ^{b}	2.61 ^{b}	10.37 ^{a}
P:C (85:15),BF	14.93 ^{AB}	4.83 ^{AB}	2.96 ^{A}	4.91 ^{A}	10.28 ^{AB}
P:C (55:45), BF	10.43 ^{BC}	3.83 ^{BC}	1.96 ^{C}	3.55 ^{B}	10.24 ^{AB}
P:C (85:15),HF	17.38 ^{AB}	5.00 ^{A}	2.68 ^{AB}	4.86 ^{A}	11.43 ^{A}
P:C (55:45),HF	8.73 ^{BC}	3.66 ^{C}	2.20 ^{BC}	2.38 ^{C}	9.53 ^{AB}

^{Y} values (n=6) in columns followed by the same small letter are not significantly different, $P\leq0.05$, regarding substrate medium and in columns followed by the same capital letter are not significantly different, $P\leq0.05$, regarding the fertigation impacts.

Several physiological parameters of pepper seedlings were affected by MSWC content (Table 2). In detail, leaf Chlorophyll a and total carotenoids content decreased in > 60% MSWC addition into peat, while the opposite was the effect for Chl b content, with greater values in higher MSWC ratios. Leaf fluorescence was decreased with the additions of MSWC into the substrate. The addition of MSWC in different ratios reflected minor fluctuation in leaf photosynthetic rate and leaf stomatal conductance among treatments. Chl a is actually the primary photosynthetic pigment and Chl b is the accessory pigment that collects the energy to pass on to Chl a. No differences were observed in the leaf stomatal conductance (averaged in 0.206 μmol/m^2/s). Examining the impact of fertigation, the greatest leaf photosynthetic rate were found with the application of HF, while higher leaf stomatal conductance and leaf internal CO_2 concentration were found in plants grown in without fertilizers for both 15% and 45% of MSWC substrates.

Table 2. Impact of fertigation (basic fertilization-BF, hydro fertilization-HF) and substrate medium (commercial peat-P, municipal solid waste compost-C) on leaf fluoresces (Fv/Fm), Chlorophyll a (Chla; μg/g fw), Chlorophyll b (Chlb; μg/g fw), total carotenoids (Car; μg/g fw), leaf photosynthetic rate (P_n: μmol/m/^{2}/s), leaf stomatal conductance (g_s: μmol/m^2/s) and leaf internal CO_2 concentration (c_i: μmol/mol) on pepper seedlings grown in the nursery.

Mixtures	Fluorescence	Chla	Chlb	Car	P_n	g_s	c_i

P:C (100:0)	0.81 ^{a,Y}	57.27 ^{a}	32.39 ^{ab}	30.22 ^{ab}	7.16 ^{a}	0.205 ^{a}	322.5 ^{ab}
P:C (85:15)	0.80 ^{b,A}	57.03 ^{a,A}	27.20 ^{bc,BC}	31.22 ^{a,A}	5.52 ^{ab,BC}	0.209 ^{a,A}	335.2 ^{ab,A}
P:C (70:30)	0.79 ^{bcd}	56.86 ^{a}	27.83 ^{bc}	29.82 ^{abc}	6.38 ^{ab}	0.180 ^{a}	316.8 ^{b}
P:C (55:45)	0.79 ^{bcd,A}	57.43 ^{a,A}	20.03 ^{c,C}	31.11 ^{a,A}	5.13 ^{b,C}	0.184 ^{a,A}	336.7 ^{ab,A}
P:C (40:60)	0.78 ^{cd}	55.15 ^{b}	39.39 ^{a}	27.58 ^{c}	5.68 ^{ab}	0.212 ^{a}	338.7 ^{a}
P:C (0:100)	0.77 ^{d}	55.38 ^{b}	33.24 ^{ab}	28.38 ^{bc}	6.43 ^{ab}	0.243 ^{a}	335.8 ^{ab}
P:C (85:15),BF	0.79 ^{A}	54.62 ^{C}	41.86 ^{A}	27.44 ^{B}	5.82 ^{BC}	0.075 ^{B}	255.3 ^{B}
P:C (55:45), BF	0.80 ^{A}	56.86 ^{A}	27.93 ^{BC}	29.90 ^{AB}	5.72 ^{BC}	0.081 ^{B}	262.2 ^{B}
P:C (85:15),HF	0.80 ^{A}	54.96 ^{BC}	40.48 ^{A}	28.22 ^{B}	8.68 ^{A}	0.104 ^{B}	240.1 ^{B}
P:C (55:45),HF	0.80 ^{A}	56.37 ^{AB}	31.91 ^{B}	31.13 ^{A}	7.61 ^{A}	0.109 ^{B}	270.7 ^{B}

^{Y} values (n=6) in columns followed by the same small letter are not significantly different, $P \leq 0.05$, regarding substrate medium and in columns followed by the same capital letter are not significantly different, $P \leq 0.05$, regarding the fertigation impacts.

Leaf elemental content in pepper seedlings revealed N increase and K decrease with the addition of MSWC into the peat. Thus, leaf N content was increased (up to 24%) and K was decreased (up to 41%) with the addition of 100% MSWC into the substrate. Indeed, Na content was almost three-to-four times greater in seedlings grown in >60% MSWC (Table 3) being in agreement with melon seedling production with the same MSWC [22]. No differences were found in leaf P content. Examining the effect of fertigation in plant leaf elemental content, leaf N content was increased in case of 45% MSWC in combination with fertigation (BF and HF) and 15%MSWC+HF comparied with the relevant control treatments. Na content was increased in 45% MSWC but fertigation seems to alter that increase. Potassium levels were increased with the application of BF or HF at the 15% MSWC, but not at the 45% MSWC, indicating the nutritive enriched medium for the latter. No differences observed in P content among seedlings grown in substrates with different MSWC content and/or fertigation enrichment. Thus, considerable nutritive value was masked due to the combination of MSWC addition and fertigation into the substrates, as well as affected soil properties [16].

Table 3. Impact of fertigation (basic fertilization-BF, hydro fertilization-HF) and substrate medium (commercial peat-P, municipal solid waste compost-C) on leaf elemental (N, K, P, Na) concentration (mg/g fresh weight) on pepper seedlings grown in the nursery.

	N	**K**	**P**	**Na**
P:C (100:0)	13.80 ^{b,Z}	0.245 ^{a}	0.013 ^{a}	0.017 ^{c}
P:C (85:15)	15.96 ^{a,B}	0.182 ^{b,B}	0.009 ^{a,A}	0.018 ^{c,B}
P:C (70:30)	16.19 ^{a}	0.175 ^{b}	0.009 ^{a}	0.027 ^{c}
P:C (55:45)	16.51 ^{a,B}	0.177 ^{b,B}	0.010 ^{a,A}	0.043 ^{b,A}
P:C (40:60)	16.29 ^{a}	0.159 ^{b}	0.009 ^{a}	0.051 ^{ab}
P:C (0:100)	17.11 ^{a}	0.144 ^{b}	0.010 ^{a}	0.061 ^{a}
P:C (85:15),BF	16.42 ^{B}	0.226 ^{A}	0.011 ^{A}	0.028 ^{B}
P:C (55:45), BF	17.64 ^{A}	0.115 ^{B}	0.010 ^{A}	0.037 ^{AB}
P:C (85:15),HF	18.24 ^{A}	0.236 ^{A}	0.010 ^{A}	0.013 ^{C}
P:C (55:45),HF	18.64 ^{A}	0.173 ^{B}	0.010 ^{A}	0.026 ^{B}

^{Z} values [represent measurements made on 3 replication (3 seedlings mixed per replication) per treatment] in columns followed by the same small letter are not significantly different, $P \leq 0.05$, regarding substrate medium and in columns followed by the same capital letter are not significantly different, $P \leq 0.05$, regarding the fertigation impacts.

Salt and osmotic stresses are responsible for both inhibition or delayed seed germination and seedling establishment [35]. Under these stresses there is a decrease in water uptake during inhibitions and furthermore salt stress may cause excessive uptake of ions [36]. In addition, a pH increase is usually observed in soils that have received MSW compost, which makes metals less mobile and less available [14]. MSW compost, on the other hand, can increase soluble salt content (electrical conductivity), which has been found to adversely affect seed and shoot growth [37]. As a matter of fact, the increased salt stress cause by the addition of MSWC, affected negatively several plant growth and physiological related parameters, as presented on Tables 1 and 2. No differences were observed in P content (averaged in 0.021 mg/g fw) among seedlings grown in substrates with different MSWC content; due to the limited nutrient support for P by the MSWC added into the peat at least in the short term.. Some researcher have found MSW compost lacks P and this nutrient is necessary to be added by alternative source such as fertilizers, while the P availability into the soil is also of great research interest [7]. This in contrast to findings by others who have found that P availability from compost is generally high and is dependent on feedstock,.

Due to the intensive crop cultivation nowadays, transplants are a more reliable method of ensuring the proper establishment of a range of commercial horticultural crops with great economic value, compared with direct sowing. The production of vegetable seedlings, especial in Mediterranean countries having expanded field and greenhouse crops areas, is a highly-competitive business; uniform and rapid seed emergence is essential prerequisites to increase yield, quality, earliness and profits in crops. Use of good crop substrates is therefore critical [38]. Additionally, improved methods of selective waste collection and compost processing will enable increasingly widespread use of this renewable organic compost, as an alternative to high-quality sphagnum peat, which – because they are non-renewable – are less available and more expensive for growers. Successful trials with MSWC into peat-based media for seedling production of cucumber, melon, eggplant, basil, and marigold [9, 18, 21-22, 39] displayed good quality indices.

4. Conclusion

MSW compost was found to be an ideal component of peat substrates for pepper seedlings growth, provided that it accounts for less than 30% of the mixture with combination of fertilizers with more positive effects observed if nutrients provided through HF rather than BF. Regarding seed emergence, HF is not recommended at early stages of seed germination, and further studies are necessary to that direction. These peat additions reduce the negative effects of high pH and EC of MSWC on seedling growth, and provide a seedling comparable to that obtained using standard peat-based mixtures. This is in all probability due to a correct balance between nutrient supply from the MSWC and the physical characteristics of peat, particularly substrate porosity and aeration.

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