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Soilless Cultivation of *Portulaca oleracea* Using Medicinal and Aromatic Plant Residues for Partial Peat Replacement

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Abstract: The industrial manufacturing of essential oils (EOs) generates a sizable volume of bulk solid waste (SW) that needs to be disposed of. The present study evaluated the potential of using *Origanum dubium* wastes (ODW) and *Sideritis cypria* waste (SCW) obtained after EO distillation for partial peat substitution (0–5–10–20–40% *v*/*v*) in *Portulaca oleracea* production. Both ODW and SCW increased pH, electrical conductivity, organic matter, and mineral content, but negatively affected the total porosity and aeration of the growing media. Plant growth was inhibited, especially when high ratios of residues were used, and this was reflected by leaf stomatal conductance and chlorophyll decrease, as well as by the activation of several nonenzymatic (phenols, flavonoids, and antioxidant capacity) and enzymatic (catalase, superoxide dismutase, and peroxidase) mechanisms and the increase in lipid peroxidation and hydrogen peroxide, indicating stress conditions. Despite that both ODW and SCW were rich in minerals, plants could not accumulate them. It can be concluded that both ODW and SCW have the potential to be used in the growing media at low ratios up to 10%, with increased antioxidant content in the final product. Nonetheless, the growing media properties, i.e., total pore space and aeration, still need to be improved to result in sufficient yields.

Keywords: purslane; distillation waste; plant growth; peat; unexploited vegetables; antioxidants; minerals; total phenols

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1. Introduction

The world's agricultural industry produces a significant amount of bioresidues (solid, liquid, and gaseous), which are considered the most abundant, profitable, and renewable resource on the planet [1]. The management and recycling of these residues should be conducted in an ecologically and environmentally friendly way; otherwise, they may result in environmental hazards, expanding our concerns about human health constraints and the environment. Any biological material that is not consciously produced during a production process is referred to as residual biomass [2]. The leftover biomass is referred as a byproduct, which could be a potential waste depending on its management [3]. In the context of economic gain, environmental sustainability, and social advantages, the efficient usage and recycling of residual biomass generated by the medicinal and aromatic plant (MAP) sector are of utmost importance.

MAP material is used raw, dried, frozen for essential oil (EOs) production and for plant extracts (e.g., infusions and decoctions). Depending on the MAP species, the herbal, perfumery, and cosmetic industries produce a variety of solid and liquid leftovers, including the byproducts of aromatic plant distillation and the nonused parts of medicinal plants. After the primary processing, certain medicinal plant components that are specifically employed for medicinal purposes are used in the form of raw pharmaceuticals, whereas the other portions of the plant are left unused and end up as waste [2].

The primary methods used to extract essential oils include hydrodistillation, steam distillation, hydro steam distillation, organic solvent extraction, and mechanical extraction. All of these methods are time and cost demanding to operate [4], while the vast amounts of biomass residues generated from aromatic plant distillation go unused and decrease the added value of the crops [5]. It is estimated that MAP residues account for more than 200,000 tons worldwide annually [6]. Therefore, the efficient recycling of this waste material could provide additional revenue to the producers of aromatic plants. To further valorize the MAPs' generated waste, both conventional and innovative ways have been suggested, and cutting-edge technologies are being developed [7]. Composting is a common process to reuse crop residues, and the obtained composts can be used as organic fertilizers and soil-improving amendments [8–10]. Other uses include distilled lavender stalks that have been implemented as bioaggregate for building material [11], *Aloe vera* waste that is being used in the diet of lactating cows [12], and ginseng residues that are used as dietary feed supplements for piglets [13]. On the other hand, the use of crop residues as growing material in soil-less agriculture, in either composted or raw form, has received less attention so far [14–17].

EO yield can range from very low contents to typically up to 5–8% of the extracted biomass, thus resulting in enormous amounts of residues (solid waste and hydrolate—the aqueous byproduct after distillation), which need to be properly managed [2]. The vast majority of these leftovers are burned and disposed of as waste in landfills [18], posing an adverse effect on the environment, increasing energy cost, and dismantling the circular use of resources, since several components remain in the residues and can be used to obtain valuable bioactive components, such as phenolic compounds [7,13,19]. The exploitation of new natural antioxidants has greatly increased over the last few decades, and still there is plenty of space to explore agroindustrial byproducts as a source of antioxidants. A solution with high potential could be the employment of these residues as an alternative source of antioxidants because of their low cost, high availability, and need for environmentally favorable handling [20].

Peat is the principal growing medium utilized in the agriculture sector due to its useful agronomic characteristics, and as a result, an estimated 14–20% of the used peat is normally allocated to the horticulture industry [21,22]. Peat extraction and use should be gradually decreased as it is a nonrenewable resource and a large CO_2 sink [23]. Several peat alternatives have been searched so far, including the use of several agroindustry wastes as growing media in soil-less or pot-grown ornamental and horticultural crops [14,24–29]. During the growing medium preparation, the material, the ratio, the fertility, and the physicochemical properties of the individual components can be appropriately selected [25,26,30,31]. However, there are several farmers who use unprocessed materials in their fields without considering any possible harmful effects on the crops, the ecosystem, and the general public health [32,33]. The use of fresh rice hull in deciduous tree and flowering shrub cultivation [34], fresh rice and kenaf for the production of *Pinus halepensis* seedlings [35], olive mill waste (OMW) and grape mill waste (GMW) in vegetable production [36], and shredded paper waste [24,37] has been reported, which all present specific limitations for their successive application, depending on the material used, the growing/environmental conditions, and the plant species examined.

Peat can be partially replaced on a commercial scale only when the alternative materials meet or substitute some of the peat's main properties. Purslane is a wild herb, popular in Mediterranean and Asian diets, with high nutritive and pharmacological properties, which attribute its name as "the future superfood" [38–41]. Considering the adaptability of the species to adverse environmental conditions, it is also suggested as a potential alternative crop to mitigate the negative impacts of climate change and soil degradation on crop production [42,43]. Therefore, the main objective of this study was to explore the use of byproducts from the MAP sector to partially replace peat in the production of unexploded vegetables such as purslane (*Portulaca oleracea*). The second objective was to determine how the tested byproducts impacted the nutritional value, chemical content, and bioactive components of purslane leaves to identify the best growing medium that could enhance plant growth parameters and boost the final product's quality.

2. Materials and Methods

2.1. Plant Material and Growing Media Preparation

The present study took place at the hydroponic infrastructures (full climate automatic control plastic greenhouse) at the Cyprus University of Technology, Limassol, Cyprus. Commercial-based peat (professional peat, Gebr. Brill Substrate GmbH & Co. KG, Georgsdorf, Germany) was used as the growing substrate in this study. Sufficient minerals were added in peat by employing common fertilizers (Novatec, simple superphosphate, potassium sulfate) at 75 mg N/L, 22 mg P/L, 104 mg K/L of growing medium. The peat and the fertilizers were thoroughly mixed with a professional concrete mixer.

Medicinal and aromatic plant waste included *Origanum dubium* distilled waste-ODW and *Sideritis cypria* distilled waste-SCW, as derived after the steam hydro distillation process for essential oil extraction from the relevant aerial plant material. MAP material was provided by the Department of Agriculture, Sector of Medicinal and Aromatic Plants, Nicosia, Cyprus. Plants were cultivated under conventional farming practices, such as annual soil tillage, pruning of plants, fertilization, and crop protection applications with pesticides as appropriate for the region and following the best practice guides for the respective crops. MAPs were air-dried in the shade before being put through a 60 L semicommercial distillator for steam hydrodistillation. The distillation residues were left to dry (moisture was < 10%), then shredded and stored under dry conditions until further use.

Peat (P) was used as the base ingredient of the growing medium and was proportionally replaced with various ratios of ODW or SCW, resulting in the following nine media mixtures (v/v): (1) peat 100% (control), (2) P:ODW 95:5 (ODW 5%), (3) P:ODW 90:10 (ODW 10%), (4) P:ODW 80:20 (ODW 20%), and (5) P:ODW 60:40 (ODW 40%) for the oregano residues and (6) P:SCW 95:5 (SCW 5%), (7) P:SCW 90:10 (SCW 10%), (8) P:SCW 80:20 (GSC 20%) and (9) P:SCW 60:40 (SCW 40%), for the sideritis residues. Raw growing media were collected and analyzed for their physicochemical properties prior to seedling transplantation. The particle size of the shredded dried residues was also determined by using an electromagnetic and digital sieve shaker (BA-200-N for 8 × 200 mm sieves 230 V–50 Hz, CISA, Barcelona, Spain), for particle separation, fraction, and size determination, with a two-dimensional movement (a horizontal, circular motion and a vertical, tapping action), which allows particle stratification. The eight sieve sizes ranged from 4.00 mm to <75 µm. The uniformity index ($UI = d_{60}/d_{10}$) is a measure of the uniformity of particle size in the growing media and is defined as the ratio of the 60% finer size (d_{60}) to the effective size (d_{10}) (which means that 10% of the particles are finer and 90% of the particles are coarser than d_{10}) [44]. The ODW and SCW ratios were determined according to preliminary tests and/or previous experience with plant residues incorporated in growing media [24,36].

Purslane (*Portulaca oleracea* L.) seeds were bought from Hortus Sementi Srl. (Budrio, Italy; 2020 production lot) and placed in 72-cell black plastic trays filled with commercial peat, under nursery conditions. When seedlings reached the third leaf plant developmental stage, they were transferred into 0.3 L plastic pots with one of the nine different growing media. Eight replicate pots with one seedling per pot were utilized for each treatment (growing media). The pots were placed in plastic trays to preserve the drained solution after each watering. Plants were watered through the plastic trays with capillary suction, based on plants' needs. No fertilizers, insecticides, or other agrochemicals were used during the seedling growth. Throughout the cultivation season, average temperatures of 20.8 °C (Tmin of 16.9 °C; Tmax of 32.8 °C) and relative humidity levels of 57.4% were recorded.

2.2. Growing Media Characteristics

The physicochemical characteristics of the raw materials (P, ODW, and SCW) and the tested growing media were determined. Total pore space (TPS), air-filled porosity (AFP), available water holding capacity (AWHC), and bulk density (BD) by volume of the growing media were investigated based on European Standards, EN 13041 [45], as previously described [24]. The pH and the electrical conductivity (EC) of each growing media were measured in each growing medium extracted with water at a ratio of 1:5 v/v. Organic matter and organic C were determined after media ashing at 550 °C in a furnace [31]. For mineral analysis, the ash samples were then acid-digested (2 N HCl) following the protocol of Chrysargyris et al. [24], while macronutrients, such as potassium (K), sodium (Na), magnesium (Mg), and calcium (Ca), were measured using ion chromatography (ICS-3000, Dionex Aquion, Sunnyvale, CA, USA) and the IonPac CS19 (4 × 250 mm, Dionex, Co., Sunnyvale, CA, USA) analytical column. Phosphorus (P) was determined by spectrophotometry (Multiskan GO, Thermo Fischer Scientific, Waltham, MA, USA), and nitrogen (N) was determined by the Kjeldahl method (BUCHI, Digest Automat K-439 and Distillation KjelFlex K-360, Flawil, Switzerland). Data were expressed in g/kg of dry weight.

2.3. Plant Growth, Physiology, and Mineral Analysis

Purslane plants were grown for 25 days, and various growth parameters were measured in six seedlings per treatment. Seedling height and the number of leaves produced per plant were measured. Seedlings were harvested, and the upper fresh biomass was weighed (g) and dried, and then the total dry weight (g) was measured.

Additionally, several physiological parameters were recorded before harvesting. Leaf stomatal conductance was determined with a ΔT-Porometer AP4 (Delta-T Devices, Cambridge, UK). Leaf chlorophyll fluorescence was recorded on two fully expanded, sun-exposed leaves per plant (Opti-Sciences fluorometer OS-30p, Hertfordshire, UK). Leaf chlorophylls (chlorophyll a-Chl a, chlorophyll b-Chl b, total chlorophylls-total Chl) and carotenoid content were also assessed (six replications/treatment), as described previously, and the results were expressed as mg of chlorophyll (or carotenoids) per gram of fresh tissue [46].

Mineral content in plant leaves was determined in four replications/treatment (two pooled plants/replication) [46]. Plant tissue was ashed in a furnace (Carbolite, AAF 1100, GERO, Lilienthal, Germany) at 480 °C for 6 h and acid-digested (2 N HCl). Minerals (N, K, P, Na, Ca, and Mg) were determined as described above, and results were expressed in g/kg of dry weight [24].

2.4. Total Phenolic Compounds, Total Flavonoids, and Antioxidant Activity

Total phenolic compounds, total flavonoids, and total antioxidant activity were determined in the methanolic extracts obtained from plant tissues (four replicates/two pooled plants per replicate) for each treatment. For the total phenolic compounds, the Folin–Ciocalteu reagent (Merck, Darmstadt, Germany) was used, and results were presented as mg of gallic acid equivalents per g of fresh weight (fw) [47]. Total flavonoid content was determined according to the aluminum chloride colorimetric method [48], and results were presented as rutin equivalents (mg rutin/g of fw). For antioxidant activity, two assays were employed, ferric reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH), which were performed as described previously by Chrysargyris et al. [24]; results were presented as Trolox equivalents per g of fresh weight.

2.5. Lipid Peroxidation, Hydrogen Peroxide Content, and Enzyme Antioxidant Activity

Lipid peroxidation indicated by the malondialdehyde content (MDA) and hydrogen peroxide (H_2O_2) content was determined as previously described in the literature [49,50]. The results were expressed as nmol of MDA per g of fw and as μmol H_2O_2 per g of fw.

The antioxidant enzyme activity for superoxide dismutase (SOD) (EC 1.15.1.1), catalase (CAT) (EC 1.11.1.6), and peroxidase activity (POD) (EC 1.11.1.6) was determined as described previously [36]. Results were presented as enzyme units per mg of protein. The protein content was determined by the Bradford method, and bovine serum albumin (BSA) was used as standard.

2.6. Statistical Analysis

Data were statistically analyzed by the IBM SPSS v22.0 (SPSS Inc., Chicago, IL, USA) program. Prior to analysis of variance (ANOVA), data were checked for normality. Then raw data for each waste material (ODW or SCW) were subjected to one-way ANOVA, and when significant effects were recorded, the comparison of means was performed with Duncan's multiple range test (DMRT) at $p \leq 0.05$.

3. Results and Discussion

Not all crop residues are ideal for preparing suitable growing media for crop production in pots or for the production of seedlings or cuttings in nurseries of horticultural crops. The acidity, alkalinity, salinity, and presence of phytochemical compounds (such as polyphenols) at excessive levels may restrict the use of these residues due to possible phytotoxic effects [51]. Therefore, a detailed analysis of several physical, chemical, and biological variables is needed to determine the impact of growing media composition on plant growth and yield. The tested raw MAP residues (ODW and SCW) were rich in minerals and contributed to the physicochemical characteristics of the final growing media mixtures when combined at various ratios with peat (Tables 1 and 2). More specifically, ODW had a slide acidic pH (averaged values of 5.96), high organic content, and bulk density, and it contained high levels of N (10.51 g/kg), K (13.46 g/kg), P (2.83 g/kg), Na (1.22 g/kg), and Mg (2.67 g/kg), which resulted in increased EC values, compared with peat (Table 1). However, ODW had almost the half level of Ca (averaged values of 7.66 g/kg) compared with peat. Regarding SCW, it recorded an almost neutral pH (averaged values of 6.75), high organic matter, and available water holding capacity, as well as high levels of N (12.66 g/kg), K (14.06 g/kg), P (1.65 g/kg), Na (5.79 g/kg), and Mg (1.70 g/kg), which also resulted in increased EC values compared with peat (Table 2). On the other hand, SCW contained only lower amounts of Ca (averaged values of 11.58 g/kg) and recorded a lower bulk density compared with peat. In both materials, ODW and SCW revealed a uniformity index ($UI = d_{60}/d_{10}$) of UI = 20 and UI = 14.4, respectively [44], having 90% of particles with sizes lower than 0.4 mm (resulted in a dustier material) and 3.6 mm (resulted in various size materials), respectively (Figure S1). The tested MAP residues could be considered fertile material, as it has been previously reported that distilled MAP waste may contain micronutrients and macronutrients at amounts of 0.35–1.80% N, 0.45–0.60% P, and 2.00–2.25% K [52]. Due to the wide variety of crop and processing industry residues, there are no references on the properties of the tested raw materials; however, there are references on composted materials. The analyzed ODW and SCW properties were within the range of the available data from other studies, apart from the air-filled porosity of ODW, which was 1.57% [53]. The EC of the studied ODW and SCW materials was very low and below the highest recommended EC of 4 mS/cm (the Greek standard) for composted materials, which excludes any initial phytotoxic effects on young plants [54].

Adding MAP residues in different ratios into the growing media for partial peat substitution also affected the physicochemical properties of the obtained mixtures (Tables 1 and 2). The presence of ODW or SCW increased the growing media pH by almost 1.2 pH unit compared with the control (peat) media, resulting in pH values of 7.51 and 7.54 at ODW 40% media and SCW 40% media, respectively. Indeed, the pH increase recorded in mixtures that contained ODW and SCW at $\geq$20% ratios was greater than the recommended pH levels for growing media (5.3–6.5) [53]. When ODW was combined with peat at the highest ratio (ODW 40%), it had a considerable impact on the level of organic matter content in the mixture, whereas no significant effects were recorded for SCW when combined with peat (Tables 1 and 2). Considering that agricultural soils in the Mediterranean basin often contain less than 3–4% of organic matter, there is a significant amount of organic matter in the waste biomass generated during MAP processing that could be used as soil or growing medium amendments [2].

Table 1. Growing media (peat, *Origanum dubium* waste—ODW) physicochemical properties before plant transplanting.

	Peat 100%	**ODW 5%**	**ODW 10%**	**ODW 20%**	**ODW 40%**	**ODW 100%**
pH	6.32 ± 0.17 b	6.34 ± 0.05 b	6.31 ± 0.09 b	6.62 ± 0.01 b	7.51 ± 0.12 a	5.96 ± 0.07 c
EC (mS/cm)	0.84 ± 0.04 c	1.13 ± 0.07 b,c	0.89 ± 0.00 b,c	1.12 ± 0.04 b	1.70 ± 0.18 a	1.92 ± 0.01 a
Organic matter (%)	72.38 ± 1.28 c,d	73.03 ± 0.36 c	73.30 ± 0.73 c	70.16 ± 0.38 d	76.91 ± 1.08 b	92.79 ± 0.25 a
Organic C (%)	41.98 ± 0.74 c,d	42.36 ± 0.21 c	42.51 ± 0.42 c	40.69 ± 0.22 d	44.61 ± 0.63 b	53.82 ± 0.14 a
C/N ratio	50.36 ± 2.12 a	42.91 ± 0.99 b	40.92 ± 3.35 b	26.22 ± 0.67 c	28.33 ± 0.79 c	51.21 ± 0.23 a
N (g/kg)	8.35 ± 0.19 c	9.88 ± 0.20 b	10.51 ± 0.76 b	15.53 ± 0.33 a	15.77 ± 0.59 a	10.51 ± 0.05 b
K (g/kg)	2.03 ± 0.05 d	3.86 ± 0.31 c	3.96 ± 0.41 c	4.69 ± 0.13 c	7.35 ± 0.31 b	13.46 ± 0.11 a
P (g/kg)	1.12 ± 0.04 c	1.61 ± 0.29 b,c	1.72 ± 0.09 b	1.91 ± 0.18 b	2.62 ± 0.18 a	2.83 ± 0.02 a
Ca (g/kg)	15.01 ± 0.56 b	21.52 ± 2.43 a	17.62 ± 0.98 b	20.41 ± 0.21 a	20.51 ± 0.49 a	7.66 ± 0.27 c
Mg (g/kg)	0.79 ± 0.04 e	1.51 ± 0.21 d	1.50 ± 0.09 d	2.22 ± 0.02 c	3.29 ± 0.06 a	2.67 ± 0.10 b
Na (g/kg)	0.97 ± 0.03 c	1.12 ± 0.12 b	1.12 ± 0.08 a,b	1.24 ± 0.05 a,b	1.31 ± 0.03 a	1.22 ± 0.08 a,b
Total porosity %	84.97 ± 0.76 a	72.68 ± 3.31 b	77.19 ± 4.48 a,b	53.13 ± 1.37 c	48.60 ± 3.67 c	69.87 ± 3.89 b
Air-filled porosity (% *v*/*v*)	18.43 ± 1.00 a	10.47 ± 2.39 b	9.14 ± 2.26 b	7.90 ± 0.50 b	5.52 ± 0.99 b,c	1.57 ± 0.71 c
Bulk density (g/cm^3)	0.15 ± 0.00 c	0.16 ± 0.00 b,c	0.17 ± 0.00 b	0.17 ± 0.00 b	0.18 ± 0.00 b	0.29 ± 0.01 a
Available water holding capacity (% *v*/*v*)	66.54 ± 1.75 a	62.21 ± 1.28 a	68.04 ± 2.57 a	45.41 ± 1.84 b	43.07 ± 3.00 b	68.30 ± 3.17 a

Total porosity (TP), available water holding capacity (AWHC), air-filled porosity (AFP), bulk density (BD) by volume. Values are mean± SE (n = 4). In each row, values followed by the same letter do not differ significantly, according to Duncan's multiple range test at $p < 0.05$.

Table 2. Growing media (peat, *Sideritis cypria* waste—SCW) physicochemical properties before plant transplanting.

	Peat 100%	**SCW 5%**	**SCW 10%**	**SCW 20%**	**SCW 40%**	**SCW 100%**
pH	6.32 ± 1.79 d	6.27 ± 1.12 d	6.53 ± 0.00 c,d	6.91 ± 0.04 b	7.54 ± 0.01 a	6.75 ± 0.08 b,c
EC (mS/cm)	0.84 ± 0.04 b	1.26 ± 0.07 a	1.24 ± 0.11 a	1.10 ± 0.06 a	1.18 ± 0.03 a	1.19 ± 0.14 a
Organic matter (%)	72.38 ± 1.28 b	77.64 ± 2.26 b	75.39 ± 2.64 b	75.23 ± 1.45 b	76.11 ± 1.22 b	92.79 ± 0.25 a
Organic C (%)	41.98 ± 0.74 b	45.03 ± 1.31 b	43.72 ± 1.53 b	43.63 ± 0.84 b	44.14 ± 0.71 b	53.82 ± 0.14 a
C/N ratio	50.36 ± 2.12 a	50.89 ± 1.44 a	38.38 ± 1.21 b,c	36.33 ± 1.54 c	30.04 ± 0.88 d	42.57 ± 1.19 b
N (g/kg)	8.35 ± 0.19 c	8.87 ± 0.45 c	11.40 ± 0.46 b	12.04 ± 0.44 b	14.73 ± 0.65 a	12.66 ± 0.37 b
K (g/kg)	2.03 ± 0.05 f	3.11 ± 0.25 e	4.20 ± 0.32 d	6.31 ± 0.25 c	8.75 ± 0.25 b	14.06 ± 0.35 a
P (g/kg)	1.12 ± 0.04 c	1.39 ± 0.05 bc	1.70 ± 0.06 b	1.75 ± 0.07 b	2.51 ± 0.28 a	1.65 ± 0.10 b
Ca (g/kg)	15.01 ± 0.56 b	16.37 ± 1.19 b	20.02 ± 0.33 a	22.57 ± 1.07 a	21.27 ± 0.73 a	11.58 ± 0.50 c
Mg (g/kg)	0.79 ± 0.04 d	1.02 ± 0.08 d	1.30 ± 0.03 c	1.82 ± 0.08 b	2.25 ± 0.06 a	1.70 ± 0.11 b
Na (g/kg)	0.97 ± 0.03 e	1.03 ± 0.07 e	1.20 ± 0.05 d	1.65 ± 0.03 c	2.03 ± 0.01 b	5.79 ± 0.04 a
Total porosity %	84.97 ± 0.76 a,b	91.82 ± 3.87 a	77.63 ± 3.41 b,c	69.01 ± 3.70 c,d	62.88 ± 5.28 d	98.19 ± 1.62 a
Air-filled porosity (% *v*/*v*)	18.43 ± 1.00 a	15.52 ± 2.21 a,b	14.28 ± 1.46 a,b	13.42 ± 2.65 a,b	9.62 ± 2.91 b	17.14 ± 1.43 a,b
Bulk density (g/cm^3)	0.15 ± 0.00 b	0.16 ± 0.00 a	0.17 ± 0.00 a	0.17 ± 0.00 a	0.15 ± 0.00 b	0.12 ± 0.00 c
Available water holding capacity (% *v*/*v*)	66.54 ± 1.75 b	76.30 ± 1.68 a	63.35 ± 2.56 b	55.57 ± 1.44 c	53.25 ± 2.37 c	81.05 ± 0.19 a

Total porosity (TP), available water holding capacity (AWHC), air-filled porosity (AFP), bulk density (BD) by volume. Values are mean± SE (n = 4). In each row, values followed by the same letter do not differ significantly, according to Duncan's multiple range test at $p < 0.05$.

According to Zhou et al. [55], herbal residues may contain cellulose, protein, and polysaccharides that can provide soil with N, P, and K after the organic matter decomposition [56]. This was also evidenced in the MAP-enriched growing media in the present study, as the N, K, Mg, and P levels were significantly increased with increasing ratios of waste in the media. On the other hand, the EC value of the growing media was higher (ranging from 0.84 to 1.70 mS/cm) than the suggested ones for growing media [17,53]. However, any mineral amendments can always been regulated by utilizing a tailor-made fertilization strategy or by using inert materials (e.g., perlite) in case of excessive mineral contents that may increase the EC value of the growing media [57].

It has been reported that the addition of mint distillation wastes increased mustard (*Brassica juncea*) productivity and also improved soil physicochemical properties, making it possible to partly substitute the fertilizer inputs [58]. Particle size, overall porosity, air-filled capacity, and water holding capacity of the growing medium are critical to the success of soil-less culture crops. In both ODW- and SCW-based growing media, total porosity (especially at high waste ratios) decreased, which resulted in decreased air-filled capacity (up to 5.52%) and available water holding capacity (up to 43.07%), suggesting an overall negative effect on the media's physical properties. Moreover, the total pore space of the tested mixtures was lower than the recommended values of ≥85% porosity (except at SCW 5%), according to Abad et al. [53]. Therefore, inert materials with big particle size, such as perlite, could be added to the growing medium to increase the porosity and alleviate the negative effects of MAP waste on this particular parameter. Another important parameter is air capacity (air-filled porosity) with recommended values of 20–30% for growing media [53]. In our study, decreasing trends for this parameter were recorded for both waste materials, especially in the case of ODW, where a gradual decrease was recorded with increasing waste ratios in the growing media. On the other hand, SCW performed better with the lowest values being recorded for the SCW 40% treatment, while lower rates of SCW did not differ significantly from peat despite the decreasing trends with increasing amounts of SCW.

The effects of adding MAP waste in peat-based growing media on purslane growing parameters are presented in Table 3. The presence of ODW or SCW in the growing media at levels $\geq$ 10% reduced plant height and the number of leaves produced, with more noticeable impacts at the highest SCW ratio (SCW 40%) and the treatments of ODW 20% and 40%, in comparison with control treatment (peat 100%). This negative impact on plant growth also derived in decreased fresh biomass, even at ODW 5% or SCW 10%, as well as in decreased dry weight, especially in the case of ODW ratios $\geq$ 20% and SCW 40% treatment (Table 3). In other studies, the addition of MAP residues from Chinese herbs in the soil boosted the dry matter content of tomato and cabbage plants [8], whereas in the present experiment, dry weight was similar or lower than control (peat). Similarly, the addition of olive mill waste in peat at high ratios (>10%) could reduce the growth of potted ornamental plants and the market potential of the harvested product [24]. In contrast, composted olive mill waste increased shoot biomass when applied on tomato crop [59], highlighting the benefits obtained of a stable material, derived through the composting process instead of using raw waste material. Indeed, it is simpler to handle, store, and transfer smaller plants, since the reduction in plant height in nurseries or greenhouses is not always a negative parameter [24,60]. These findings demonstrate the variable effects of introducing crop residues to soil- and soil-less-culture systems. However, the use of high ratios of MAP residues employed in the current study should be excluded unless other crop management practices that improve plant productivity could be considered to mitigate the lower fresh biomass production, which consequently affects crop productivity. These practices involve the employment of a fertigation system, the enhancement of the physicochemical characteristics of the growing medium, and possibly the use of semi- or fully composted material. Reduced plant growth could be mostly associated with substrate parameters, such as total and air-filled porosity. Therefore, proper aeration of the growing medium could be enhanced by incorporating inert materials in the mixture, such as perlite, pumice, or sand, up to 15–20%, resulting in improved results for plant growth and development.

Leaf stomatal conductance was decreased in purslane plants grown in ≥10% ODW and ≥5% SCW when compared with the control treatment (peat 100%), with greater effects being evident at the highest ratio (e.g., 40%) of the wastes into the media (Table 4). These results indicate that increasing the waste ratio at values higher than 5% and 10% for SCW and ODW puts purslane plants under stressful conditions since stomatal closure is associated with a plant's response to stress. The results of the current study are consistent with earlier studies on stomatal closure in tomato plants grown in sand and irrigated with olive mill wastewater [61], or in *Brassica* seedlings grown in peat-based media with olive mill waste [15]. Therefore, it could be suggested that the incorporation of waste material in growing media should be carefully considered, since high EC values may impose waster stress on plants due to the high osmotic potential of the growing media.

Table 3. Impact of growing media (peat; *Origanum dubium* waste—ODW; *Sideritis cypria* waste—SCW) on purslane seedlings' height (cm), leaf number, upper part fresh weight (g/plant), and dry weight (g/plant) on plants grown in greenhouse/nursery.

	Height	Leaf No.	Fresh Weight	Dry Weight
Peat 100%	22.74 ± 0.79 a [Y]	41.00 ± 3.11 a	12.52 ± 0.60 a	0.56 ± 0.01 a
ODW 5%	18.12 ± 3.31 a,b	27.60 ±5.80 a,b	6.43 ± 2.30 b	0.54 ± 0.20 a
ODW 10%	15.48 ± 3.03 b	21.60 ±8.50 b	6.28 ± 2.76 b	0.39 ± 0.17 a,b
ODW 20%	9.34 ± 0.66 c	7.60 ± 0.74 c	0.98 ± 0.12 c	0.07 ± 0.01 b
ODW 40%	7.30 ± 0.99 c	4.00 ± 0.71 c	0.34 ± 0.09 c	0.03 ± 0.00 b
Peat 100%	22.74 ± 0.79 a	41.00 ± 3.11 a	12.52 ± 0.60 a	0.56 ± 0.01 a
SCW 5%	22.48 ± 1.74 a	39.40 ± 3.04 a	10.36 ± 1.64 a,b	0.46 ± 0.11 a
SCW 10%	17.04 ± 2.77 b	27.60 ± 8.80 a,b	5.55 ± 2.27 bc	0.49 ± 0.16 a
SCW 20%	15.90 ± 1.79 b,c	21.00 ± 3.17 b,c	3.93 ± 0.67 c	0.30 ± 0.11 a,b
SCW 40%	11.24 ± 1.56 c	10.80 ± 0.96 c	1.51 ± 0.32 c	0.11 ± 0.01 b

[Y] Mean values ($n = 6$) in the same column followed by the same letter for the same waste material (ODW or SCW), are not significantly different according to Duncan's multiple range test (DMRT), at $p < 0.05$.

Table 4. Impact of growing media (peat, *Origanum dubium* waste—ODW, *Sideritis cypria* waste—SCW) on purslane chlorophyll fluorescence (Fv/Fm), stomatal conductance (s/cm), chlorophylls (Chl a, Chl b, total Chls; mg/g fw), and carotenoid (mg/g fw) content.

	Stomatal Conductance	Chlorophyll Fluorescence	Chl a	Chl b	Total Chls	Carotenoids
Peat 100%	110.16 ± 8.67 a [Y]	0.80 ± 0.00 a	0.39 ± 0.02 a	0.10 ± 0.00 a	0.49 ± 0.03 a	0.07 ± 0.00 a
ODW 5%	82.00 ± 5.50 a,b	0.77 ± 0.00 b	0.36 ± 0.06 a	0.08 ± 0.01 a	0.45 ± 0.07 a	0.08 ± 0.01 a
ODW 10%	65.00 ± 5.85 b	0.75 ± 0.00 b,c	0.20 ±0.03 b	0.04 ± 0.01 b	0.24 ± 0.04 b	0.04 ± 0.00 b
ODW 20%	62.5 ± 0.50 b	0.74 ± 0.00 c	0.18 ±0.04 b	0.03 ± 0.01 b,c	0.21 ± 0.05 b	0.04 ± 0.01 b
ODW 40%	n.m.	n.m.	0.09 ±0.00 b	0.01 ± 0.00 c	0.09 ± 0.00 b	0.03 ± 0.00 b
Peat 100%	110.16 ± 8.67 a	0.80 ± 0.00 a	0.39 ± 0.02 a	0.10 ± 0.00 a	0.49 ± 0.03 a	0.07 ± 0.00 a
SCW 5%	69.00 ± 6.80 b	0.72 ± 0.03 b	0.28 ± 0.03 b	0.06 ± 0.01 b	0.35 ± 0.04 b	0.05 ± 0.01 b
SCW 10%	59.50 ± 3.50 b,c	0.75 ± 0.01 a,b	0.18 ± 0.00 c,d	0.04 ± 0.00 c,d	0.22 ± 0.00 c,d	0.04 ± 0.00 b,c
SCW 20%	55.00 ± 5.85 b,c	0.74 ± 0.01 a,b	0.24 ± 0.01 b,c	0.05 ± 0.00 b,c	0.29 ± 0.01 b,c	0.05 ± 0.00 b,c
SCW 40%	33.50 ± 0.50 c	0.65 ± 0.01 c	0.14 ± 0.00 d	0.03 ± 0.00 d	0.17 ± 0.00 d	0.03 ± 0.00 c

[Y] Mean values ($n = 6$) in columns followed by the same letter for the different wastes (ODW, SCW) are not significantly different, according to Duncan's multiple range test (DMRT), at $p < 0.05$. n.m.: not measured due to small leaf area.

The synthesis of leaf pigments, such as chlorophyll a, chlorophyll b, and total chlorophylls, as well as carotenoids, was decreased in purslane plants grown in ≥10% ODW and ≥10% SCW media, compared with purslane grown in 100% peat (Table 4). Chlorophyll content is directly related to the photosynthetic capacity of the plant [62]. Therefore, the reduced chlorophyll levels recorded in the present work reflect the reduced plant growth when high ODW and SCW ratios were implemented. MAP residues improved mineral availability to the plants through the increased mineral content of the growing media mixtures; however, the use of raw residues may have consumed a portion of the available N for the decomposition process, on one hand, whereas the negative effects on the physicochemical properties of the mixtures, on the other hand, could have prevented the efficient supply of minerals to the plants. Therefore, the particular decrease in plant growth in the present study should not be related to the mineral status of the growing media. Instead, it is more likely related to the negative effects on the physicochemical properties of the growing media, such as air-filled porosity. In this regard, initiatives to improve the qualities of the growing media should be considered, either increasing the quantity of inert material (i.e., adding 15–20% of perlite) or combining different inert materials (perlite, sand, zeolite, vermiculate, etc.) along with the tested waste. Moreover, efforts should be made to supplement N to counteract N losses due to its utilization by microorganisms for organic matter decomposition.

Table 5 presents the content of minerals accumulated in purslane plants grown in ODW- or SCW-based growing media after a cultivation period of 25 days. Plants grown in ODW-based media revealed lower N, Na, and Mg accumulation compared with plants grown in peat. However, the lowest N and Na content were found in ODW mixtures that contained 5–10% of ODW, indicating the contribution of ODW to mineral accumulation in the growing media. The highest Mg content was found in plants grown in peat, while the highest Ca contest was found in plants grown in ODW 40% media. In the case of SCW mixtures, N and Mg levels decreased with the presence of SCW in the growing media, whereas Na content increased in plants grown in both control (100% peat) and SCW 40%. No main differences were found in Ca content in SCW-based grown plants.

Table 5. Impact of growing media (peat, *Origanum dubium* waste—ODW, *Sideritis cypria* waste—SCW) on mineral element content (mg/g dry weight) of purslane plants.

	N	K	P	Na	Ca	Mg
Peat 100%	35.22 ± 0.27 a [Y]	86.96 ± 1.10 b	11.40 ± 0.31 a,b	12.12 ± 0.09 c	6.26 ± 0.16 a	5.20 ± 0.18 a
ODW 5%	27.87 ± 1.09 c	84.13 ± 4.11 b	9.27 ± 1.56 b,c	11.78 ± 0.56 c	5.56 ± 0.05 b,c	3.14 ± 0.46 b
ODW 10%	25.34 ± 0.48 d	99.95 ± 4.05 a	12.17 ± 0.59 a	12.41 ± 0.22 c	5.33 ± 0.30 c	3.29 ± 0.40 b
ODW 20%	32.74 ± 0.32 b	86.31 ± 1.69 b	10.92 ± 0.21 a,b	14.61 ± 0.28 b	6.10 ± 0.12 a,b	3.61 ± 0.07 b
ODW 40%	31.23 ± 0.24 b	60.35 ± 1.18 c	7.15 ± 0.14 c	16.96 ± 0.33 a	5.40 ± 1.10 c	2.81 ± 0.05 b
Peat 100%	35.22 ± 0.27 a	86.96 ± 1.10 b,c	11.40 ± 0.31 b	12.12 ± 0.09 b	6.26 ± 0.16 a	5.20 ± 0.18 a
SCW 5%	28.56 ± 0.15 b	84.55 ± 0.54 b,c	8.51 ± 0.64 c	10.71 ± 0.05 c	5.60 ± 0.04 b	3.96 ± 0.06 b
SCW 10%	25.95 ± 0.87 c	89.59 ± 3.90 b	11.51 ± 0.27 b	11.42 ± 0.33 c	6.15 ± 0.21 a	3.92 ± 0.28 b
SCW 20%	25.92 ± 0.12 c	100.43 ± 1.96 a	12.85 ± 0.25 a	11.17 ± 0.22 c	4.99 ± 0.09 c	3.55 ± 0.07 b
SCW 40%	25.89 ± 0.14 c	81.78 ± 1.60 c	5.49 ± 0.11 d	13.69 ± 0.26 a	4.86 ± 0.09 c	4.05 ± 0.08 b

[Y] Mean values (n = 4) in columns followed by the same letter for the different wastes (ODW, SCW) are not significantly different, according to Duncan's multiple range test (DMRT), at $p < 0.05$.

Our results indicate that when ODW or SCW were added, the N that was provided was mostly organic and only partially available to the plants. Moreover, a large part of N seems to be consumed by microorganisms through organic matter decomposition, as illustrated by the decreased C/N ratios (Tables 1 and 2), the decreased N accumulation in purslane tissues (Table 5), and the decreased N levels at the growing media after harvesting (Tables S1 and S2). This finding could explain why plants grew slowly and had limited quantities of chlorophyll and photosynthetic capacity, parameters that are directly associated with N availability [61]. One of the biggest drawbacks of using raw materials in growing media is the variability in the nutrients that are accumulated in plant tissues. Another issue is the practical challenges of performing preliminary studies prior to the usage of MAP-based media. This can be prevented by implementing a tailor-made fertilization regime [63], since, according Chrysargyris et al. [24], the use of an adjusted hydroponic fertilizer solution in ornamental plants may alleviate mineral abnormalities caused by the uncomposted growing medium.

The use of MAP waste as a partial substitute of peat into plant growing media also affected the total phenolic compound content, total flavonoids, and antioxidant capacity of the produced plants, as presented in Figure 1. In the case of ODW, the content of total phenolic compounds in purslane was increased up to 30.2% for ratios of ODW between 5% and 20% and further increased 1.5 times at the highest ratio of ODW (ODW 40%) compared with the control treatment (Figure 1(A1)). Purslane antioxidant activity, as assayed by DPPH and FRAP, significantly increased at ≥20% of ODW and ≥5% of SCW, respectively, while the highest ratio of ODW (ODW 40%) more than doubled the antioxidant activity for both assays compared with the control treatment (Figure 1(A2,A3,B2,B3)). Similarly, total flavonoid content increased (up to 2.2 times) at 40% ODW in comparison with the control treatment, while a less profound increase was recorded for the respective treatment of SCW (Figure 1(A4,B4)). The main response of plants to stress conditions is reflected by the activation of several enzymatic and nonenzymatic mechanisms. In this case, various nonenzymatic responses were indicated by increased phenolic compounds, flavonoids, and antioxidant capacity of purslane. Therefore, despite the decreased yield observed when high ratios of ODW and SCW were implemented, the improved antioxidant capacity of plants could be important since it is associated with an increased nutritional value of the plant (high antioxidant compound content). Similar responses of *Brassica* plants to stress conditions when they were grown in OMW-based media were also reported, confirming our argument that the incorporation of raw crop residues in growing media may put plants under stressful conditions and consequently result in increased antioxidant compound content [15].

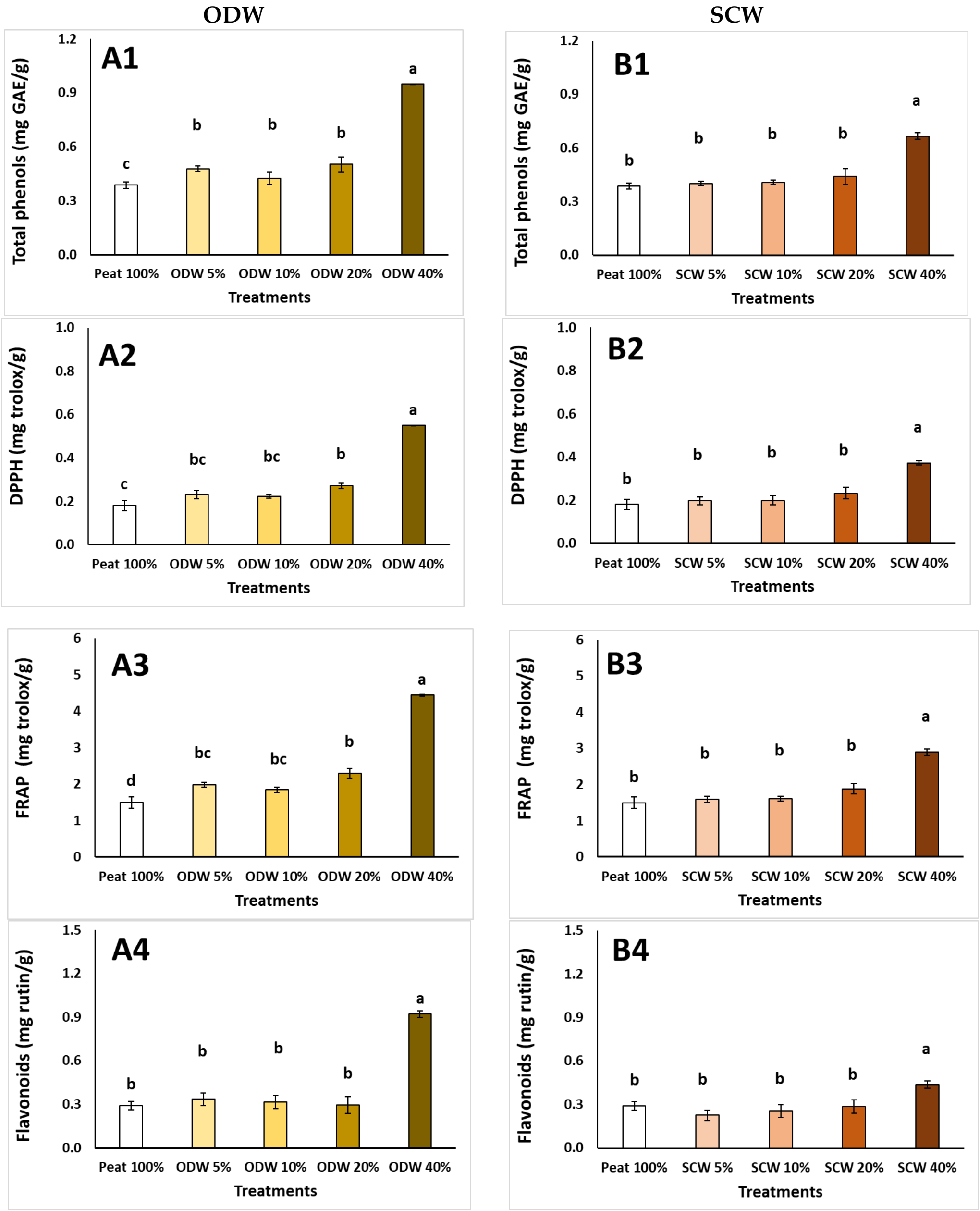

Figure 1. Effect of growing media (peat, *Origanum dubium* waste—ODW, *Sideritis cypria* waste—SCW) on total phenolic compound content (mg GAE/g fw), antioxidant activity (DPPH, FRAP: mg Trolox/g fw), and flavonoid content (mg rutin/g fw) of purslane plants (ODW: **A1**–**A4**; SCW: **B1**–**B4**). Values are means± SE ($n = 6$). Mean values followed by the same letter do not differ significantly at $p \geq 0.05$ according to Duncan's multiple range test.

Throughout their growth cycle, plants are exposed to a range of challenging stress situations. These situations frequently entail both biotic (such as diseases and pests) and abiotic stressors, such as intense heat, dry seasons, extremely saline and osmotic soils, and high mineral/heavy metal concentrations. Plants have developed a number of detoxification processes to overcome the oxidative stress from the reactive oxygen species that accumulate in cells under stressful conditions. The formation of MDA, which is linked to increased lipid peroxidation under stress conditions, is one of the most used stress markers. MDA levels increase when plant antioxidants fail to scavenge ROS as a first-step response to stressors. In our study, MDA content increased in purslane plants grown at ODW 40%, having also high levels of H_2O_2, which indicate stress conditions associated with cellular damage (Table 6). This was evidenced by the increased SOD activity, followed by increased POD activity for the same treatment (ODW 40%). Several nonenzymatic (phenols, proline, ascorbic acid, etc.) and enzymatic antioxidants (SOD, CAT, POD, etc.) are activated to neutralize ROS accumulation in cells [64]. In the case of SCW waste, MDA levels were low at the high SCW ratios (20–40%), and H_2O_2 and POD levels increased at the highest SCW ratio (SCW 40%), whereas SOD levels were not affected by the ratio of SCW in the growing medium. This indicates that the antioxidant role of SOD was exhausted to decreased MDA levels, and the POD increased in order to scavenge the high levels of H_2O_2.

Table 6. Impact of growing media (peat, *Origanum dubium* waste—ODW, *Sideritis cypria* waste—SCW) on hydrogen peroxide (H_2O_2) (µmol/g), lipid peroxidation (MDA) (nmol/g), and antioxidant enzyme activity of superoxide dismutase (SOD; units/mg protein), catalase (CAT; units/mg protein), and peroxidase (POD; units/mg protein) of purslane plants.

	H_2O_2	MDA	SOD	CAT	POD
Peat 100%	0.20 ± 0.01 b,c [Y]	8.84 ± 0.74 b	0.94 ± 0.12 b	3.61 ± 0.71 b,c	0.54 ± 0.05 c
ODW 5%	0.23 ± 0.01 b,c	8.68 ± 0.59 b,c	1.15 ± 0.07 b	11.65 ± 0.85 a	0.81 ± 0.06 b
ODW 10%	0.19 ± 0.00 c	7.46 ± 0.86 c	0.82 ± 0.11 b	5.10 ± 0.60 b	0.68 ± 0.03 b,c
ODW 20%	0.24 ± 0.01 b	10.93 ± 0.91 a,b	1.08 ± 0.08 b	1.68 ± 0.41 c	0.86 ± 0.09 b
ODW 40%	0.46 ± 0.03 a	12.87 ± 0.71 a	1.85 ± 0.04 a	3.19 ± 0.35 b,c	1.30 ± 0.16 a
Peat 100%	0.15 ± 0.00 b,c	7.85 ± 0.57 a	0.94 ± 0.12	3.61 ± 0.71 b,c	0.54 ± 0.05 c
SCW 5%	0.17 ± 0.01 a,b	5.25 ± 0.67 b	1.13 ± 0.04	4.69 ± 0.22 b	0.86 ± 0.03 a,b
SCW 10%	0.12 ± 0.00 c	5.11 ± 0.78 b,c	1.01 ± 0.12	9.03 ± 0.91 a	0.84 ± 0.07 a,b
SCW 20%	0.15 ± 0.02 b,c	3.73 ± 0.14 b,c	1.14 ± 0.07	2.04 ± 0.58 c	0.76 ± 0.02 b
SCW 40%	0.21 ± 0.03 a	3.27 ± 0.52 c	1.15 ± 0.07	2.38 ± 0.85 b,c	0.99 ± 0.08 a

[Y] Values (n = 4) in columns followed by the same letter for the different wastes (ODW, SCW) are not significantly different, according to Duncan's multiple range test at $p < 0.05$.

For commercially producing vegetables, ornamentals, seedlings, and potted plants, it is essential to ensure the rapid growth and vigor of plants. In addition, it is crucial to use peat substitutes that are more environmentally friendly by mixing them in growing media in different combinations. Reduced peat use and consumption could lower seedling costs and contribute to the preservation of peatlands. Future research should focus on adjusting the ratios of the ingredients used to prepare commercial substrates, always considering the fertilization and irrigation regimes. For this purpose, minerals and organic matter found in crop residues can improve the physicochemical properties of the soil and growing medium. Even though some studies with potted plants may result in improved soil properties by adding MAP residues, there are still some differences between pot experiments and actual agricultural practice in order to extrapolate these results to field condition and suggest the introduction of MAP waste in commercial farming [10].

4. Conclusions

The two most important issues that researchers should focus on when evaluating new materials as potential components in substrate mixtures are to increase growing media fertility and to establish the appropriate physicochemical properties of the final mixture. In the current study, ODW and SCW were explored as a partial substitute for peat in the growth of purslane seedlings. The physicochemical properties of the growing media were altered by the addition of both MAP residues to the peat-based mixtures. The media's ability to hold water and free air was significantly reduced as a consequence of the observed reduction in free pore space. Nonetheless, there was an increase in the amount of organic matter and minerals that were available for use by plants in both of the used wastes. The addition of ODW and SCW in the growing medium had a negative effect on a plant's physiological characteristics and reduced leaf stomatal conductance, especially at high residue ratios of 20–40%. Moreover, the degradation of organic waste increased mineral availability, which accumulated in plant tissues (especially P, K, and Na). However, the use of high ratios of MAP waste significantly inhibited the growth of purslane plants, a finding that could be attributed to the development of stress conditions since both nonenzymatic and enzymatic antioxidant mechanisms were induced. The current study concludes that both ODW and SCW can be used in growth media at low ratios (up to 10%), which, despite a slight growth inhibition, may result in increased antioxidant compound content and improved nutritional benefits of the edible plant parts. However, the introduction of these new materials as peat substitutes requires the investigation of agronomic practices that could further improve the properties of the growing media's improvement and ensure high crop yields. MAP residues can also be considered to fertilize agricultural soils that can soften the observed negative effects found on the growing media's properties. Additionally, the use of inert materials with big particle size, such as perlite, in the growing media in higher ratios, i.e., 20–30%, could increase porosity and alleviate the negative effects of MAP waste on this particular parameter. Composting is also a practice that can be considered in order to produce stable material, but limitations of the process also need to be considered, such as time, space, energy, and cost-demanding process.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/horticulturae9040474/s1, Figure S1. MAP residues' particle size and uniformity index evaluation for *Origanum dubium* waste (ODW) and *Sideritis cypria* waste (SCW). Table S1. Growing media's (peat, *Origanum dubium* waste (ODW)) physicochemical properties after plant harvesting (at the end of the growing period). In parenthesis is the percentage of properties' changes compared with the start of the experiment—see Table 1. Table S2. Growing media's (peat, *Sideritis cypria* waste (SCW)) physicochemical properties after plant harvesting (at the end of the growing period). In parenthesis is the percentage of properties' changes compared with the start of the experiment—see Table 2.

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References

1. Santana-Méridas, O.; González-Coloma, A.; Sánchez-Vioque, R. Agricultural residues as a source of bioactive natural products. *Phytochem. Rev.* **2012**, *11*, 447–466. [CrossRef]
2. Saha, A.; Basak, B.B. Scope of value addition and utilization of residual biomass from medicinal and aromatic plants. *Ind. Crops Prod.* **2020**, *145*, 111979. [CrossRef]
3. Olofsson, J.; Börjesson, P. Residual biomass as resource—Life-cycle environmental impact of wastes in circular resource systems. *J. Clean. Prod.* **2018**, *196*, 997–1006. [CrossRef]
4. Ferhat, M.A.; Meklati, B.Y.; Chemat, F. Comparison of different isolation methods of essential oil from Citrus fruits: Cold pressing, hydrodistillation and microwave 'dry' distillation Mohamed. *Flavour Fragr. J.* **2008**, *22*, 494–504. [CrossRef]
5. Saha, A.; Tripathy, V.; Basak, B.B.; Kumar, J. Entrapment of distilled palmarosa (*Cymbopogon martinii*) wastes in alginate beads for adsorptive removal of methylene blue from aqueous solution. *Environ. Prog. Sustain. Energy* **2018**, *37*, 1942–1953. [CrossRef]
6. Sayed-Ahmad, B.; Talou, T.; Saad, Z.; Hijazi, A.; Merah, O. The Apiaceae: Ethnomedicinal family as source for industrial uses. *Ind. Crops Prod.* **2017**, *109*, 661–671. [CrossRef]
7. Skendi, A.; Irakli, M.; Chatzopoulou, P.; Bouloumpasi, E.; Biliaderis, C.G. Phenolic extracts from solid wastes of the aromatic plant essential oil industry: Potential uses in food applications. *Food Chem. Adv.* **2022**, *1*, 100065. [CrossRef]
8. Zhou, Y.; Manu, M.K.; Li, D.; Johnravindar, D.; Selvam, A.; Varjani, S.; Wong, J. Effect of Chinese medicinal herbal residues compost on tomato and Chinese cabbage plants: Assessment on phytopathogenic effect and nutrients uptake. *Environ. Res.* **2023**, *216*, 114747. [CrossRef] [PubMed]
9. Gruda, N.S. Increasing sustainability of growing media constituents and stand-alone substrates in soilless culture systems. *Agronomy* **2019**, *9*, 298. [CrossRef]
10. Ma, J.; Chen, Y.; Wang, K.; Huang, Y.; Wang, H. Re-utilization of Chinese medicinal herbal residues improved soil fertility and maintained maize yield under chemical fertilizer reduction. *Chemosphere* **2021**, *283*, 131262. [CrossRef] [PubMed]
11. Ratiarisoa, R.V.; Magniont, C.; Ginestet, S.; Oms, C.; Escadeillas, G. Assessment of distilled lavender stalks as bioaggregate for building materials: Hygrothermal properties, mechanical performance and chemical interactions with mineral pozzolanic binder. *Constr. Build. Mater.* **2016**, *124*, 801–815. [CrossRef]
12. Singh, P.; Hundal, J.S.; Patra, A.K.; Wadhwa, M.; Sharma, A. Sustainable utilization of *Aloe vera* waste in the diet of lactating cows for improvement of milk production performance and reduction of carbon footprint. *J. Clean. Prod.* **2021**, *288*, 125118. [CrossRef]
13. Xiao, D.; Shao, H.; Huo, Y.; Agung Nugroho, W.; Ifeoluwa Ogunniran, B.; Fan, W.; Huo, M. Reclamation of ginseng residues using two-stage fermentation and evaluation of their beneficial effects as dietary feed supplements for piglets. *Waste Manag.* **2022**, *154*, 293–302. [CrossRef] [PubMed]
14. Chrysargyris, A.; Antoniou, O.; Xylia, P.; Petropoulos, S.; Tzortzakis, N. The use of spent coffee grounds in growing media for the production of *Brassica* seedlings in nurseries. *Environ. Sci. Pollut. Res.* **2021**, *28*, 24279–24290. [CrossRef] [PubMed]
15. Chrysargyris, A.; Antoniou, O.; Athinodorou, F.; Vassiliou, R.; Papadaki, A.; Tzortzakis, N. Deployment of olive-stone waste as a substitute growing medium component for *Brassica* seedling production in nurseries. *Environ. Sci. Pollut. Res.* **2019**, *26*, 35461–35472. [CrossRef] [PubMed]
16. Patsalou, M.; Chrysargyris, A.; Tzortzakis, N.; Koutinas, M. A biorefinery for conversion of citrus peel waste into essential oils, pectin, fertilizer and succinic acid via different fermentation strategies. *Waste Manag.* **2020**, *113*, 469–477. [CrossRef] [PubMed]
17. Bolechowski, A.; Moral, R.; Bustamante, M.A.; Bartual, J.; Paredes, C.; Pérez-Murcia, M.D.; Carbonell-Barrachina, A.A. Winery-distillery composts as partial substitutes of traditional growing media: Effect on the volatile composition of thyme essential oils. *Sci. Hortic.* **2015**, *193*, 69–76. [CrossRef]
18. Lu, Q.; Li, C. Comprehensive utilization of Chinese medicine residues for industry and environment protection: Turning waste into treasure. *J. Clean. Prod.* **2021**, *279*, 123856. [CrossRef]
19. Ilangovan, M.; Guna, V.; Hu, C.; Nagananda, G.S.; Reddy, N. *Curcuma longa* L. plant residue as a source for natural cellulose fibers with antimicrobial activity. *Ind. Crops Prod.* **2018**, *112*, 556–560. [CrossRef]
20. Bistgani, Z.E.; Hashemi, M.; DaCosta, M.; Craker, L.; Maggi, F.; Morshedloo, M.R. Effect of salinity stress on the physiological characteristics, phenolic compounds and antioxidant activity of *Thymus vulgaris* L. and *Thymus daenensis* Celak. *Ind. Crops Prod.* **2019**, *135*, 311–320. [CrossRef]
21. Bustamante, M.A.; Paredes, C.; Moral, R.; Agulló, E.; Pérez-Murcia, M.D.; Abad, M. Composts from distillery wastes as peat substitutes for transplant production. *Resour. Conserv. Recycl.* **2008**, *52*, 792–799. [CrossRef]
22. Giménez, A.; Fernández, J.A.; Pascual, J.A.; Ros, M.; Saez-Tovar, J.; Martinez-Sabater, E.; Gruda, N.S.; Egea-Gilabert, C. Promising composts as growing media for the production of baby leaf lettuce in a floating system. *Agronomy* **2020**, *10*, 1540. [CrossRef]
23. Ceglie, F.G.; Bustamante, M.A.; Ben Amara, M.; Tittarelli, F. The challenge of peat substitution in organic seedling production: Optimization of growing media formulation through mixture design and response surface analysis. *PLoS ONE* **2015**, *10*, e0128600. [CrossRef]
24. Chrysargyris, A.; Antoniou, O.; Tzionis, A.; Prasad, M.; Tzortzakis, N. Alternative soilless media using olive-mill and paper waste for growing ornamental plants. *Environ. Sci. Pollut. Res.* **2018**, *25*, 35915–35927. [CrossRef]
25. Petropoulos, S.; Fernandes, Â.; Stojković, D.; Pereira, C.; Taofiq, O.; Di Gioia, F.; Tzortzakis, N.; Soković, M.; Barros, L.; Ferreira, I.C.F.R. Cotton and cardoon byproducts as potential growing media components for *Cichorium spinosum* L. commercial cultivation. *J. Clean. Prod.* **2019**, *240*, 118254. [CrossRef]

26. Chrysargyris, A.; Stamatakis, A.; Moustakas, K.; Prasad, M.; Tzortzakis, N. Evaluation of Municipal Solid Waste Compost and/or Fertigation as Peat Substituent for Pepper Seedlings Production. *Waste Biomass Valorization* **2018**, *9*, 2285–2294. [CrossRef]
27. Chrysargyris, A.; Tzortzakis, N. Municipal solid waste compost as a peat substitute for vegetable seedling production. A case study on cucumber and endive seedlings. In *Municipal Solid Waste: Management Strategies, Challenges and Future Directions*; Tzortzakis, N., Ed.; Nova Science Publishers, Inc.: Hauppauge, NY, USA, 2017; pp. 367–386.
28. Mill, L.A.; Najar, B.; Demasi, S.; Caser, M.; Gaino, W.; Cioni, P.L.; Pistelli, L.; Scariot, V. Cultivation substrate composition influences morphology, volatilome and essential oil of *Lavandula angustifolia* Mill. *Agronomy* **2019**, *9*, 411.
29. Fan, R.; Luo, J.; Yan, S.; Zhou, Y.; Zhang, Z. Effects of Biochar and Super Absorbent Polymer on Substrate Properties and Water Spinach Growth. *Pedosphere* **2015**, *25*, 737–748. [CrossRef]
30. Chrysargyris, A.; Saridakis, C.; Tzortzakis, N. Use of Municipal Solid Waste Compost as Growing Medium Component for Melon Seedlings Production. *J. Plant Biol. Soil Health* **2013**, *2*, 1–5.
31. Chrysargyris, A.; Prasad, M.; Kavanagh, A.; Tzortzakis, N. Biochar type, ratio, and nutrient levels in growing media affects seedling production and plant performance. *Agronomy* **2020**, *10*, 1421. [CrossRef]
32. Tubeileh, A.M.; Souikane, R.T. Effect of olive vegetation water and compost extracts on seed germination of four weed species. *Curr. Plant Biol.* **2020**, *22*, 100150. [CrossRef]
33. Kelepesi, S.; Tzortzakis, N.G. Olive mill wastesA growing medium component for seedling and crop production of lettuce and chicory. *Int. J. Veg. Sci.* **2009**, *15*, 325–339. [CrossRef]
34. Kuczmarski, D. Amending the cost of media. *Am. Nurs. Manag.* **1994**, *179*, 47–52.
35. Tsakaldimi, M. Kenaf (*Hibiscus cannabinus* L.) core and rice hulls as components of container media for growing Pinus halepensis M. seedlings. *Bioresour. Technol.* **2006**, *97*, 1631–1639. [CrossRef]
36. Chrysargyris, A.; Hajisolomou, E.; Xylia, P.; Tzortzakis, N. Olive-mill and grape-mill waste as a substitute growing media component for unexploded vegetables production. *Sustain. Chem. Pharm.* **2023**, *31*, 100940. [CrossRef]
37. Tebenkova, D.N.; Lukina, N.V.; Vorobyev, R.A.; Orlova, M.A.; Gagarin, Y.N. Germination and biometric parameters of seedlings grown on solid pulp and paper waste medium. *Contemp. Probl. Ecol.* **2015**, *8*, 892–900. [CrossRef]
38. Chugh, V.; Mishra, V.; Vishal Chugh, C.; Dwivedi, S.; Sharma, K. Purslane (*Portulaca oleracea* L.): An underutilized wonder plant with potential pharmacological value. *Pharma Innov. J.* **2019**, *8*, 236–246.
39. Kumar, A.; Sreedharan, S.; Kashyap, A.K.; Singh, P.; Ramchiary, N. A review on bioactive phytochemicals and ethnopharmacological potential of purslane (*Portulaca oleracea* L.). *Heliyon* **2022**, *8*, e08669. [CrossRef]
40. Petropoulos, S.A.; Fernandes, Â.; Calhelha, R.C.; Rouphael, Y.; Petrović, J.; Soković, M.; Ferreira, I.C.F.R.; Barros, L. Antimicrobial properties, cytotoxic effects, and fatty acids composition of vegetable oils from purslane, linseed, luffa, and pumpkin seeds. *Appl. Sci.* **2021**, *11*, 5738. [CrossRef]
41. Carrascosa, A.; Pascual, J.A.; Ros, M.; Petropoulos, S.A.; Alguacil, M. Agronomical Practices and Management for Commercial Cultivation of *Portulaca oleracea* as a Crop: A Review. *Plants* **2023**, *12*, 1246. [CrossRef]
42. Petropoulos, S.A.; Karkanis, A.; Martins, N.; Ferreira, I.C.F.R. Edible halophytes of the Mediterranean basin: Potential candidates for novel food products. *Trends Food Sci. Technol.* **2018**, *74*, 69–84. [CrossRef]
43. Thalassinos, G.; Petropoulos, S.A.; Antoniadis, V. The Response of Purslane (*Portulaca oleracea*) to Soil-Added Pb: Is It Suitable as a Potential Phytoremediation Species? *Toxics* **2023**, *11*, 153. [CrossRef]
44. Eliasson, J. *Sand/Media Specifications*; Washington State Department of Health: Tumwater, WA, USA, 2002.
45. *European Standard EN 13041*; Soil Improvers and Growing Media—Determination of Physical Properties—Dry Bulk Density, Air Volume, Water Volume, Shrinkage Value and Total Pore Space. European Committee for Standardization: Brussels, Belgium, 1999.
46. Chrysargyris, A.; Nikolaidou, E.; Stamatakis, A.; Tzortzakis, N. Vegetative, physiological, nutritional and antioxidant behavior of spearmint (*Mentha spicata* L.) in response to different nitrogen supply in hydroponics. *J. Appl. Res. Med. Aromat. Plants* **2017**, *6*, 52–61. [CrossRef]
47. Tzortzakis, N.; Pitsikoulaki, G.; Stamatakis, A.; Chrysargyris, A. Ammonium to Total Nitrogen Ratio Interactive Effects with Salinity Application on *Solanum lycopersicum* Growth, Physiology, and Fruit Storage in a Closed Hydroponic System. *Agronomy* **2022**, *12*, 386. [CrossRef]
48. Meyers, K.J.; Watkins, C.B.; Pritts, M.P.; Liu, R.H. Antioxidant and antiproliferative activities of strawberries. *J. Agric. Food Chem.* **2003**, *51*, 6887–6892. [CrossRef]
49. Loreto, F.; Velikova, V. Isoprene produced by leaves protects the photosynthetic apparatus against ozone damage, quenches ozone products, and reduces lipid peroxidation of cellular membranes. *Plant Physiol.* **2001**, *127*, 1781–1787. [CrossRef] [PubMed]
50. De Azevedo Neto, A.D.; Prisco, J.T.; Enéas-Filho, J.; De Abreu, C.E.B.; Gomes-Filho, E. Effect of salt stress on antioxidative enzymes and lipid peroxidation in leaves and roots of salt-tolerant and salt-sensitive maize genotypes. *Environ. Exp. Bot.* **2006**, *56*, 87–94. [CrossRef]
51. Rinaldi, S.; De Lucia, B.; Salvati, L.; Rea, E. Understanding complexity in the response of ornamental rosemary to different substrates: A multivariate analysis. *Sci. Hortic.* **2014**, *176*, 218–224. [CrossRef]
52. Chand, S.; Anwar, M.; Patra, D.D.; Khanuja, S.P.S. Effect of Mint Distillation Waste on Soil Microbial Biomass in a Mint-Mustard Cropping Sequence. *Commun. Soil Sci. Plant Anal.* **2004**, *35*, 243–254. [CrossRef]
53. Abad, M.; Noguera, P.; Burés, S. National inventory of organic wastes for use as growing media for ornamental potted plant production: Case study in Spain. *Bioresour. Technol.* **2001**, *77*, 197–200. [CrossRef]

54. Lasaridi, K.; Protopapa, I.; Kotsou, M.; Pilidis, G.; Manios, T.; Kyriacou, A. Quality assessment of composts in the Greek market: The need for standards and quality assurance. *J. Environ. Manag.* **2006**, *80*, 58–65. [CrossRef] [PubMed]
55. Zhou, Y.; Selvam, A.; Wong, J.W.C. Effect of Chinese medicinal herbal residues on microbial community succession and anti-pathogenic properties during co-composting with food waste. *Bioresour. Technol.* **2016**, *217*, 190–199. [CrossRef] [PubMed]
56. Wang, P.; Zhan, S.; Yu, H.; Xue, X.; Hong, N. The effects of temperature and catalysts on the pyrolysis of industrial wastes (herb residue). *Bioresour. Technol.* **2010**, *101*, 3236–3241. [CrossRef] [PubMed]
57. Ribeiro, H.M.; Romero, A.M.; Pereira, H.; Borges, P.; Cabral, F.; Vasconcelos, E. Evaluation of a compost obtained from forestry wastes and solid phase of pig slurry as a substrate for seedlings production. *Bioresour. Technol.* **2007**, *98*, 3294–3297. [CrossRef] [PubMed]
58. Patra, D.D.; Anwar, M.; Chand, S. Integrated nutrient management and waste recycling for restoring soil fertility and productivity in Japanese mint and mustard sequence in Uttar Pradesh, India. *Agric. Ecosyst. Environ.* **2000**, *80*, 267–275. [CrossRef]
59. Tüzel, Y.; Ekinci, K.; Öztekin, G.B.; Erdal, I.; Varol, N.; Merken, Ö. Utilization of olive oil processing waste composts in organic tomato seedling production. *Agronomy* **2020**, *10*, 797. [CrossRef]
60. Papafotiou, M.; Kargas, G.; Lytra, I. Olive-mill waste compost as a growth medium component for foliage potted plants. *HortScience* **2005**, *40*, 1746–1750. [CrossRef]
61. Ouzounidou, G.; Asfi, M.; Sotirakis, N.; Papadopoulou, P.; Gaitis, F. Olive mill wastewater triggered changes in physiology and nutritional quality of tomato (*Lycopersicon esculentum* Mill.) depending on growth substrate. *J. Hazard. Mater.* **2008**, *158*, 523–530. [CrossRef]
62. Kiarostami, K.; Mohseni, R.; Saboora, A. Biochemical changes of *Rosmarinus officinalis* under salt stress. *J. Stress Physiol. Biochem.* **2010**, *6*, 114–122.
63. Carmona, E.; Moreno, M.T.; Avilés, M.; Ordovas, J. Composting of wine industry wastes and their use as a substrate for growing soilless ornamental plants. *Span. J. Agric. Res.* **2012**, *10*, 482. [CrossRef]
64. Chrysargyris, A.; Maggini, R.; Incrocci, L.; Pardossi, A.; Tzortzakis, N. Copper tolerance and accumulation on *Pelargonium graveolens* l'hér. Grown in hydroponic culture. *Plants* **2021**, *10*, 1663. [CrossRef] [PubMed]