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Use of Medicinal and Aromatic Plant Residues for Partial Peat Substitution in Growing Media for *Sonchus oleraceus* Production

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Abstract: A substantial quantity of solid waste that is high in phenolics and biocomponents is produced during the industrial manufacturing of essential oils (EOs); this presents an important management challenge for the EO sector. This currently produces a significant amount of residue, causing issues of disposal and management and the impact that the residues have on both the environment and human health. The present study evaluated the potential use of *Origanum dubium* Boiss. residues (ODR) and *Sideritis cypria* Post. residues (SCR) derived via distillation at different levels (0–5–10–20–40% v/v) for use in partial peat substitution in the production of *Sonchus oleraceus* L. (sowthistle) plants. Both ODR and SCR accelerated the pH, electrical conductivity, organic matter content, and mineral content of the growing media, but also negatively affected several of the physical characteristics of the media, such as the total porosity and aeration. This resulted in decreased plant growth, which was more noticeable at the high residue ratios. Plants responded to this by decreasing the leaf stomatal conductance, decreasing the chlorophyll content at 40% ODR and 20% SCR mixtures, and activating several non-enzymatic (phenols, flavonoids, and antioxidant capacity) and enzymatic (superoxide dismutase) mechanisms to challenge the observed stress conditions, as indicated by lipid peroxidation and the hydrogen peroxide increase. Plants grown in residue media exhibited changes in mineral accumulation, even though both ODR and SCR were rich in minerals. It may be concluded that ODR and SCR, when employed at low levels of 10% and 20%, respectively, have the potential for use in the preparation of growing media as they may increase plant material antioxidants, but further improvement of the growing media's properties is needed to ensure adequate yield.

Keywords: sowthistle; distillation; plant growth; peat; wild edible species; antioxidants; minerals

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1. Introduction

Recently, there has been increased scientific interest in medicinal and aromatic plants (MAPs), particularly in members of the Lamiaceae family, which represent a reservoir of natural bioactive molecules with possible applications not only within the pharmaceutical and cosmetics industries but also in the food sector [1]. MAP material is used in its raw, dried, or frozen form for the production of essential oils (EOs) and to obtain plant extracts with various biocidal activities and uses [2,3]. The industry for EOs is primarily centered on extracting them from MAPs using various traditional and/or cutting-edge techniques, each of which has a different effect on the yield, content, and quality of the final product [4]. Essential oil extraction mainly takes place via hydro distillation, steam distillation, hydro-steam distillation, with organic solvents, and, less frequently, by mechanical extraction, but all techniques make high demands in terms of time and operational costs [5,6]. Several new technologies, whether eco-friendly or sustainable, and whether more or less economically viable, are currently being tested [4]; however, the issue of the MAP residues following the extraction process still remains unsolved, with the residues comprising more than 200,000 tons worldwide each year [7]. EO yield can vary from very little to usually up to 5–8% of the extracted biomass; therefore, huge amounts of residues (solid waste and hydrolate, the aqueous byproduct) need to be handled and disposed of [8]. The majority of these byproducts are dealt with by burning them or dumping them in landfills as garbage [9]; however, this practice not only impacts the environment but also wastes resources, since many of the components that remain in the residue can be used to gather useful products, such as phenolics and bioactive components [4,10,11].

The reuse of plant residues is attracting research interest but is also of great environmental concern. A recent method of reusing the residue is biotransformation; this is considered a fascinating method for recycling herbal leftovers, including in fermentation or composting processes [12]. Moreover, other MAP residue uses have been reported, including the use of lavender stalks after distillation as bioaggregate construction material [13], the use of *Aloe vera* residues to supplement the diet of lactating cows [14], and the use of distilled rosemary (*Rosmarinus officinalis*) in the partial substitution of oat hay into the diets of Tunisian goats without negative effects on the diets' digestibility and the goats' milk production [15]. Indeed, often, the extraction of different components require novel ideas or specific methods (i.e., heating, alkali, enzymatic treatment, and microbial conversion) [16]. Several studies have been performed on the use of plant residues in agriculture after they have been composted, along with a variety of other residues, as well as the benefits of using the composted material as organic fertilizers and soil enhancers [1,17,18]; however, their utility as a growing material in soilless agriculture, either composted or raw, has received less attention [19–21].

Peat is the principal growing medium component used in agriculture because of its suitable agronomic features; consequently, an estimated 14–20% of collected peat is typically distributed to the horticulture industry [22,23]. However, according to Council Directive 92/43/EEC, peatlands are protected areas since they are natural habitats for their untouched fauna and vegetation, and several environmental constraints are in place to counter peat extraction. Peat use should, then, gradually be decreased as it is a non-renewable feedstock and acts as a large carbon dioxide sink, and the exploration of high-quality alternatives that are also inexpensive should be stepped up [22,24]. For the replacement of peat, several agroindustry residues have been suggested in several studies on substrate- or pot-grown ornamental and horticultural crops, with promising applications in terms of plant growth in nurseries, greenhouses, and field crops [19,25–30]. When preparing a growing medium, the main considerations are the choice of material used, their ratios and material stability, the mineral status, the method of fertilization used, and the physicochemical properties [26,27,31,32]. Usually, a potting medium consists of two or more components and is made up of a blend of materials, to achieve the most appropriate medium characteristics possible. It is well known that composting is the primary waste management method; it is frequently practiced with plant residues, producing a consistent material that is suitable for agricultural use, mainly for soil amendment and, less frequently, as organic fertilizing material [33–36]. Nonetheless, this procedure necessitates the commitment of a significant amount of time, land space, and knowledge, and may occasionally yield harmful components that may even be phytotoxic [37,38]. Some composted materials have been combined with peat at a ratio of more than 50% to achieve superior growth media [39]. Additionally, there are examples where farmers employ unprocessed material in their fields without taking into account the potential harm that it may do to the crops, ecosystem, and public health [40,41]. It has been reported that the use of fresh rice hull on deciduous trees and flowering shrubs [42], fresh rice and kenaf in the production of *Pinus halepensis* seedlings [43], spent coffee grounds in the production of *Brassica* seedlings [19], olive-mill wastes and grape-mill wastes in vegetable production [44], shredded paper waste in the production of ornamental plants and conifer seedlings [25,45] can cause some limitations in terms of their successive application, depending on the material used, the mixture's physicochemical properties, the growing/environmental conditions, and the plant species examined.

Due to its scarcity and high cost, peat may only be used in nurseries to a limited extent before being substantially substituted with other materials. In order to offer alternate applications for bulky byproducts, the primary goal of this research was to look into the utilization of residues from the MAP sector to partially substitute peat in the production of wild edible species and unusual vegetables such as sowthistle (*Sonchus oleraceus* L.). The second objective of this study was to determine how the examined byproducts impacted the nutritional value, chemical content, and bioactive components of sowthistle leaves, in an attempt to identify the best growing conditions that could enhance plant growth parameters and boost the final product's quality. *S. oleraceus* flowers, leaves, and stems are used in vegetable pies, soups, and fresh or boiled/steamed salads [46]. The high nutritional value of *Sonchus* species has been studied and is widely recognized since they have strong antioxidant activity [47] and high contents of polyphenols, flavonoids, and organic acids [47–49] and deserve to be classified as nutraceuticals [50]. Examining wild edible species and unusual vegetables such as sowthistle can reveal their documented properties, such as anti-tumor [51], antioxidant [47,52], nutritional [53], antidiabetic, anti-inflammatory, antipyretic, cytotoxic, and antimicrobial activities [54], to name a few, while MAP residues in the context of soilless culture give an element of innovation to the present study.

2. Materials and Methods

2.1. Plant Material and Growing Media Preparation

The present study took place at the Hydroponic Greenhouse structures (with completely automated climate control) of the Cyprus University of Technology, at Limassol, Cyprus. Peat (professional-grade peat from Gebr. Brill Substrate GmbH & Co. KG, Georgsdorf, Germany) was used as the control growing media for the study. Peat was supplemented with minerals using fertilizers (Novatec, simple superphosphate, and potassium sulfate) to achieve 75 mg N/L, 50 mg P_2O_5/L, and 125 mg K_2O/L, respectively, reaching the adequate mineral levels for growing media. The peat and fertilizers were then mixed thoroughly.

Origanum dubium Boiss. distilled residues (ODR) and *Sideritis cypria* Post. distilled residues (SCR) were obtained after a steam-hydro distillation process for extracting the essential oils from the relevant plant material. Plants were grown under a conventional cultivation scheme and were provided by the Department of Agriculture's Sector of Medicinal and Aromatic Plants, Nicosia, Cyprus. Common cultivation management was applied to the crops, including annual tillage, pruning, fertilizer or manure application, and crop protection application with pesticides, as were usually adopted in the selected region. Plant material was air-dried under shading and then subjected to steam-hydro distillation using semi-commercial distillatory equipment of 60 L capacity. The distillation residues were left to dry (the moisture level was $\leq$10%) and then shredded (laboratory grinding mill, Polymix® System PX-MFC 90d, Kinematica GmbH, Eschbach, Germany) and stored in dry conditions until use. The characteristics of the ODR 100% and SCR 100% material were analyzed as described in Section 2.2.

Several growing media were prepared using peat (P) as the basic component, then peat was proportionally substituted at different ratios (by volume) of ODR or SCR, resulting in the following 9 media mixtures (*v*/*v*): for the oregano residues, (1) peat at 100% (control), (2) P:ODR 95:5 (ODR 5%), (3) P:ODR 90:10 (ODR 10%), (4) P:ODR 80:20 (ODR 20%), and (5) P:ODR 60:40 (ODR 40%); for the *Sideritis* residues, (1) 100% peat (control), (6) P:SCR 95:5 (SCR 5%), (7) P:SCR 90:10 (SCR 10%), (8) P:SCR 80:20 (GSC 20%), and (9) P:SCR 60:40 (SCR 40%),. Prior to seedling transplantation, the raw growing media were sampled and analyzed for their physicochemical characteristics. The ODR and SCR levels were determined, based on preliminary tests and/or previous experiences with plant residues incorporated in growing media [25,44].

Sowthistle (*Sonchus oleraceus* L.) seeds were purchased and placed in black plastic trays filled with peat for germination. When the seedlings had 3 true leaves, they were transplanted into 0.3 L plastic pots containing the 9 different growing media under evaluation.

For each type of growing media, 8 replicate pots were utilized, and each pot had a single seedling. The pots were placed on plastic trays to maintain the drained solution after each watering. During the seedling growth, there was no application of fertilizers, insecticides, or other plant protection products, and the seedlings were subjected to uniform experimental conditions. Climatic conditions based on temperature, humidity, and light were observed during the cultivation period, and averaged 19.9 °C, 58.1%, and 1477.5 Lux, respectively.

2.2. Growing Media Characteristics

The physicochemical characteristics of the tested growing media and those of the raw materials were analyzed. Total pore space (TPS), air-filled porosity (AFP), available water-holding capacity (AWHC), and bulk density (BD) by volume of the growing media were determined based on the European Standard EN 13,041 [55], as described elsewhere [25]. The pH and the electrical conductivity (EC) of each growing medium were measured (1:5 v/v). Organic matter content and organic C were determined when the media were burned to ash at 550 °C in a furnace [32]. For mineral analysis, the ash samples were then digested with acid (2 N HCl), and the macronutrients of potassium (K) and sodium (Na) were measured using a flame photometer (Lasany Model 1832, Lasany International, Panchkula, India) to establish phosphorus (P) by spectrophotometry (Multiskan GO, Thermo Fisher Scientific, Waltham, MA, USA), while magnesium (Mg) and calcium (Ca) were measured with an atomic absorption spectrophotometer (PG Instruments AA500FG, Leicestershire, UK). Nitrogen (N) was determined by the Kjeldahl method (BUCHI, Digest Automat K-439 and Distillation Kjelflex K-360, Flawil, Switzerland) following the method of Chrysargyris et al. [25]. Data were expressed in g/kg of dry weight.

2.3. Plant Growth, Physiology, and Mineral Analysis

Sowthistle plants were grown for 27 days, and then several growth-related parameters were measured, with 6 seedlings per treatment. Leaf numbers per plant and seedling height were recorded. Seedlings were harvested and the upper fresh biomass was weighed (g) and dried, then the total dry weight (in g) was measured.

Moreover, various physiological parameters were recorded before harvesting. Leaf stomatal conductance was measured with a ΔT-Porometer AP4 (Delta-T Devices, Cambridge, UK). Leaf chlorophyll fluorescence was recorded on 2 fully expanded leaves per plant (Opti-Sciences fluorometer OS-30p, Hertfordshire, UK). The contents of the leaf chlorophylls/pigments were also determined (6 replications/treatment) after dimethyl sulfoxide (DMSO) extraction, and chlorophyll a (Chl a), chlorophyll b (Chl b), total chlorophylls (total Chl), and carotenoid contents were expressed as mg of chlorophyll (or carotenoids) per g of fresh weight (mg Chl/g fw or mg Car/g fw) [56].

Mineral content in plant leaves was determined on 4 replications/treatment (2 pooled plants/replication). The plant tissue was dried (~0.35 g), ashed, and acid-digested with 2 N HCl. Phosphorus content was assessed via spectrophotometry (Multiskan GO, Thermo Fischer Scientific, Waltham, MA, USA), and N was assessed with the Kjeldahl method (BUCHI, Digest automat K-439 and Distillation Kjelflex K-360, Switzerland) following the method used by Chrysargyris et al. [25]. Potassium, Na, Mg, and Ca were measured by Ion Chromatography (ICS-3000, Dionex Aquion, Sunnyvale, CA, USA) and an IonPac CS19 analytical column (4 × 250 mm, Dionex Corporation). Data were expressed in g/kg of dry weight.

2.4. Total Phenolics, Total Flavonoids, and Antioxidant Activity

Methanolic extracts from the plant tissue were produced, from 4 samples (2 pooled plants/sample) for each treatment, for the determination of total phenolics, total flavonoids, and the total antioxidant activity. Folin–Ciocalteu reagent (Merck, Darmstadt, Germany) was used to determine the total phenols and the results were expressed as mg of gallic acid equivalents per g of fresh weight [57]. Total flavonoid content was determined according to the aluminum chloride colorimetric method [58]; the results were expressed as mg of rutin equivalents per g of fresh weight. For antioxidant activity, two assays were used, namely, ferric-reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH). These were performed, as described previously [20], and the results were expressed as Trolox equivalents per g of fresh weight.

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

Lipid peroxidation, in terms of malondialdehyde content (MDA) and hydrogen peroxide (H_2O_2) content, was determined as described previously [59,60]. The results were expressed as the MDA content, reported in nmol of MDA per g of fresh weight and as μmol H_2O_2 per g of fresh weight.

The antioxidant enzymes activities for superoxide dismutase (SOD) (EC 1.15.1.1) and for catalase (CAT) (EC 1.11.1.6) were determined, as described previously [44], and the absorbance was determined to be 560 nm for SOD and 240 nm for CAT. Peroxidase activity (POD) (EC 1.11.1.6) was determined following the increase in absorbance at 430 nm as described previously [44]. Results were expressed as enzyme units per mg of protein. The protein content was determined via the Bradford method and bovine serum albumin was used as standard.

2.6. Statistical Analysis

Statistical analysis was performed using the IBM SPSS program, version 22.0 (SPSS Inc., Chicago, IL, USA). Prior to the analysis of variance (ANOVA), data were examined for normality. Mean comparisons were performed using Duncan's multiple range test (DMRT) at $p \leq 0.05$, following the one-way ANOVA.

3. Results and Discussion

Not all plant residues are candidates as good growing media for seedling or cutting production in nurseries or for plant growth in pots. The use and application of these residues may be restricted by the pH, salt levels, and other phytochemical components (such as polyphenols levels), as these may result in phytotoxic stress [61]. In this framework, evaluating the effects of the growing media's composition on plant growth and yield is a very complex subject that demands the evaluation of several physical, chemical, and biological variables. Both the examined MAP residues (ODR and SCR) in the current study were rich in minerals and contributed to the growing media mixture characteristics when used in various ratios with peat (Tables 1 and 2). Specifically, ODR contained slide acidic pH (averaged at 5.95), high organic content and bulk density, as well as high levels of N (1.05%), K (1.34%), P (0.28%), Na (0.12%), and Mg (0.26%), which led to a higher EC when compared to peat (Table 1). However, ODR, when compared to peat, contained only a small amount of Ca (0.76%). In terms of SCR, it was observed to have a practically neutral pH (averaged in 6.75), enhanced organic matter content and available water-holding capacity, as well as high levels of N (1.26%), K (1.41%), P (0.16%), Na (0.57%), and Mg (0.17%), which resulted in an increased EC (Table 2). However, SCR, when compared to peat, contained only a small amount of Ca (1.15%) and bulk density. It has been reported that distillation residues often contain micronutrients in sufficient amounts, together with 0.35–1.80% N, 0.45–0.60% P, and 2.00–2.25% K [62] when considering the examined MAP residues as a fertile material. However, in the present work, the micronutrients were not evaluated; this will be important to consider in future studies. There are no reference values for the raw materials' properties due to the great diversity of the raw materials and the decomposition status; however, more reports are available on the composted material, which is a more stable material when decomposed. Therefore, the properties of the examined ODR and SCR were within limitations, except for the air-fill porosity of ODR, which was 1.57% [63]. The EC of the studied ODR and SCR raw materials was measured below the recommended EC of 4 mS/cm for composted materials, indicating the safe use of the residues without any initial phytotoxicity in the young plants [37].

Table 1. Growing media (peat and *Origanum dubium* Boiss. residue (ODR)), showing its physicochemical properties before plant transplantation.

	Peat 100%	ODR 5%	ODR 10%	ODR 20%	ODR 40%	ODR 100%
pH	6.32 ± 0.31 b	6.39 ± 0.09 b	6.31 ± 0.16 b	6.63 ± 0.02 b	7.51 ± 0.28 a	5.95 ± 0.15 c
EC (mS/cm)	0.84 ± 0.08 c	1.14 ± 0.13 bc	0.89 ± 0.04 bc	1.12 ± 0.07 b	1.70 ± 0.32 a	1.92 ± 0.23 a
Organic matter (%)	72.39 ± 2.23 cd	73.03 ± 0.63 c	73.30 ± 1.27 c	70.16 ± 0.66 d	76.92 ± 1.88 b	92.80 ± 0.43 a
Organic C (%)	41.99 ± 1.28 cd	42.37 ± 0.37 c	42.52 ± 0.73 c	40.70 ± 0.38 d	44.62 ± 1.09 b	53.83 ± 0.25 a
C/N ratio	50.37 ± 3.68 a	42.91 ± 1.72 b	40.92 ± 5.81 b	26.22 ± 1.16 c	28.34 ± 1.38 c	51.21 ± 0.41 a
N (g/kg)	8.35 ± 0.34 c	9.88 ± 0.35 b	10.52 ± 1.33 b	15.54 ± 0.58 a	15.78 ± 0.0.58 a	10.51 ± 0.08 b
K (g/kg)	2.03 ± 0.07 d	3.86 ± 0.55 c	3.97 ± 0.72 c	4.70 ± 0.22 c	7.36 ± 0.53 b	13.46 ± 0.19 a
P (g/kg)	1.13 ± 0.07 c	1.61 ± 0.50 bc	1.73 ± 0.16 b	1.92 ± 0.31 b	2.62 ± 0.32 a	2.83 ± 0.05 a
Ca (g/kg)	15.02 ± 0.79 b	21.52 ± 4.21 a	17.62 ± 1.71 b	20.41 ± 0.36 a	20.51 ± 0.85 a	7.66 ± 0.47 c
Mg (g/kg)	0.79 ± 0.06 e	1.51 ± 0.36 d	1.51 ± 0.16 d	2.23 ± 0.04 c	3.29 ± 0.11 a	2.68 ± 0.17 b
Na (g/kg)	0.97 ± 0.04 c	1.13 ± 0.08 b	1.19 ± 0.05 ab	1.17 ± 0.02 ab	1.32 ± 0.06 a	1.22 ± 0.14 ab
Total porosity (% *v*/*v*)	84.97 ± 1.07 a	72.68 ± 5.74 b	77.19 ± 7.76 ab	53.32 ± 2.31 c	48.60 ± 6.36 c	69.87 ± 5.50 b
Air filled porosity (% *v*/*v*)	18.43 ± 1.41 a	10.48 ± 4.14 b	9.14 ± 3.92 b	7.90 ± 0.87 b	5.51 ± 1.72 bc	1.57 ± 1.01 c
Bulk density (g/cm)	0.15 ± 0.00 c	0.17 ± 0.01 bc	0.17 ± 0.01 b	0.17 ± 0.01 b	0.18 ± 0.01 b	0.29 ± 0.01 a
Container capacity (% *v*/*v*)	66.55 ± 2.48 a	62.21 ± 2.23 a	68.05 ± 4.46 a	45.41 ± 3.19 b	43.08 ± 5.20 b	68.31 ± 4.49 a

Total porosity (TP), available water-holding capacity (AWHC-container capacity), air-filled porosity (AFP), and bulk density (BD) by volume. Values are mean ± SD (n = 4). In each row, values followed by the same letter do not differ significantly at $p < 0.05$.

Table 2. Growing media (peat and *Sideritis cypria* residue (SCR)), showing the mixture's physicochemical properties before plant transplanting.

	Peat 100%	SCR 5%	SCR 10%	SCR 20%	SCR 40%	SCR 100%
pH	6.32 ± 0.31 d	6.27 ± 0.21 d	6.53 ± 0.01 cd	6.91 ± 0.07 b	7.54 ± 0.02 a	6.71 ± 0.12 bc
EC (mS/cm)	0.84 ± 0.08 b	1.27 ± 0.13 a	1.25 ± 0.19 a	1.10 ± 0.02 a	1.19 ± 0.05 a	1.23 ± 0.19 a
Organic matter (%)	72.39 ± 2.22 b	77.64 ± 3.92 b	75.38 ± 4.58 b	75.22 ± 2.51 b	76.11 ± 2.12 b	92.80 ± 0.43 a
Organic C (%)	41.99 ± 1.28 b	45.03 ± 2.28 b	43.73 ± 2.65 b	43.63 ± 1.45 b	44.15 ± 1.23 b	53.83 ± 0.25 a
C/N ratio	50.37 ± 3.68 a	50.89 ± 2.49 a	38.38 ± 2.09 bc	36.34 ± 2.67 c	30.05 ± 1.53 d	42.57 ± 2.07 b
N (g/kg)	8.35 ± 0.34 c	8.87 ± 0.78 c	11.41 ± 0.79 b	12.04 ± 0.77 b	14.73 ± 1.13 a	12.66 ± 0.65 b
K (g/kg)	2.03 ± 0.07 f	3.12 ± 0.45 e	4.20 ± 0.56 d	6.32 ± 0.44 c	8.75 ± 0.44 b	14.60 ± 0.61 a
P (g/kg)	1.13 ± 0.07 c	1.39 ± 0.10 bc	1.70 ± 0.10 b	1.76 ± 0.12 b	2.52 ± 0.49 a	1.65 ± 0.17 b
Ca (g/kg)	15.02 ± 0796 b	16.37 ± 2.06 b	20.02 ± 0.57 a	22.57 ± 1.86 a	21.27 ± 1.27 a	11.58 ± 0.87 c
Mg (g/kg)	0.79 ± 0.06 d	1.02 ± 0.13 d	1.31 ± 0.06 c	1.82 ± 0.13 b	2.25 ± 0.11 a	1.70 ± 0.18 b
Na (g/kg)	0.97 ± 0.04 e	1.03 ± 0.12 e	1.20 ± 0.09 d	1.65 ± 0.05 c	2.03 ± 0.02 b	5.79 ± 0.07 a
Total porosity (% *v*/*v*)	84.97 ± 1.07 ab	91.82 ± 6.70 a	77.64 ± 5.91 bc	69.00 ± 6.42 cd	62.88 ± 9.15 d	98.19 ± 2.29 a
Air filled porosity (% *v*/*v*)	18.43 ± 1.41 a	15.52 ± 3.83 ab	14.29 ± 2.53 ab	13.43 ± 4.59 ab	9.62 ± 5.04 b	17.14 ± 2.02 ab
Bulk density (g/cm)	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
Container capacity (% *v*/*v*)	66.54 ± 2.48 b	76.30 ± 2.91 a	63.35 ± 4.44 b	55.58 ± 2.50 c	53.26 ± 4.11 c	81.05 ± 0.26 a

Total porosity (TP), available water-holding capacity (AWHC-container capacity), air-filled porosity (AFP), and bulk density (BD) by volume. Values are the mean ± SD (n = 4). In each row, values followed by the same letter do not differ significantly at $p < 0.05$.

The MAP residues of the peat substitute in the growing medium affected the physicochemical properties of the tested mixtures (Tables 1 and 2). Adding ODR or SCR increased the mixture's pH compared to the peat media, which was above the suggested pH range (5.3–6.5) in those cases where there was ≥20% ODR and ≥20% SCR [63]. Both ODR and SCR materials were rich in organic matter and improved the level of organic matter contents in the mixtures, with significant effects when ODR was added to the growing media (Tables 1 and 2). There is a substantial amount of organic matter in the residues' biomass produced by MAPs enterprises, which can be utilized as soil or growing media amendments [8], especially when considering that soils in the Mediterranean region are poor in organic matter, which is often at less than 2–4%.

The residue left over from extracting the pharmaceutical components from Chinese medicinal herb plants contains cellulose, protein, and polysaccharides [64], which can provide soils with N, P, and K [65]. This was evidenced in the MAP-enriched growing media in the present study, as the N, K, Mg, and P levels were significantly ($p < 0.001$) increased in the media in comparison to peat. The ODR-based media exhibited 0.98–1.57% N, 0.16–0.26% P, 0.15–0.33% Mg, and 0.38–0.73% K, while the SCR-based media exhibited 0.88–1.47% N, 0.14–0.25% P, 0.10–0.22% Mg, and 0.31–0.87% K. Moreover, Ca content was significantly ($p < 0.001$) increased at an SCR of $\geq$ 10% in comparison to peat. The EC of the MAP-based growing media was higher (ranging from 0.89 to 1.70 mS/cm) than the recommended values for growing media [63,66]. However, any mineral amendments can always be addressed by appropriate irrigation and fertilization management or by adding inert materials (i.e., sand, perlite, pumice, etc.) in the case of high mineral levels [67].

The addition of mint residues after distillation increased mustard (*Brassica juncea*) yield and improved the soil physicochemical characteristics, and may possibly be a partial substitute for the fertilizers used [68]. The physical properties of the growing media (particle size, total porosity, air-fill capacity, and water-holding capacity) are key elements for the successful culture of soilless crops. In both ODR- and SCR-based growing media, MAP residues in the growing media decreased the total porosity (this being more evident at high residue ratios), and this is reflected in the decreased air fill capacity (up to 5.51%) and available water-holding capacity (up to 43.08%), negatively affecting the properties of the growing media. The total pore space value of the tested mixtures was lower than the values of $\geq$85% porosity (except at SCR 5%) recommended by Abad et al. [63]. Perlite, for example, has a large particle size and might be added to the growing medium to increase porosity. An air capacity of 20–30% is recommended for growing media [63], although if irrigation is carefully handled, an AFP of between 7% and 10% is appropriate [69]. The above limitation to AFP reflects the negative results obtained with the use of ODR at 40% in the present work.

The effects of the MAP-based growing media on the sowthistle growing parameters are presented in Table 3. The presence of ODR or SCR in the growing media at $\geq$ 20% decreased the plant height and leaf number produced significantly, with more pronounced effects at the higher ODR or SCR levels compared to peat. This resulted in fresh biomass reduction at $\geq$20% ODR or at 40% SCR and thereby to the decreased dry weight of sowthistle (Table 3). However, Chinese MAP residues in soil increased the dry biomass of tomato and cabbage plants [17], whereas, in the present study, the sowthistle dry weight was similar to or had decreased in comparison to the plants grown in peat. This is evidence of the different plant responses when adding residues in soil and soilless culture. Previous studies reported that a high ratio (>10%) of plant residues in the growing media may possibly decrease the plant growth and marketability of the harvested product, as indicated in the case of marigold, petunia, and *Matthiola* potted plants grown in peat with olive mill residue [25]; however, such decreases were observed at higher levels, i.e., at 20% of the examined MAP residues. The decrease in plant height is not necessarily a negative parameter during plant production under nursery or greenhouse conditions, as this makes it easier to handle, store, and transport the shorter plants [25,70]. However, the decreased fresh biomass, which reflects the crop yield, is an obstacle to eliminating the high ratio of MAPs residues used in the present study and in terms of crop management strategies to improve plant performance. These strategies include an additional fertigation scheme to improve the physicochemical properties of the growing media and the possible semi- or fully composted material to be used. The examined mixtures already had a high initial C/N ratio (i.e., >25) (Tables 1 and 2), indicating unstable material that is going to partially decompose. Indeed, the C/N ratio of the examined mixtures remained in high values (i.e., >25) after growing a crop, due to the very short period of crop-growing (a short period for decomposition) and the decrease in available N in the mixtures (which is necessary for microorganisms' decomposing activity) as part of the N is used for the plants' growing needs (Tables S1 and S2 and Figure S1 in the Supplementary Materials). The reduction in plant growth was associated with the characteristics of the inadequate substrate, such as its total and air-filled porosity. The aeration level of the growing medium may be improved by adding inert material, such as perlite, pumice, or sand at up to 20–30%, leading to better results in terms of plant growth and development.

Table 3. The effect of growing media (peat, *O. dubium* residue—ODR, and *S. cypria* residue—SCR) on the sowthistle seedlings' height (cm/plant), leaf number, upper part fresh weight (fw; g/plant), and dry weight (dw; g/plant) on plants grown in the greenhouse/nursery.

	Height	Leaf No	Fresh Weight	Dry Weight
Peat 100%	13.52 ± 3.21 a	10.70 ± 1.44 ab	4.65 ± 2.11 a	0.44 ± 0.16 ab
ODR 5%	15.10 ± 2.43 a	12.40 ± 1.34 a	5.37 ± 1.28 a	0.54 ± 0.06 a
ODR 10%	13.78 ± 1.70 a	11.60 ± 2.19 ab	3.90 ± 1.94 a	0.34 ± 0.03 ab
ODR 20%	9.22 ± 3.92 b	9.20 ± 2.58 bc	1.57 ± 1.66 b	0.21 ± 0.20 bc
ODR 40%	4.02 ± 1.23 c	7.20 ± 0.83 c	0.52 ± 0.07 b	0.07 ± 0.02 c
Peat 100%	13.52 ± 3.21 ab	10.70 ± 1.44 ab	4.64 ± 2.11 a	0.44 ± 0.16 ab
SCR 5%	15.88 ± 3.91 a	12.60 ± 1.67 a	5.60 ± 3.81 a	0.66 ± 0.41 a
SCR 10%	14.30 ± 2.45 ab	12.80 ± 2.77 a	4.33 ± 1.84 a	0.44 ± 0.19 ab
SCR 20%	11.50 ± 2.84 b	13.20 ± 1.78 a	3.96 ± 1.87 ab	0.38 ± 0.16 ab
SCR 40%	7.10 ± 1.56 c	8.20 ± 2.38 b	0.69 ± 0.34 b	0.10 ± 0.13 b

Values are mean ± SD ($n = 6$). Values in the columns that are followed by the same letter for the different residues (ODR and SCR) are not significantly different ($p < 0.05$).

Leaf stomatal conductance was significantly decreased in sowthistle grown in ODR- or SCR-based media, even with low rates of the residues in the mixtures when compared to the control (100% peat) treatment, while greater effects were found with high levels of the residues in the media (Table 4). When under stress, a plant closes its leaf stomata. The findings of the present work are in accordance with earlier reports on stomata closure in broccoli, cauliflower, and cabbage seedlings grown in peat-based media mixed with olive mill residue [20] and in tomato plants grown in sand and irrigated with olive mill wastewater; this could be because of water stress caused by the increased EC of the material [71].

Table 4. Effects of the growing media (Peat, *O. dubium* residue—ODR, and *S. cypria* residue—SCR) on sowthistle chlorophyll fluorescence (Fv/Fm), stomatal conductance (s/cm), chlorophyll levels (Chl a, Chl b, total Chls; mg/g fw), and carotenoid (mg/g fw) content on plants grown in a greenhouse/nursery.

	Stomatal Conductance	Chlorophyll Fluorescence	SPAD	Chl a	Chl b	Total Chls	Carotenoids	Chla:Chlb	Carotenoids: Total Chls
Peat 100%	960.00 ± 144.08 a	0.80 ± 0.01 a	34.95 ± 3.24 ab	0.87 ± 0.04 a	0.36 ± 0.05 a	1.24 ± 0.07 a	0.18 ± 0.01 a	2.40 ± 0.19 b	0.15 ± 0.00 cd
ODR 5%	651.25 ± 229.28 b	0.79 ± 0.01 a	37.42 ± 5.14 a	1.01 ± 0.06 a	0.35 ± 0.02 a	1.36 ± 0.08 a	0.20 ± 0.01 a	2.83 ± 0.10 ab	0.14 ± 0.00 d
ODR 10%	626.66 ± 191.39 b	0.80 ± 0.01 a	38.57 ± 5.25 a	0.80 ±0.29 a	0.26 ± 0.08 a	1.06 ± 0.38 a	0.17 ± 0.05 a	2.98 ± 0.10 a	0.15 ± 0.01 bc
ODR 20%	609.00 ± 12.72 b	0.80 ± 0.00 a	38.15 ± 4.12 a	0.77 ±0.01 a	0.27 ± 0.00 a	1.04 ± 0.02 a	0.16 ± 0.00 a	2.79 ± 0.02 ab	0.16 ± 0.01 b
ODR 40%	175.59 ± 3.67 c	0.76 ± 0.03 b	28.70 ± 5.13 b	0.24 ±0.00 b	0.09 ± 0.00 b	0.33 ± 0.00 b	0.07 ± 0.00 b	2.59 ± 0.01 ab	0.21 ± 0.01 a
Peat 100%	960.00 ± 144.07 a	0.80 ± 0.01 a	34.95 ± 3.24 b	0.87 ± 0.04 ab	0.36 ± 0.05 a	1.24 ± 0.07 a	0.18 ± 0.01 a	2.40 ± 0.19 b	0.15 ± 0.00 b
SCR 5%	713.33 ± 87.36 b	0.82 ± 0.00 a	49.60 ± 13.05 a	0.99 ± 0.19 a	0.35 ± 0.08 a	1.35 ± 0.27 a	0.20 ± 0.03 a	2.84 ± 0.12 ab	0.15 ± 0.00 b
SCR 10%	523.33 ± 106.92 b	0.80 ± 0.02 a	44.37 ± 3.64 a	0.84 ± 0.03 ab	0.28 ± 0.01 ab	1.12 ± 0.02 ab	0.17 ± 0.01 ab	3.03 ± 0.18 a	0.15 ± 0.01 b
SCR 20%	542.00 ± 166.45 b	0.74 ± 0.05 b	35.55 ± 3.65 b	0.64 ± 0.03 b	0.21 ± 0.02 b	0.85 ± 0.05 b	0.13 ± 0.00 b	2.99 ± 0.07 a	0.16 ± 0.00 ab
SCR 40%	292.33 ± 59.75 c	0.64 ± 0.00 c	22.72 ± 1.18 c	0.88 ± 0.01 ab	0.26 ± 0.00 ab	1.14 ± 0.01 ab	0.19 ± 0.03 a	3.36 ± 0.00 a	0.17 ± 0.00 a

Values are mean ± SD ($n = 6$). Values in columns that are followed by the same letter for the different residues (ODR and SCR) are not significantly different ($p < 0.05$).

The contents of the leaf pigments, such as chlorophyll a, chlorophyll b, and total chlorophylls, as well as the carotenoid content, was significantly decreased in sowthistle grown in 40% ODR media and in 20% SCR media, compared to sowthistle grown in 100% peat (Table 4). Similar results were observed for the leaf chlorophyll fluorescence and SPAD measurements. This decrease in chlorophyll content may be due to an increase in chlorophyll degradation or a decrease in chlorophyll synthesis. During the process of chlorophyll degradation, Chl b is converted to Chl a [72]; this may explain the increase in the ratio of Chl a to Chl b at 10% ODR and at ≥10% SCR in terms of stressed leaves, together with a lowering of chlorophyll content. Furthermore, leaf chlorophyll content and the ratio of Chl a:Chl b are known to change as a response to the drivers of climate and global change, such as air pollution [73] and salt stress [72]. The content of photoprotective pigments tends to increase in stressed environments, as has been observed in cases of nitrogen starvation [74] or drought [75]. The carotenoid:chlorophyll ratio increased in plants grown with ≥20% ODR and with 40% SCR. Since the amount of chlorophyll is directly tied to photosynthesis and the photosynthetic capacity of the plant, any reduction in that level will lead to a reduction in the growth parameters [76].

The reduced plant growth seen with high ODR and SCR ratios mirrored this finding as well. It has been demonstrated that proper fertigation with a full-strength nutrient solution in a substrate mixture with 30% olive mill waste can give ornamental plants vigor and force them to overcome a drop in chlorophyll levels [25]. Although minerals were readily accessible for the plant, the immature residues would possibly use part of the available N for the decomposition process; the decreasing C/N ratio at the end of the crop, however, may be due to the short crop cycle that was not observed (Tables 1 and 2; Tables S1 and S2 in the Supplementary Materials). Indeed, the physicochemical characteristics of the mixtures prevented nutrients from being supplied to the plants by decreasing the water and nutrient absorption, due to stomatal closure. Therefore, the observed reduction in plant growth in the current study is not linked to the mineral levels of the growing medium; it is more likely to be related to the negative properties of unsuitable growing media, such as air-filled porosity. In this respect, efforts to enhance the properties of the growing media should consider either raising the proportion of inert material (i.e., adding 20–30% of perlite) or combining different inert materials (perlite, sand, zeolite, vermiculite, etc.). Efforts should also be made to provide some N to balance the N losses/utilization by the microorganisms in the process of organic matter decomposition.

Table 5 presents the levels of the minerals accumulated in sowthistle grown in ODR- or SCR-based growing media after a 27-day cultivation period. In the case of SCR mixtures, the sowthistle N and P contents significantly decreased at ≥20% SCR; K accumulated in plants grown with 40% SCR, while Ca accumulation was more marked at 10% SCR. Sowthistle plants grown in SCR-based media had higher Na contents compared with the plants grown in peat. However, in the case of sowthistle grown in ODR-based media, the mineral accumulation fluctuated in the different mixtures. Therefore, the highest N and Mg contents in the plants were found for ODR treatment at 10%; K, P, and Na accumulated more strongly in plants grown with 20% ODR, in peat, and with 40% ODR, respectively. Calcium content was significantly decreased at ≥20% ODR.

Table 5. Effects of growing media (Peat, *O. dubium* residue—ODR, *S. cypria* residue—SCR) on mineral element contents (mg/g dry weight) in sowthistle plants grown in the greenhouse/nursery.

	N	K	P	Na	Ca	Mg
Peat 100%	46.41 ± 0.17 b	48.57 ± 1.59 b	8.44 ± 1.17 a	12.65 ± 035 bc	11.77 ± 0.29 a	1.23 ± 0.09 b
ODR 5%	43.70 ± 0.29 c	49.21 ± 1.45 b	7.23 ± 0.22 ab	12.99 ± 0.55 bc	11.74 ± 0.14 a	1.34 ± 0.11 b
ODR 10%	48.64 ± 0.68 a	43.72 ± 0.45 c	5.82 ± 1.57 b	13.33 ± 0.22 ab	11.73 ± 0.19 a	1.55 ± 0.06 a
ODR 20%	37.17 ± 0.77 d	60.83 ± 2.09 a	5.27 ± 0.18 b	11.99 ± 0.41 c	9.04 ± 0.31 b	1.38 ± 0.04 ab
ODR 40%	22.01 ± 0.46 e	49.64 ± 1.71 b	7.14 ± 0.24 ab	14.06 ± 0.48 a	7.98 ± 0.27 c	1.02 ± 0.03 c
Peat 100%	46.41 ± 0.17 a	48.57 ± 1.59 b	8.44 ± 1.17 a	12.65 ± 0.35 b	11.77 ± 0.29 b	1.23 ± 0.09
SCR 5%	45.60 ± 5.19 a	52.94 ± 3.30 b	6.23 ± 1.09 ab	14.62 ± 0.27 a	11.06 ± 0.79 b	1.09 ± 0.10
SCR 10%	43.43 ± 0.59 ab	52.49 ± 7.87 b	9.47 ± 2.79 a	15.19 ± 1.06 a	13.92 ± 1.44 a	1.32 ± 0.17
SCR 20%	38.16 ± 0.79 bc	50.81 ± 3.43 b	4.48 ± 0.59 bc	15.24 ± 0.43 a	11.43 ± 0.46 b	1.09 ± 0.03
SCR 40%	31.42 ± 0.65 c	71.69 ± 2.47 a	2.58 ± 0.08 c	15.54 ± 0.53 a	10.21 ± 0.35 b	1.31 ± 0.04

Values are mean ± SD (n = 4). The values in the columns that are followed by the same letter for the different residues (ODR and SCR) are not significantly different ($p < 0.05$).

When ODR or SCR was added, the N that was provided was mostly organic and was only partially available to the plants. Moreover, part of the N may be consumed by microorganisms through organic matter decomposition and mineralization (Tables S1 and S2 in the Supplementary Materials) affecting N accumulation in the sowthistle tissue (Table 5) and decreased N levels in the growing media after plant harvesting (Tables S1 and S2 and Figure S1 in the Supplementary Materials). Moreover, growing media with high ODR levels exhibited a significantly decreased mineral content, except in the case of Na (Figure S1 in the Supplementary Materials). This may explain why the resulting plants grew slowly, had less chlorophyll, and had low levels of photosynthetic capacity [71]. The fluctuation in the amounts of nutrients accumulating in plant tissue is one of the main disadvantages of utilizing raw materials. The practical difficulties when conducting specific research as preliminary testing before the use of MAP-based media present another problem. With the appropriate application of fertilizer, this issue can be avoided [77]. Any mineral imbalances derived from the uncomposted growing media can be ameliorated by an adjusted nutrient solution, as used in hydroponics, as has previously been applied to ornamental plants [25].

The use of MAP residues as a partial peat substitute in growing media impacted the levels of total phenols, total flavonoids, and the antioxidant activity of the harvested sowthistle, as presented in Figure 1. In the case of ODR, the content of the total phenols in sowthistle was significantly increased by 1.2 times in plants grown with 20% ODR and reached a 4.4-times increase in the 40% ODR-grown plants (Figure 1A1). Sowthistle antioxidant activity, as assayed by DPPH and FRAP, increased by up to 2.5 and 2.2 times, respectively, at ≥20% ODR and actually increased up to 6.7 and 5.9 times, respectively, at the highest examined ratio of 40% ODR (Figure 1A2,A3). Total flavonoid contents steadily increased with the increased ODR levels in the growing media and exhibited an increase of up to 3.5 times at 40% ODR, in comparison with the control treatment (Figure 1A4). The same trend was observed in sowthistle grown in SCR-based media (Figure 1B1–B4), but with lower increments. The response of plants to stress is to activate several enzymatic and non-enzymatic mechanisms. In this case, various non-enzymatic responses were indicated by increased phenolics and flavonoids and the increased antioxidant capacity of sowthistle. Despite the decreased yield observed with the high ODR and SCR mixtures, the improved antioxidant capacity of a plant can be very noteworthy since it increases the nutritional value of the plant (due to its high antioxidant content). Similar responses have been reported in *Brassica* plants under stress conditions when they were grown in olive-mill waste-based media [20].

Plants are subjected to a variety of stressful conditions during their growth cycle. Most of the time, these conditions involve both biotic stresses (such as diseases and pests) and abiotic stresses, such as extreme heat, periods of drought, highly salty and osmotic soils, and excessive mineral/heavy metal levels. To eliminate excess reactive oxygen species (ROS) that accumulate in cells under stressful conditions, plants have evolved a variety of detoxification systems. One of the most widely used stress markers is the production of MDA, which is connected to rising lipid peroxidation in stress conditions. Once plant antioxidants lack the ability to scavenge ROS, as an initial step in detoxifying what is causing the stress conditions, MDA levels rise. Therefore, MDA levels have risen in sowthistle plants growing in media with ODR at 40%, where high levels of H_2O_2 production indicate a stress condition that causes cellular damage (Table 6). This was evidenced by the increased SOD activity as a plant's first reaction to stresses, while CAT remained at low levels and POD levels remained unchanged. Several non-enzymatic (such as phenols, proline, ascorbic acid, etc.) and enzymatic antioxidants (SOD, CAT, POD, etc.) are activated by the plant's ability to neutralize ROS accumulation in cells, which is increased in stress conditions [20]. The earliest enzymatic defense starts with SOD increment, to fend off the negative consequences of the increased ROS levels. This implies increased O_2-induced detoxification-related H_2O_2 levels, followed by increased CAT or POD activity for H_2O_2 breakdown [78]. Catalase converts hydrogen peroxide into water and molecules of oxygen, whereas peroxidase breaks down hydrogen peroxide via co-substrate oxidation with phenolic compounds and/or antioxidants. Superoxide and hydrogen peroxide, two potentially hazardous molecules, are converted into water in the final step of the process. In the case of SCR-grown sowthistle, MDA and H_2O_2 levels were high with the 40% SCR mixtures; SOD levels started to increase but both CAT and POD remained at low production levels. This indicates that the antioxidant role of SOD was initiated but not the roles of CAT and POD, which was probably due to the increased non-enzymatic antioxidant mechanisms (phenolics and flavonoids).

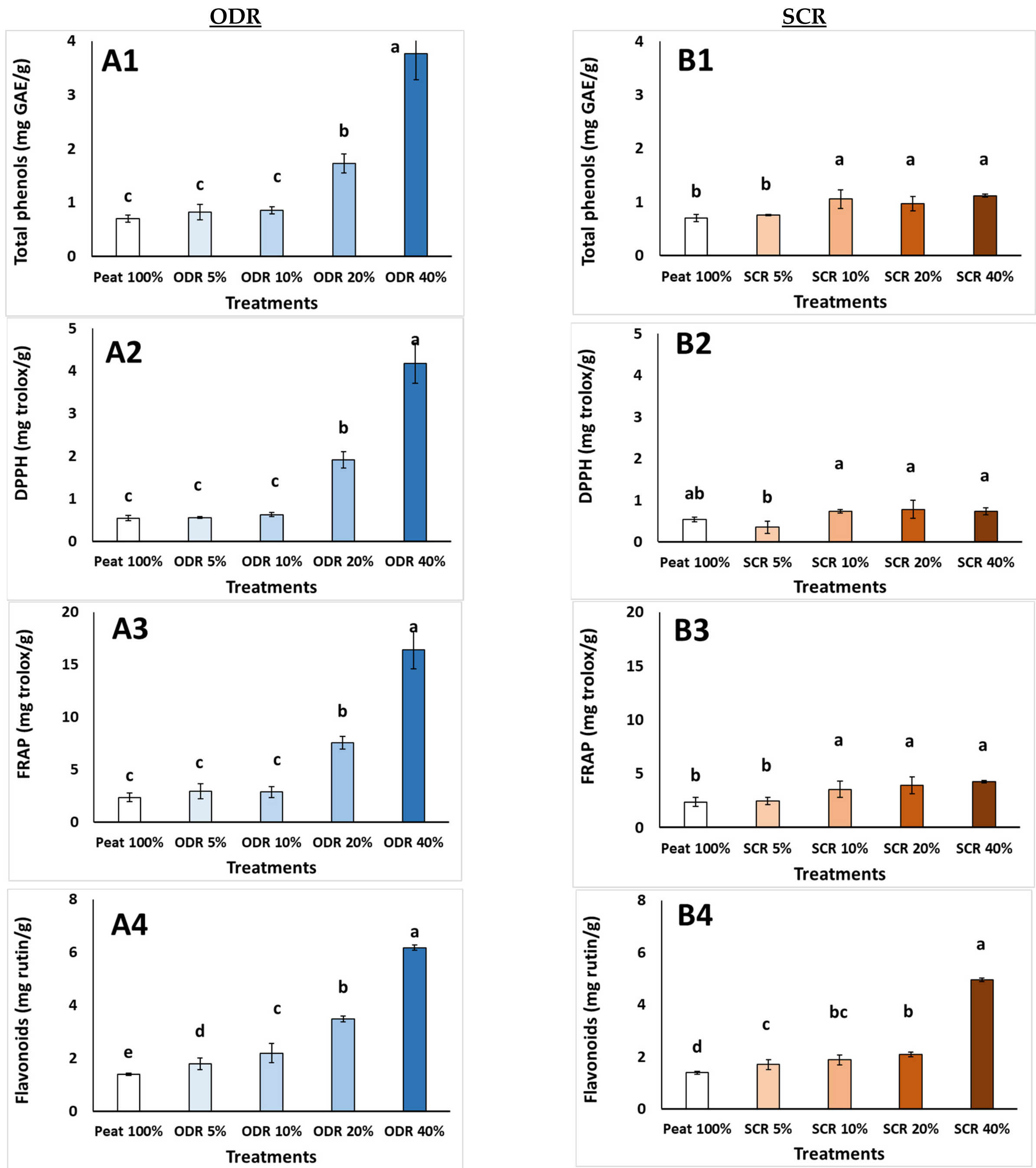

Figure 1. Effects of growing media (peat, *O. dubium* residue—ODR, and *S. cypria* residue—SCR) on total phenols (mg GAE/g fw), antioxidant activity (DPPH, FRAP: mg trolox/g fw), and flavonoids (mg rutin/g fw) in sowthistle plants (ODR: (**A1**–**A4**); SCR: (**B1**–**B4**)). Values are mean ± SD (n = 6). Mean values followed by the same letter do not differ significantly at $p \geq 0.05$, according to Duncan's Multiple Range Test.

Table 6. Effects of growing media (Peat, *O. dubium* residue—ODR, and *S. cypria* residue—SCR) on hydrogen peroxide—H_2O_2 (μmol/g), lipid peroxidation—MDA (nmol/g) and the antioxidant enzyme activity of superoxide dismutase (SOD; units/mg of protein), catalase (CAT; units/mg of protein), and peroxidase (POD; units/mg of protein) in sowthistle plants grown in a greenhouse/nursery.

	H_2O_2	MDA	SOD	CAT	POD
Peat 100%	0.09 ± 0.01 cd	14.97 ± 0.92 b	0.89 ± 0.11 b	17.56 ± 3.02 a	1.57 ± 0.11
ODR 5%	0.18 ± 0.02 b	15.68 ± 2.16 b	0.87 ± 0.07 b	17.39 ± 2.76 a	1.47 ± 0.24
ODR 10%	0.07 ± 0.01 d	14.30 ± 3.14 b	1.05 ± 0.15 b	10.60 ± 1.19 b	1.23 ± 0.15
ODR 20%	0.12 ± 0.02 c	14.15 ± 1.17 b	0.79 ± 0.09 b	8.23 ± 2.37 b	1.24 ± 0.27
ODR 40%	0.23 ± 0.02 a	38.24 ± 4.61 a	1.56 ± 0.33 a	7.49 ± 1.18 b	1.39 ± 0.22
Peat 100%	0.09 ± 0.02 c	14.97 ± 0.92 b	0.89 ± 0.11 b	17.56 ± 3.02 a	1.57 ± 0.11 a
SCR 5%	0.11 ± 0.02 c	11.40 ± 0.40 c	0.86 ± 0.04 b	11.56 ± 0.77 b	0.89 ± 0.08 bc
SCR 10%	0.14 ± 0.05 c	14.98 ± 2.21 b	0.85 ± 0.04 b	12.16 ± 0.78 b	0.81 ± 0.04 c
SCR 20%	0.21 ± 0.01 b	17.61 ± 0.47 b	1.14 ± 0.03 a	13.93 ± 0.80 ab	1.08 ± 0.15 b
SCR 40%	0.44 ± 0.03 a	22.56 ± 2.92 a	0.96 ± 0.15 b	13.73 ± 3.72 ab	0.55 ± 0.08 d

Values are mean ± SD ($n = 4$). Values in the columns that are followed by the same letter for the different residues (ODR and SCR) are not significantly different ($p < 0.05$).

Trying to ensure that cultivated plants grow quickly and are in good health is crucial for producing vegetables, ornamental plants, seedlings, and potted plants profitably. Moreover, it is important to select peat alternatives that are more environmentally conscious when adding them to growing media mixtures. For a healthy plant to grow, alternative materials must be physically produced and processed, and the plants must be given the proper biological and physicochemical conditions [24,79]. A reduction in peat use and consumption could reduce the cost of growing seedlings and aid in the preservation of peatlands, this being an environmental constraint. Future studies should concentrate on changing the amounts of the components used to make substrates, always taking into consideration the quantity and frequency of fertilization and irrigation. Plant residues are rich in minerals and organic matter that can benefit both the soil and the properties of growing media. Even though some potting studies might result in the improvement of soil properties when adding MAP residues, there are still some differences between pot experiments and actual agricultural practice, in the context of MAP residue recycling in soil and the substitution of fertilizers [1].

4. Conclusions

While assessing new materials as prospective components in substrate mixtures, the two major challenges that researchers must face are improving growing media fertility and establishing the proper physicochemical characteristics. In the current study, the partial replacement of peat used for the growth of sowthistle seedlings with ODR and SCR was investigated. Both the MAP residues added to the peat-based mixtures affected the physicochemical characteristics of the growing media. The blends' apparent decrease in free pore space was accompanied by a sharp decrease in the available water-holding capacity and the free air capacity of the media. However, with both the residues used, there was an increase in the organic matter and mineral levels that were available for the plants to use. ODR and SCR both decreased plant growth, negatively affecting the plants' physiological attributes and causing decreased leaf stomatal conductance, with more profound impacts at the high ratios of 20–40% of residues. Minerals accumulated in the plant tissues, as evidenced by the decomposition of the organic material of the residues. MAP residues at a high ratio adversely affected the sowthistle growth under stress conditions since several non-enzymatic and enzymatic antioxidant mechanisms were induced. Finally, the current study indicates that both ODR and SCR can be employed in the growing media at low ratios of 10% and 20%, respectively, resulting in increased antioxidant values and nutritional values; however, the further improvement of growing media properties and possible fertigation need to be examined. Moreover, future studies may consider evaluating not only the effects of the composted residues on plant growth but also the effects of the application of raw residues directly to the soil under field conditions.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy13041074/s1, Table S1. Growing media (Peat and *O. dubium* residue—ODR) physicochemical properties after plant harvesting (at the end of the growing period); Table S2. Growing media (Peat and *S. cypria* residue—SCR) physicochemical properties after plant harvesting (at the end of the growing period); Figure S1. Growing media (Peat and *O. dubium* residue—ODR) mineral composition (% of changes from the initial to final materials) after plant harvesting (at the end of the growing period).

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