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The Application of Conventional and Organic Fertilizers During Wild Edible Species Cultivation: A Case Study of Purslane and Common Sowthistle

Efraimia Hajisolomou [1], Giannis Neofytou [1], Spyridon A. Petropoulos [2] and Nikolaos Tzortzakis [1,*]

[1] Department of Agricultural Sciences, Biotechnology and Food Science, Cyprus University of Technology, Limassol 3603, Cyprus
[2] Department of Agriculture, Crop Production and Rural Environment, University of Thessaly, 38446 Volos, Greece
* Correspondence: nikolaos.tzortzakis@cut.ac.cy

Abstract: The introduction of alternative crops, including wild edible and medicinal plants, in organic cultivation systems presents an attractive approach to producing healthy and high-quality products due to their content in beneficial compounds and increased nutritional value. The current study evaluated the impact of organic and conventional fertilization on the growth, quality, nutrient status and stress response of the two wild edible species, e.g., purslane (*Portulaca oleracea* L.) and common sowthistle (*Sonchus oleraceus* L.), under field conditions. The fertilization treatments included the following: a control (NoFert) treatment with no fertilizers added, base dressing with conventional fertilization (CoFert), base dressing with organic fertilization (OrFert), base dressing and side dressing with conventional fertilization (OrFert + S_{CoFert}) and base dressing and side dressing with organic fertilization (CoFert + S_{CoFert}). Organic fertilization was carried out using a commercial vinasse-based organic fertilizer. In both purslane and common sowthistle, the application of organic fertilizers provided comparable or even enhanced plant growth traits, macronutrient content (i.e., P and K for purslane, and N for sowthistle) and quality (i.e., total soluble solids) compared to the application of conventional fertilizers. On the other hand, conventional fertilization with supplementary fertilization positively influenced the plant growth of purslane (i.e., plant height and stems biomass), as well as its physiological parameters (i.e., chlorophylls content), total phenolics content and antioxidant capacity (i.e., DPPH and FRAP). Similarly, conventional fertilization led to increased total phenolics and antioxidants in common sowthistle, while variable effects were observed regarding plant physiology, stress response and antioxidant capacity indices. In conclusion, the use of organic fertilization in both purslane and common sowthistle exhibited a performance similar to that of conventional fertilization, although further optimization of fertilization regimes is needed to improve the quality of the edible products.

Keywords: organic farming; sustainable fertilization; *Portulaca oleracea*; *Sonchus oleraceus*; total phenolic compounds; antioxidant capacity; wild edible species

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1. Introduction

Addressing the global demand for safe and healthy food in the context of a continuously growing population presents a critical challenge for modern agriculture [1,2]. This issue demands not only an increase in global agricultural production to protect food security, but also the adoption of practices that ensure food safety and nutritional quality [3,4]. The current strategy involves highly intensive crop production systems [5], which rely heavily on the application of excessive fertilization methods, predominantly utilizing inorganic fertilizers to enhance crop yields [6]. However, this approach is accompanied by a range of environmental and health implications, including the degradation of soils, loss of nutrients via leaching, increase in greenhouse gasses emission and eventually the pollution of water, air and soil [3,7].

Recently, there has been a significant increase in consumers' demand for products derived from organic cultivation practices [8,9]. Organic practices prohibit the use of inorganic fertilizers, and utilize eco-friendly fertilizers such as organic manure which are within the scope of sustainability and biodiversity and promote resources conservation [3,10,11]. In this context, wild plant species hold significant ecological value, particularly in the context of soil degradation, as they possess inherent natural adaptations to challenging soil and climate conditions [12]. Additionally, organic farming has the potential to produce healthier and higher-quality plant products, while also maintaining a reduced environmental footprint [5,6]. This is particularly relevant for wild edible (WEP) and medicinal (MP) plants, as their true value derives from their quality and beneficial compounds [3,13]. In this regard, the introduction of alternative crops such as WEPs and MPs to organic crop production aligns with the scope of this strategy, as these species are characterized by low requirements in terms of inputs (e.g., fertilizers, agrochemicals, irrigation) [14].

Portulaca oleracea (L.) commonly known as purslane, is an annual herbaceous plant, exhibiting prostate or erect growth. It is classified within the Portulacaceae family and demonstrates a worldwide distribution [15,16]. This wild edible plant serves as a common component of the Mediterranean diet, often used as a salad garnish, and is widely appreciated for its high nutritional value [17]. Purslane has also been utilized as a traditional medicine in various countries, due to its antiseptic, antioxidant, antibacterial, antidiabetic, anticancer and wound-healing properties [18,19]. It is characterized by a high content of omega-3 fatty acids, minerals, proteins, carbohydrates, tocopherols, ascorbic acid and carotenoids [17]. Recognized for its diverse traits, purslane is increasingly acknowledged as a "wonder crop", although it remains highly underutilized [19].

Sonchus oleraceus (L.), commonly known as common sowthistle, is a member of the genus *Sonchus*, which includes various annual, biennial and perennial herbaceous plants, typically found across Asia, Africa and Europe [20]. Although reported to be a damaging, invasive weed, common sowthistle has been a part of the human diet in numerous geographical areas, due to its therapeutic and nutritional properties [21,22]. Common sowthistle is also regarded as an important medicinal plant due to its high content of various phytochemical compounds such as sesquiterpene lactones, flavonoids, flavonols and phenols, as well as fatty acids, carotenoids and minerals [23,24]. Sowthistle plant extract has also been shown to have anti-diabetic, antioxidant and antibacterial activity [25,26], and has been utilized as a post-harvest preservative in fresh-cut vegetables [27], and as a bio-herbicide [28].

Given the potential of common sowthistle and purslane as potential candidates for commercial cropping, it is essential to ensure optimal yields and enhanced quality parameters, in the context of implementing sustainable agricultural practices. These practices will help to mitigate the environmental impact of the current agricultural sector, driven by a booming interest in certified organic products [29]. Therefore, the current study was conducted to evaluate the efficacy of a commercially available organic fertilizer, in comparison to conventional inorganic fertilization on the growth and quality features of purslane and common sowthistle plants grown under field conditions. Additionally, supplementary fertilization was administered in both scenarios (i.e., conventional and organic supplementary fertilization), to investigate the effect of the fertilization regime and determine the nutrients requirements of the tested wild edible species.

2. Materials and Methods

2.1. Plant Material, Soil Analysis and Experimental Conditions

Portulaca oleracea and *Sonchus oleraceus* seedlings were produced in the nursery of the Cyprus University of Technology. Young seedlings were transplanted to the field at the growth stage of 2–3 leaves and 4–5 cm in height (approximately 3 weeks after sowing) during the spring of 2024 in a commercial organic farm at Anogyra, Limassol, Cyprus (34°44′16.53′ N; 32°44′40.86′ E, 427 m above sea level). The climate of this region is dry with an average midday temperature and air humidity during the summer months of approximately 30 °C and 54%, respectively. The soil had a clay–loam texture, with the majority of the sieved particles (~80%) being sized at <4.75 mm. Furthermore, the soil had 4.61% of organic matter; 60.48% of available $CaCO_3$; a pH of 7.66; and an EC of 1.10 mS cm^{-1}. Moreover, the minerals content was as follows; N of 2.459 g kg^{-1}, P of 0.057 g kg^{-1}, K of 0.364 g kg^{-1}, Ca of 6.304 g kg^{-1}, Mg of 0.604 g kg^{-1}, and Na of 0.119 g kg^{-1}.

2.2. Cultivation Procedures

The experiment field used was 190 m^2 (10 m × 19 m). Young seedlings were transplanted into soil plots and arranged in triple rows at distances of 0.33 m between rows and 0.33 m within the same row. The experiment was carried out in a completely randomized design, where the experimental farm was divided into five treatments: (i) no fertilizers (NoFert), (ii) conventional fertilization–base dressing (CoFert), (iii) organic fertilization–base dressing (OrFert), (iv) base and side dressing with conventional fertilization (CoFert + S_{CoFert}) and (v) base and side dressing with organic fertilization (OrFert + S_{OrFert}). Conventional fertilization was carried out using Fertiflow 20–20−20 (ICL Fertilizers, Tel Aviv-Yafo, Israel), which contains N (20%) in the form of ammonium nitrogen (2.7%) and urea (17.3%), P_2O_5 (20%) and K_2O (20%). Organic fertilization was carried out using Phenix (Hello Nature, Italy), a vinasse-based fertilizer which contains N (6.0%), P_2O_5 (8.0%), K_2O (15.0%), MgO (3.0%) and is characterized by a high organic matter content (50%). A total of 30 plants were cultivated per plot (3.3 m^2) and species, while two replicated plots per species were also used, resulting in 60 individual plants per treatment and per plant species. No pesticides were used in the present study.

The plants were irrigated every day with approx. 0.2 L $plant^{-1}$ for 10 min or according to the plant's needs (irrigated water electrical conductivity of 0.93 dS m^{-1}; pH of 8.1), depending on the environmental conditions. The base dressing of the conventional (20–20−20) and the organic fertilizer was conducted on 24 April 2024, and both fertilizers were broadcast before transplanting, and were lightly incorporated in the soil. For the CoFert + S_{CoFert} and OrFert + S_{OrFert} treatments, additional fertigation was applied on 30 April 2024, 15 May 2024 and 28 May 2024 (Table S1).

2.3. Plant Growth and Physiology

At the end of the experiment (21 June 2024), several measurements were conducted. Plants (six replicates) were harvested at 1 cm above soil; their upper fresh weight was weighed (g), dried at 42 °C to constant weight and the total dry matter content (%) was then calculated.

Leaf photochemistry features were also assessed; relative chlorophyll content values were obtained with an optical chlorophyll meter (SPAD-502, Minolta, Osaka, Japan). Additionally, fresh plant tissue (six replications/treatment; each replication was a pool of two plants tissue; 0.1 g) was used for chlorophyll extraction, with the addition of 7 mL methanol 100% as described by Richardson et al. [30]. The absorbance was then measured at 470, 653 and 666 nm (Multiskan GO, Thermo Fischer Scientific Oy, Vantaa, Finland). Photosynthetic leaf pigments, chlorophyll a (Chl a), chlorophyll b (Chl b), total chlorophyll (total Chl) and carotenoids content were then calculated (mg g^{-1} fresh weight).

2.4. Total Phenolics Content, Antioxidant Capacity, Flavonoids and Ascorbic Acid

To determine total phenolics and antioxidant capacity, plant tissue samples (six replications per treatment) were collected, weighed (approximately 0.9 g) and stored at −20 °C. An extraction procedure was followed by the addition of 10 mL of methanol 50% to each sample, and the mixture was homogenized (ULTRA TURRAK, IKA-Werke, Staufen, Germany). The samples were then incubated in an ultrasound water bath (WB-11, Witeg, Wertheim, Germany), and centrifuged at 4045× *g* and 4 °C for 15 min (Primo R Centrifuge, Thermo Fisher Scientific Oy, Finland). Finally, the supernatant was collected and stored at −20 °C and measured within 12 h.

The antioxidant capacity of the methanol plant extracts was determined by using the assays of 2,2-diphenyl-1-picrylhydrazyl (DPPH) and ferric-reducing antioxidant power (FRAP), as previously described by Chrysargyris et al. [31], as well as the 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS•+) assay as described previously [32]. Multiple radical scavenging assays were used, to provide a more comprehensive and reliable assessment of the plant's antioxidant properties, particularly when different fertilization methods were applied. It helps to account for the complexity of plant chemistry and the influence of different agricultural practices; in fact, it is recommended to employ at least two distinct methods [33]. The three spectrophotometric methods selected assayed the free radical-scavenging activity (DPPH, ABTS•+), and the ability to reduce ferric ions (FRAP) [34].

For DPPH determination, the scavenging activity was measured by bleaching with a 0.3 M DPPH solution. Afterwards, 1 mL of the DPPH solution was mixed with 15 µL of the extract and 1985 µL methanol (50%), and incubated in the dark for 30 min. A control was prepared using 2 mL of buffer solution with 1 mL DPPH solution, a curve blank using 1 mL methanol (100%) and ethanol 100%. Blanks for each sample were prepared using 15 µL of plant extract, 1985 µL of 50% methanol and 1 mL of 100% methanol. Absorbance measurements were conducted at 517 nm using Multiskan GO (Thermo Fisher Scientific Oy, Vantaa, Finland). The FRAP assay was also conducted, wherein Fe^{3+} was reduced to Fe^{2+} in the presence of antioxidants in a redox-linked colorimetric reaction. A FRAP solution was prepared using 2.5 mL $CH_3COONa{\cdot}3H_2O$ (0.3 mol L^{-1}, pH 3.6), 0.25 mL TPTZ (Tripyridil-s-triazine, 10 mmol L^{-1}), 0.25 mL $FeCl_3$ (40 mmol L^{-1}) and 15 µL of the plant tissue extract. A blank was also prepared. The absorbance was then estimated at 734 nm. Finally, the ABTS•+ assay, which measures the capacity of antioxidants to scavenge the ABTS•+ radical cation, was also conducted through the addition of 3 mL of ABTS•+ solution which was added to 50 µL of the extracts. Absorbance was then measured at 734 nm. The results were expressed as the Trolox (6-Hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid) equivalent (mg Trolox g^{-1} of fresh weight).

Total phenolic content was measured using the Folin–Ciocalteu method. The Folin–Ciocalteu reagent (125 µL) was mixed with 1375 µL water and 250 µL of the sample. The samples were stirred and were left for 5 min before adding 1250 µL Na_2CO_3 7%. Following incubation in the dark for 1 h, the samples were optometrically measured at 755 nm and the results were expressed as gallic acid equivalents (µmol GAE g^{-1} of fresh weight), as described previously by Tzortzakis et al. [35].

Total flavonoids were measured using the aluminum chloride colorimetric method. Firstly, 5% $NaNO_2$ (Merck, Darmstadt, Germany) and plant tissue extracts were incubated for 6 min. Afterwards, following a wait time of 5 min, 0.15 mL $AlCl_3$ (10%) solution was added. After an additional 5 min wait time, 0.5 mL NaOH (1 M) was added, and distilled water was used to achieve a final volume of 2.5 mL. After thorough mixing, the absorbance of the solution was measured at 510 nm (Multiskan GO, Thermo Fischer Scientific Oy, Finland). The results were expressed as rutin equivalents per gram of fresh weight (mg rutin g^{-1} FW).

Finally, the ascorbic acid (AA) determination required approximately 1 g of plant tissue, which was weighted and homogenized (ULTRA TURRAX, IKA-Werke, Staufen, Germany) with 10 mL 4% oxalic acid. Afterwards, the samples were centrifuged at 4500× *g* and 25 °C for 15 min (Primo R Centrifuge, Thermo Fisher Scientific Oy, Finland). Finally, 10 mL of the supernatant was titrated against a DCIP dye solution (2,6-dichloro-indophenol). The titrate of the dye solution was calculated using a standard ascorbic acid solution (1 mg mL^{-1}). The results were expressed as mg of AA per 100 g of fresh weight (mg AA 100 g^{-1} FW) [36].

2.5. Lipid Peroxidation and Hydrogen Peroxide Content

The lipid peroxidation in terms of malondialdehyde (MDA) was determined by using the thiobarbituric (TBA) acid reaction. Briefly, MDA content was determined by homogenizing the plant tissue (0.2 g) with 0.1% trichloroacetic acid (TCA) and the extract was centrifuged at 15,000× *g* for 10 min. The extract (0.5 mL) was then mixed with 1.5 mL of 0.5% TBA in 20% TCA, and was incubated at 95 °C for 25 min. Following cooling in an ice bath, the absorbance was determined at 532 nm. The results were expressed as micromole of H_2O_2 per gram of fresh weight (μmol g^{-1}). H_2O_2 was determined as previously described [37]. Plant tissue (0.2 g) was ground in ice cold 0.1% TCA, and centrifuged at 15,000× *g* for 15 min. The supernatant (0.5 mL) was collected and mixed with 0.5 mL potassium-phosphate buffer with a pH of 7, and 1 mL of 1 M potassium iodide. Afterwards, the absorbance was measured at 390 nm. The results were expressed as nmol of MDA g^{-1} of fresh weight (nmol g^{-1}).

2.6. Plant Tissue and Nutrient Analysis

At the end of the experiment, samples from the upper parts of the plant (leaves and stems) were used to determine the mineral content, in six replications per treatment (three pooled plants per replication). Plant tissue was dried to constant weight (at 42 °C), ash burned (Carbolite AAF 1100, GERO, Mayen, Germany) at 450 °C for 6 h and then acid digested (2 M HCl). The nutrient content was determined as follows: potassium (K) and sodium (Na) were determined photometrically (Flame photometer, Lasany Model 1832, Lasany International, Haryana, India); phosphorus (P) was determined spectrophotometrically (Multiskan GO, Thermo Fischer Scientific Oy, Finland); and nitrogen (N) was determined by the Kjeldahl method (BUCHI, Digest automat K-439 and Distillation Kjeldahl K-360, Flawil, Switzerland). Data were expressed in g kg^{-1} of dry weight.

2.7. Statistical Methods

To test the effect of fertilization regimes on plant growth, physiological parameters and chemical composition of purslane and common sowthistle plants, a one-way analysis of variance (ANOVA) was used, followed by a comparison of the means with the Duncan's multiple range test at $p < 0.05$ with the fertilization regime as a fixed factor and all the tested parameters as responses. All data were checked for normality and homoscedasticity using Shapiro–Wilk and Bartlett's test, respectively. Statistical analysis was performed using IBM SPSS version 22. Measurements were applied in four to six biological replications/treatment (each replication consisted of a pool of three individual measures/samples), depending on the parameters, as indicated in the respective Tables and Figures.

3. Results

3.1. Purslane and Sowthistle Plant Growth

The effect of the studied fertilization regimes on purslane and common sowthistle plant growth and physiology are presented in Table 1. In the case of purslane, plant height was significantly ($p < 0.05$) increased (15.6% and 17.3%, respectively) with base and side dressing in both OrFert and CoFert treatments (CoFert + S_{CoFert} and OrFert + S_{OrFert}) compared to the NoFert application (control). Purslane plants grown with the NoFert application produced the lowest leaf and stem fresh weights. Furthermore, the addition of a side dressing in the CoFert treatment (CoFert + S_{CoFert}) increased the fresh weight of stems, whereas the opposite result was observed in the respective treatment with organic fertilizer (OrFert + S_{OrFert}). In accordance with the abovementioned results, the NoFert application produced purslane plants with the lowest total fresh biomass weight, while the highest values were recorded for the OrFert and CoFert + S_{CoFert} treatments. Interestingly, the application of a side dressing decreased the total fresh biomass production of plants grown under the OrFert + S_{OrFert} regime. The lowest leaf dry matter content was observed for the OrFert application, while OrFert + S_{OrFert} increased the values of this parameter by

35.2%. Finally, no significant differences were observed in the case of the stems and total dry matter content.

Table 1. The effect of fertilization regimes on purslane height (cm), leaf, stems and total plant fresh weight (FW; g plant^{-1}), and dry matter content (DM; %), and common sowthistle plant height (cm), leaf number, total plant fresh weight (FW; g plant^{-1}), and dry matter content (DM; %). Values are means (±SE) of six replicates for each treatment.

Plant	Parameters	NoFert *	CoFert	OrFert	CoFert + S_{CoFert}	OrFert + S_{OrFert}
Purslane	Plant height	46.00 ± 2.08 c	49.17 ± 1.30 bc	46.17 ± 1.49 c	56.83 ± 2.06 a	54.17 ± 2.95 ab
	Leaves FW	72.85 ± 17.45 b	172.65 ± 14.39 a	168.47 ± 24.61 a	145.00 ± 18.92 a	123.98 ± 12.31 ab
	Stems FW	243.17 ± 49.00 c	422.70 ± 24.40 b	599.43 ± 58.36 a	606.47 ± 66.29 a	403.52 ± 45.95 b
	Plant FW	316.02 ± 47.30 c	595.35 ± 35.28 ab	767.90 ± 74.95 a	751.47 ± 82.91 a	527.50 ± 56.79 b
	Leaves DM	9.20 ± 0.91 ab	8.62 ± 0.13 abc	7.14 ± 0.65 c	7.60 ± 0.22 bc	9.65 ± 0.45 a
	Stems DM	7.11 ± 0.87	7.92 ± 0.57	6.86 ± 0.67	6.66 ± 0.16	8.03 ± 0.41
	Total DM	7.48 ± 0.71	8.09 ± 0.43	6.93 ± 0.65	6.85 ± 0.17	8.43 ± 0.39
Sowthistle	Plant height	23.67 ± 1.28 ab	20.75 ± 0.73 b	24.58 ± 1.57 a	21.00 ± 0.58 b	22.00 ± 0.76 ab
	Leaf number	17.83 ± 2.04 ab	16.83 ± 1.56 b	18.67 ± 1.41 ab	23.83 ± 2.77 a	19.17 ± 1.58 ab
	Plant FW	36.37 ± 2.58	35.08 ± 2.72	33.38 ± 4.51	46.82 ± 7.49	49.17 ± 12.91
	Plant DM	15.61 ± 0.75 b	15.43 ± 0.72 b	18.30 ± 0.60 a	16.43 ± 0.81 b	15.14 ± 0.21 b

* No fertilization (NoFert), conventional fertilization–base dressing (CoFert), organic fertilization–base dressing (OrFert), conventional fertilization with side dressing of CoFert (CoFert + S_{CoFert}) and organic fertilization with side dressing of OrFert (OrFert + S_{OrFert}); significant differences ($p < 0.05$) among the treatments are indicated by different letters in the same row.

In common sowthistle, the highest plant height was observed for plants treated with OrFert, while both CoFert and CoFert + S_{CoFert} decreased plant height compared to the abovementioned treatment. Furthermore, the highest and lowest numbers of leaves were observed for CoFert + S_{CoFert} and CoFert, respectively, showing an increase of 41.6% in the case of CoFert + S_{CoFert} treatment. Regarding the plant dry matter content, it was beneficially affected under the OrFert treatment, where an increase of up to 20.9% was recorded compared to the rest of the treatments, Finally, the fresh weight of plants remained unaffected by the examined fertilization regimes.

3.2. Purslane and Sowthistle Plant Physiology

Table 2 presents the effects of the examined fertilization regimes on selected purslane and common sowthistle physiological parameters. In the case of purslane, the application of CoFert + S_{CoFert} resulted in decreased chlorophyll fluorescence compared to the NoFert application, while, remarkably, the same treatment produced plants with the highest content of Chl a, Chl b, total chlorophylls and carotenoids. Furthermore, the content of chlorophylls (Chl a, Chl b, total chlorophylls) was the lowest with the application of CoFert, while the introduction of a side dressing to this treatment (CoFert + S_{CoFert}) increased these values. Finally, the carotenoids-to-total chlorophylls ratio was significantly increased with the application of the CoFert treatment, compared to the other applications. Both SPAD and the Chl a-to-Chl b ratio remained unaffected by the examined parameters.

In common sowthistle, the application of a side dressing in both types of fertilizer (e.g., CoFert + S_{CoFert} and OrFert + S_{OrFert}) resulted in a decreased chlorophyll content compared to the NoFert application (except for CoFert + S_{CoFert} where no significant differences were recorded), whereas the highest values were recorded for the NoFert and OrFert treatments. Moreover, CoFert + S_{CoFert} and OrFert + S_{OrFert} resulted in an increased ratio of Chl a to Chl b, while CoFert increased significantly SPAD values, especially when compared to the NoFert treatment. Finally, chlorophyll fluorescence (Fv Fm^{-1}), total carotenoids content and the ratio of total carotenoids to chlorophylls content were not affected by the studied fertilization regimes.

Table 2. The effect of different fertilization regimes on purslane and common sowthistle SPAD value, leaf chlorophyll fluorescence (Fv Fm^{-1}), chlorophyll content (Chl a, Chl b, total Chl; mg g^{-1} fresh weight), carotenoids content (Total Car, mg g^{-1} fresh weight), Chl a:Chl b and Car:Chl ratios. Values are means (±SE) of six replicates for each treatment.

Plant	Parameters	NoFert *	CoFert	OrFert	CoFert + S_{CoFert}	OrFert + S_{OrFert}
Purslane	SPAD	33.38 ± 0.47	34.85 ± 1.07	33.82 ±1.84	35.75 ± 1.46	35.02 ± 2.40
	Fv Fm^{-1}	0.71 ± 0.00 a	0.69 ± 0.02 ab	0.71 ± 0.01 ab	0.67 ± 0.01 b	0.69 ± 0.01 ab
	Chl a	0.34 ± 0.05 b	0.21 ± 0.02 c	0.38 ± 0.04 b	0.57 ± 0.05 a	0.28 ± 0.03 bc
	Chl b	0.12 ± 0.01 b	0.07 ± 0.00 c	0.14 ± 0.01 b	0.19 ± 0.02 a	0.10 ± 0.01 bc
	Total Chl	0.45 ± 0.06 b	0.29 ± 0.02 c	0.51 ± 0.05 b	0.76 ± 0.06 a	0.39 ± 0.04 bc
	Total Car	0.06 ± 0.01 b	0.05 ± 0.00 b	0.07 ± 0.01 b	0.11 ± 0.01 a	0.06 ± 0.01 b
	Chl a:Chl b	2.81 ± 0.11	2.85 ± 0.06	2.69 ± 0.13	2.93 ± 0.04	2.72 ± 0.05
	Car:Chl	0.14 ± 0.01 b	0.18 ± 0.01 a	0.14 ± 0.01 b	0.15 ± 0.00 b	0.16 ± 0.01 b
Sowthistle	SPAD	47.97 ± 2.82 b	54.72 ± 1.91 a	50.78 ± 0.47 ab	49.70 ± 2.83 ab	53.07 ± 0.88 ab
	Fv Fm^{-1}	0.76 ± 0.01	0.74 ± 0.01	0.75 ± 0.01	0.74 ± 0.01	0.76 ± 0.01
	Chl a	1.05 ± 0.02 a	1.00 ± 0.05 a	1.06 ± 0.01 a	0.96 ± 0.04 ab	0.88 ± 0.05 b
	Chl b	0.65 ± 0.05 a	0.56 ± 0.05 ab	0.63 ± 0.02 a	0.48 ± 0.03 b	0.46 ± 0.05 b
	Total Chl	1.70 ± 0.06 a	1.56 ± 0.09 ab	1.69 ± 0.03 a	1.45 ± 0.06 b	1.34 ± 0.10 b
	Total Car	0.12 ± 0.01	0.11 ± 0.01	0.11 ± 0.00	0.12 ± 0.01	0.11 ± 0.01
	Chl a:Chl b	1.65 ± 0.09 b	1.83 ± 0.08 ab	1.69 ± 0.04 b	2.02 ± 0.07 a	1.95 ± 0.08 a
	Car:Chl	0.072 ± 0.007	0.075 ± 0.007	0.065 ± 0.003	0.080 ± 0.006	0.082 ± 0.003

* No fertilization (NoFert), conventional fertilization–base dressing (CoFert), organic fertilization–base dressing (OrFert), conventional fertilization with side dressing of CoFert (CoFert + S_{CoFert}) and organic fertilization with side dressing of OrFert (OrFert + S_{OrFert}); significant differences ($p < 0.05$) among the treatments are indicated by different letters in the same row.

3.3. Purslane and Sowthistle Plant Macronutrient Content

Table 3 presents the macronutrients content of purslane and sowthistle plants grown under different fertilization regimes. In purslane, the N content in leaves and stems was the highest for the treatment of OrFert + S_{OrFert}, while the lowest one was recorded for the NoFert treatment. In the case of leaf P, K and Na content, the highest values were reported for the OrFert treatment, being significantly different from the rest of the treatments. Interestingly, the additional application of a side dressing with organic fertilizer (OrFert + S_{OrFert}) decreased the P, K and Na contents, compared to the base dressing of the same fertilizer (OrFert). The P content in leaves was the lowest with the application of the CoFert fertilization, while an increase in P content was observed with the combined application of base and side dressing (CoFert + S_{CoFert}). Both NoFert and CoFert treatments produced plants with the same content of P and K in stems, while the highest P and K contents were recorded for the CoFert + S_{CoFert} and OrFert + S_{OrFert} treatments, respectively. Finally, the application of OrFert significantly increased Na content in stems, compared to the rest of fertilization regimes.

In common sowthistle, the NoFert treatment significantly decreased (up to 22.0%) leaf N content, compared to the other treatments. Furthermore, P content was significantly influenced by the examined treatments, as the OrFert treatment produced plants with the lowest P content, although an increase of 5.2% was recorded for the OrFert + S_{OrFert} treatment. Moreover, the highest P content was recorded for the CoFert + S_{CoFert} treatment, presenting an increase of 24.6% compared to the treatment of base dressing with the same fertilizer, and an overall increase of up to 34.4% compared to the rest of the treatments. The highest and lowest K content in leaves were recorded for the CoFert + S_{CoFert} and OrFert treatments, respectively. Furthermore, the side dressing with both fertilizers increased the K content. Finally, CoFert produced plants with the lowest Na content, while the addition of side dressing increased the Na content, resulting in similar values to the respective OrFert treatment (OrFert + S_{OrFert}).

Table 3. The effect of different fertilization regimes on purslane and sowthistle macronutrients content (g kg^{-1}). Values are means (±SE) of six replicates for each treatment.

Plant	Parameters	NoFert *	CoFert	OrFert	CoFert + S_{CoFert}	OrFert + S_{OrFert}
Purslane	Leaves N	18.57 ± 0.64 c	23.94 ± 0.21 b	23.36 ± 0.19 b	24.17 ± 0.43 b	28.23 ± 0.72 a
	Leaves P	1.90 ± 0.06 d	1.48 ± 0.05 e	4.23 ± 0.06 a	3.09 ± 0.05 b	2.85 ± 0.02 c
	Leaves K	88.58 ± 0.84 c	94.44 ± 1.36 b	99.39 ± 0.90 a	93.57 ± 0.21 b	90.58 ± 0.90 c
	Leaves Na	5.01 ± 0.04 b	5.01 ± 0.07 b	5.30 ± 0.07 a	4.51 ± 0.02 c	4.53 ± 0.07 c
	Stems N	8.93 ± 0.44 e	15.47 ± 0.30 b	13.68 ± 0.70 c	10.97 ± 0.19 d	16.84 ± 0.32 a
	Stems P	0.59 ± 0.04 c	0.71 ± 0.02 c	1.15 ± 0.12 b	1.06 ± 0.01 b	1.39 ± 0.07 a
	Stems K	116.40 ± 4.68 c	116.04 ± 2.25 c	123.71 ± 3.34 bc	137.05 ± 1.13 a	127.77 ± 2.06 b
	Stems Na	1.92 ± 0.05 b	1.94 ± 0.05 b	2.53 ± 0.18 a	2.06 ± 0.02 b	2.18 ± 0.08 b
Sowthistle	Leaves N	24.31 ± 0.27 b	29.03 ± 0.19 a	29.66 ± 0.90 a	29.63 ± 0.47 a	29.20 ± 0.18 a
	Leaves P	2.09 ± 0.02 b	2.07 ± 0.04 b	1.92 ± 0.04 c	2.58 ± 0.02 a	2.02 ± 0.02 b
	Leaves K	63.01 ± 0.51 b	59.93 ± 0.91 c	52.26 ± 0.39 e	65.20 ± 0.97 a	56.15 ± 0.54 d
	Leaves Na	2.78 ± 0.01 b	2.32 ± 0.04 d	2.68 ± 0.03 c	3.58 ± 0.03 a	3.60 ± 0.04 a

* No fertilization (NoFert), conventional fertilization–base dressing (CoFert), organic fertilization–base dressing (OrFert), conventional fertilization with side dressing of CoFert (CoFert + S_{CoFert}) and organic fertilization with side dressing of OrFert (OrFert + S_{OrFert}); significant differences ($p < 0.05$) among the treatments are indicated by different letters in the same row.

3.4. Total Soluble Solids Content, Total Acidity and Sweetness Index in Purslane and Common Sowthistle Plants

Total soluble solids (TSSs), total acidity (TA), and sweetness index (TSSs/TA) were affected by the different fertilization regimes in both tested plants, e.g., purslane and common sowthistle (Table 4). In purslane, TSSs exhibited decreased values with the NoFert and CoFert treatments, whereas a contrasting trend was recorded for TA where NoFert and CoFert recorded the highest values. Finally, the OrFert + S_{OrFert} treatment recorded the lowest overall values for the sweetness index, compared to the rest of the treatments.

Table 4. The effect of different fertilization regimes on purslane and sowthistle total soluble solids (TSSs; %), total acidity (TA; % malic acid) and sweetness index (TSSs:TA ratio). Values are means (±SE) of six replicates for each treatment.

Plant	Parameters	NoFert *	CoFert	OrFert	CoFert + S_{CoFert}	OrFert + S_{OrFert}
Purslane	TSS	1.23 ± 0.04 b	1.23 ± 0.08 b	1.43 ± 0.11 a	1.53 ± 0.03 a	1.53 ± 0.02 a
	TA	3.17 ± 0.31 a	2.75 ± 0.03 a	2.10 ± 0.27 b	2.03 ± 0.14 b	1.34 ± 0.05 c
	TSS/TA	0.58 ± 0.04 a	0.51 ± 0.03 a	0.45 ± 0.08 a	0.46 ± 0.03 a	0.31 ± 0.01 b
Sowthistle	TSS	0.58 ± 0.05	0.58 ± 0.03	0.55 ± 0.03	0.50 ± 0.04	0.48 ± 0.03
	TA	2.62 ± 0.20 a	2.26 ± 0.19 ab	1.83 ± 0.10 c	1.99 ± 0.04 bc	1.21 ± 0.05 d
	TSS/TA	1.56 ± 0.19 b	1.83 ± 0.25 b	2.09 ± 0.29 ab	1.69 ± 0.14 b	2.71 ± 0.20 a

* No fertilization (NoFert), conventional fertilization–base dressing (CoFert), organic fertilization–base dressing (OrFert), conventional fertilization with side dressing of CoFert (CoFert + S_{CoFert}) and organic fertilization with side dressing of OrFert (OrFert + S_{OrFert}); significant differences ($p < 0.05$) among the treatments are indicated by different letters in the same row.

In common sowthistle, TSSs remained unaffected by the examined fertilization regimes, with values that ranged from 0.48 to 0.58%. Total acidity was the highest for the NoFert treatment, while the lowest value was observed for the OrFert + S_{OrFert} treatment, showing a decrease of 116.5% compared to the NoFert treatment. Finally, the sweetness index was the highest for the OrFert + S_{OrFert} treatment, being significantly different from the rest of the treatments (except for the OrFert treatment where no significant differences were recorded).

3.5. Total Phenolics Content, Antioxidant Capacity, Flavonoids Content and Ascorbic Acid Content in Purslane and Common Sowthistle Plants

The different fertilization regimes significantly affected the antioxidant capacity, as well as the content of total phenolics, flavonoids and ascorbic acid, for purslane and common sowthistle (Figures 1 and 2, respectively).

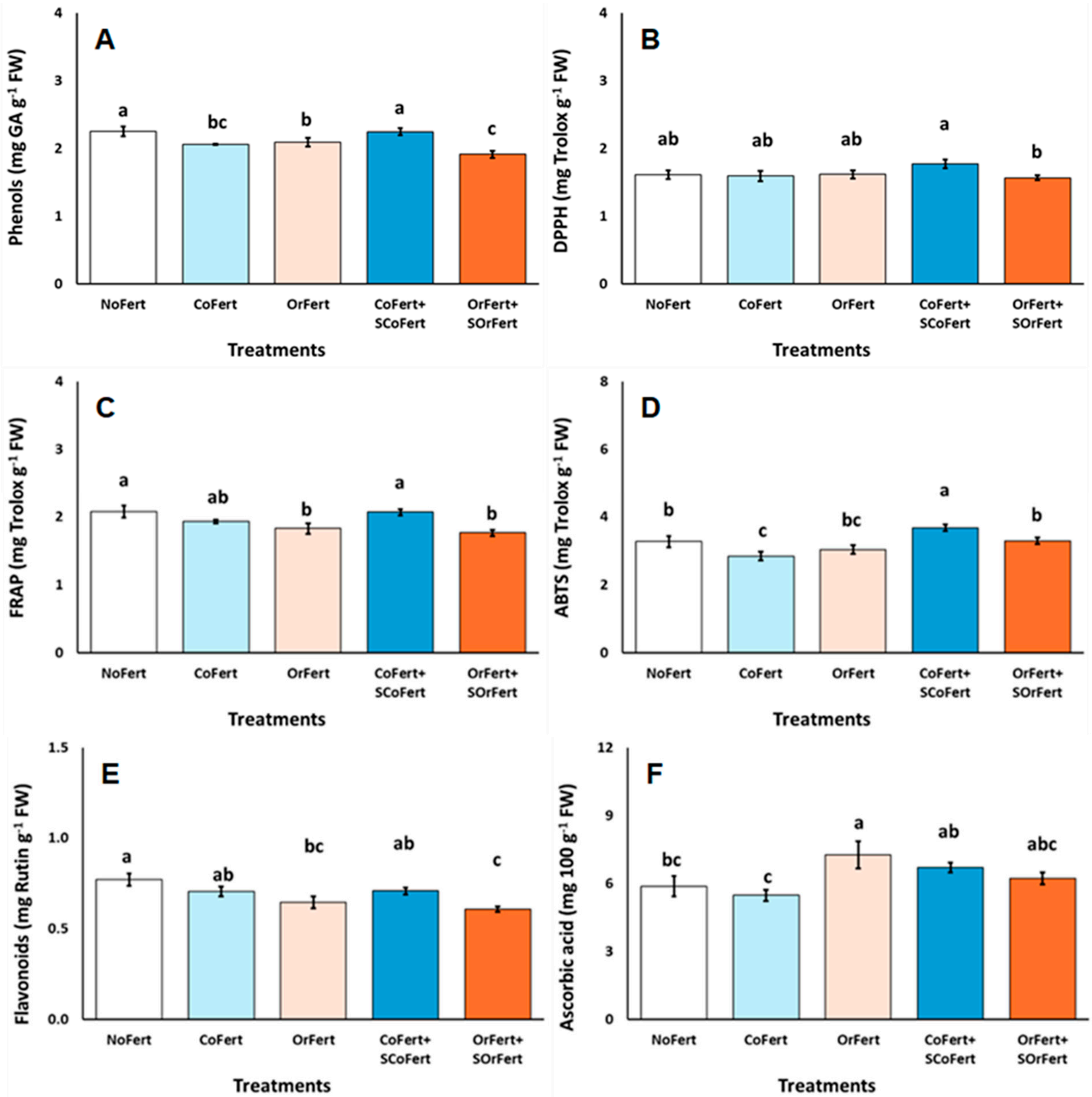

Figure 1. The effect of different fertilization regimes on purslane's (**A**) total phenols content (mg g^{-1} FW) and antioxidant capacity according to (**B**) DPPH, (**C**) FRAP, and (**D**) ABTS•+ (mg Trolox g^{-1} FW); (**E**) flavonoids content (mg Rutin g^{-1} FW) and (**F**) ascorbic acid content (mg 100 g^{-1} FW); no fertilization (NoFert), conventional fertilization–base dressing (CoFert), organic fertilization–base dressing (OrFert), conventional fertilization with side dressing of CoFert (CoFert + S_{CoFert}) and organic fertilization with side dressing of OrFert (OrFert + S_{OrFert}); significant differences ($p < 0.05$) among the treatments are indicated by different letters above the vertical bars. Values are means (±SE) of six replicates for each treatment.

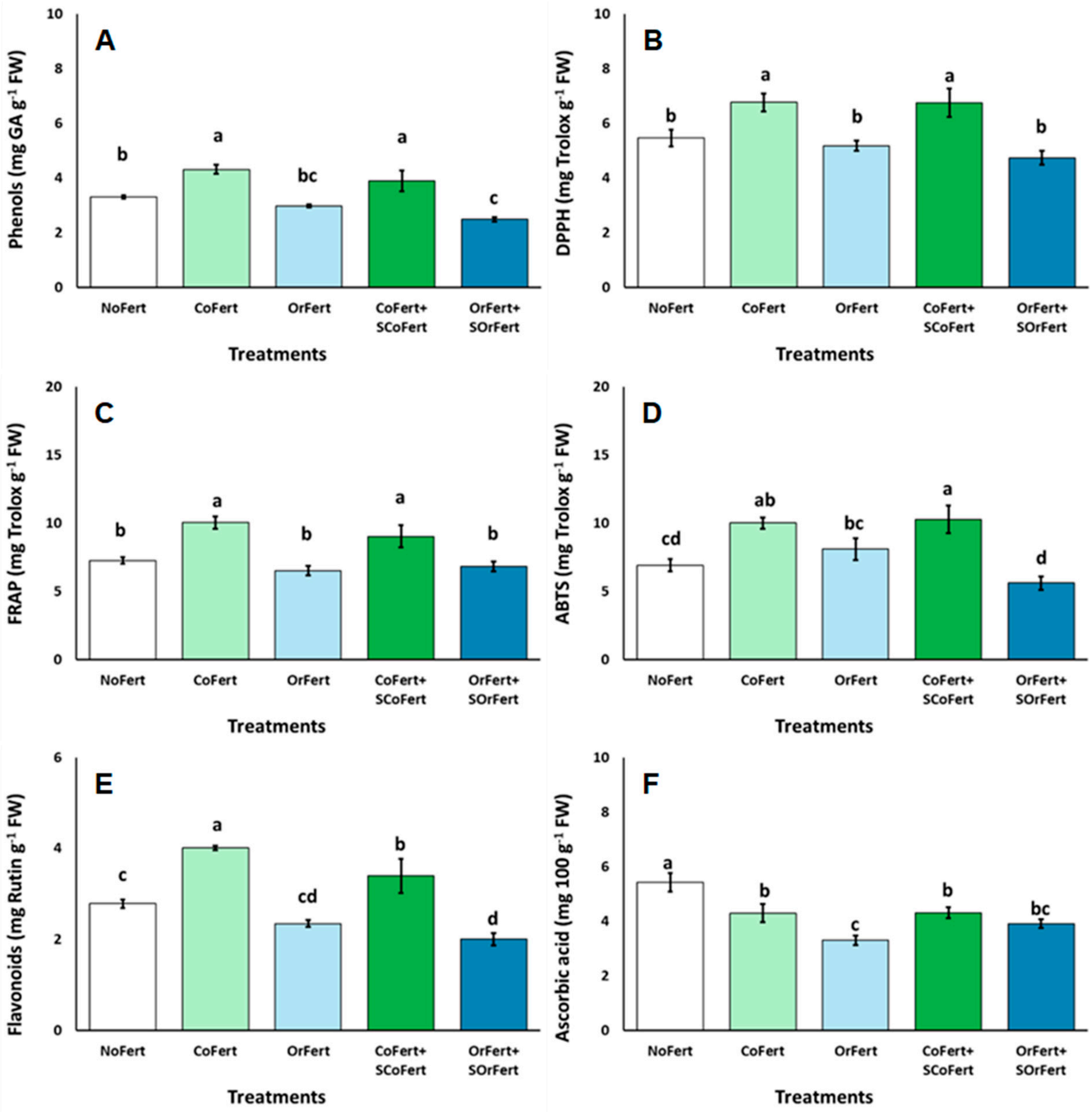

Figure 2. The effect of different fertilization regimes on common sowthistle's (**A**) total phenols (mg GA g^{-1} FW) and antioxidant capacity according to (**B**) DPPH, (**C**) FRAP, (**D**) ABTS•+ (mg Trolox g^{-1} FW); (**E**) flavonoids (mg Rutin g^{-1} FW) and (**F**) ascorbic acid content (mg 100 g^{-1} FW); no fertilization (NoFert), conventional fertilization–base dressing (CoFert), organic fertilization-base dressing (OrFert), conventional fertilization with side dressing of CoFert (CoFert + S_{CoFert}) and organic fertilization with side dressing of OrFert (OrFert + S_{OrFert}); significant differences ($p < 0.05$) among applications are indicated by different letters above the vertical bars. Values are means (±SE) of six replicates for each treatment.

In purslane, the highest total phenolics content was reported for the NoFert and CoFert + S_{CoFert} treatment, and the lowest for the OrFert + S_{OrFert} treatment, while the application of side dressing exhibited an increase compared to the base dressing with the conventional fertilizer (CoFert treatment), and a decrease for the organic fertilizer (OrFert treatment) (Figure 1A). Furthermore, the highest and lowest DPPH values were recorded for the CoFert + S_{CoFert} and OrFert + S_{OrFert} treatments, respectively (Figure 1B). Concerning FRAP, the highest values were found for the application of the NoFert and CoFert + S_{CoFert} treatments, whereas the application of organic fertilizer (both OrFert and OrFert + S_{OrFert})

resulted in decreased FRAP values (Figure 1C). ABTS•+ also exhibited varied response, as the lowest content was observed for the CoFert treatment, whereas the application of CoFert + S_{CoFert} presented the highest overall values for ABTS•+ (Figure 1D). The NoFert treatment presented the highest content of flavonoids, without being significantly different from the CoFert and CoFert + S_{CoFert} treatments (Figure 1E). In contrast, the OrFert + S_{OrFert} treatment presented the lowest flavonoids, without differing significantly from the OrFert treatment. Finally, the OrFert treatment resulted in the highest ascorbic acid content, which did not differ significantly from both CoFert + S_{CoFert} and OrFert + S_{OrFert} treatments, whereas CoFert presented the lowest content, without being different from the NoFert treatment (Figure 1F).

In common sowthistle, the total phenolics content was the highest for the CoFert and CoFert + S_{CoFert} treatments, whereas the lowest ones were recorded for the OrFert + S_{OrFert} treatment, without being significantly different from the OrFert treatment (Figure 2A). Similarly, the antioxidant capacity of common sowthistle plants, as assayed by DPPH (Figure 2B), FRAP (Figure 2C) and ABTS•+ (Figure 2D), increased with the application of CoFert and CoFert + S_{CoFert}, compared to the rest of the treatments, without being significantly different from the CoFert treatment, whereas the lowest antioxidant capacity values were recorded for the OrFert + S_{OrFert} treatment, being not significantly different from the NoFert treatment. Flavonoids recorded a notable increase with the application of the CoFert treatment, whereas the OrFert + S_{OrFert} treatment produced plants with the lowest flavonoids content (Figure 2E). Finally, the ascorbic acid content of plants was influenced by the examined treatments, as it significantly decreased when the fertilizer treatments were applied, especially in the case of OrFert where the lowest values were recorded (reduction up to 64.7%) (Figure 2F).

3.6. Lipid Peroxidation and Hydrogen Peroxide Content in Purslane and Common Sowthistle Plants

The effects of different fertilization regimes on the examined damage indicators (H_2O_2 and MDA) are presented in Figures 3 and 4, for purslane and common sowthistle plants, respectively. In purslane, the production of H_2O_2 in the leaf tissues was the highest for the NoFert treatment, whereas no significant differences were observed with the application of the OrFert treatment (Figure 3A). In contrast, plants treated with CoFert + S_{CoFert} and OrFert + S_{OrFert}, recorded the lowest H_2O_2 production. Finally, MDA was the lowest for the CoFert, whereas the highest values were observed for the OrFert + S_{OrFert} treatment, without being significantly different from either the NoFert or CoFert + S_{CoFert} treatments (Figure 3B).

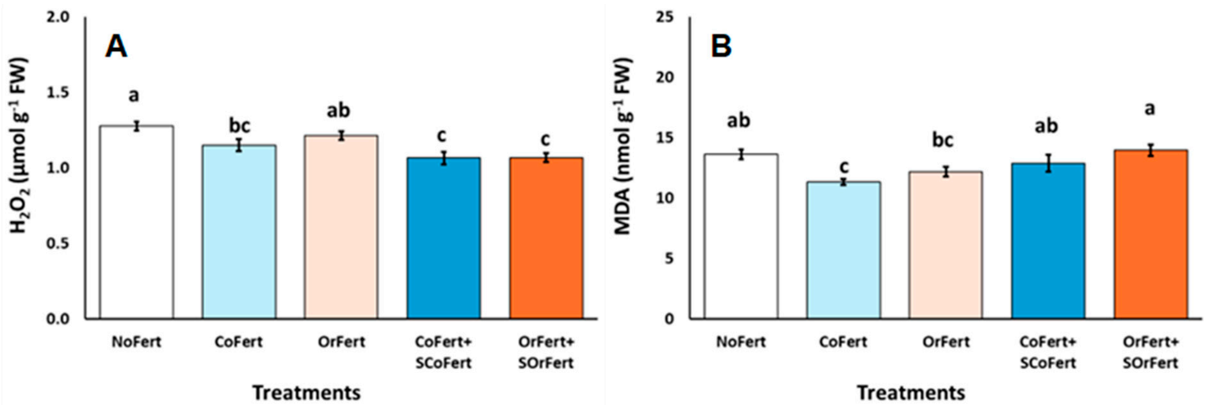

Figure 3. The effect of different fertilization regimes on (**A**) hydrogen peroxide–H_2O_2 (μmol g^{-1}) and (**B**) lipid peroxidation–MDA (nmol g^{-1}) of purslane plants. No fertilization (NoFert), conventional fertilization–base dressing (CoFert), organic fertilization–base dressing (OrFert), conventional fertilization with side dressing of CoFert (CoFert + S_{CoFert}) and organic fertilization with side dressing of OrFert (OrFert + S_{OrFert}); significant differences ($p < 0.05$) among applications are indicated by different letters above the vertical bars. Values are means (±SE) of six replicates for each treatment.

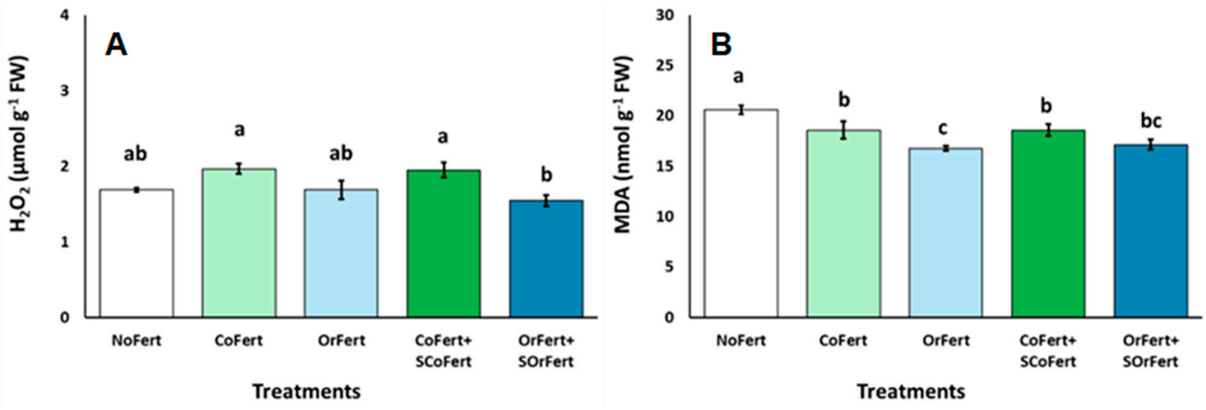

Figure 4. The effect of different fertilization regimes on (**A**) hydrogen peroxide–H_2O_2 (μmol g^{-1}) and (**B**) lipid peroxidation–MDA (nmol g^{-1}) of common sowthistle plants. No fertilization (NoFert), conventional fertilization–base dressing (CoFert), organic fertilization–base dressing (OrFert), conventional fertilization with side dressing of CoFert (CoFert + S_{CoFert}) and organic fertilization with side dressing of OrFert (OrFert + S_{OrFert}); significant differences ($p < 0.05$) among applications are indicated by different letters above the vertical bars. Values are means (±SE) of six replicates for each treatment.

In common sowthistle, the production of H_2O_2 was the highest for the CoFert and CoFert + S_{CoFert} treatments, whereas the OrFert + S_{OrFert} treatment recorded the lowest overall values (Figure 4A). Finally, MDA significantly decreased when plants were treated with fertilizers, regardless of the application regime, compared to the NoFert treatment, with no significant differences being observed between base dressing and the combined base and side dressing for both fertilizers (Figure 4B).

4. Discussion

Organic farming and the application of organic fertilizers falls within the context of sustainability and biodiversity conservation [3,10]. The organic cultivation of alternative crops such as WEPs and MPs is particularly relevant, as such species are adapted to biotic and abiotic stresses, and are characterized by low requirements in terms of inputs, which facilitates the application of organic farming practices [14,15]. In this regard, the current research was conducted to examine and promote the use of sustainable cultivation methods using as case study of two very promising WEPs and MPs, e.g., purslane and common sowthistle. Considering that fertilization has a crucial role in the growth and quality of crops and eventually in the crop yield, it is imperative to maintain an appropriate balance of inputs within the context of sustainable and organic agriculture [12,38].

Previous studies have highlighted the importance of fertilization on the growth and physiology of purslane and sowthistle plants. For example, Carrascosa et al. [12] indicated that the application of organic compost extracts, applied at rates based on N content in the nutrient solution (e.g., 300 mg L^{-1}), supported the growth of purslane in line with the use of inorganic N-P-K fertilization at 100-100-100 mg L^{-1}, in terms of leaf, stem and aerial biomass fresh and dry weights. A similar performance was also reported, in terms of total biomass production, in comparison to several inorganic fertilization regimes with fluctuating N-P-K rates, although varying results were obtained for different purslane genotypes. At the same time, increased N levels using inorganic fertilizers (e.g., 600 mg L^{-1}) resulted in a significantly greater biomass. This is also aligned with the findings of Nastou et al. [39], who demonstrated the positive impact of increased rates of N on the growth of different purslane genotypes. The current study reported similar results for purslane plants, as conventional and organic fertilization produced plants with equivalent growth traits (e.g., aerial biomass production), although in some cases, organic fertilization exceeded the performance of inorganic fertilization, and matched the performance of base and side dressing with conventional fertilizers. In the case of common sowthistle, Carrascosa et al. [12]

reported that the total aerial biomass of plants treated with organic fertilization was similar to various inorganic N-P-K applications (i.e., 300-100-100, 300-200-100, 300-300-100, 300-200-200 mg L^{-1}), although fertilization regimes with increased N (600 mg L^{-1}) and K (300 mg L^{-1}) recorded increased plant biomass. In addition, the application of alternative fertilization (insect frass) at three rates (0.5, 1.0, and 2.0% w/w) produced common sowthistle plants with a similar fresh weight to those that received calcium ammonium nitrate (applied at 100 kg N ha^{-1}) [40]. Moreover, previous reports suggest that vinasse-based fertilizers exhibited a better supplementation of N in the short term, compared to frass fertilizers [41]. In the current study, common sowthistle showed no significant differences in fresh weight production among the examined treatments, while the application of OrFert produced plants with increased height and dry matter content. In the studies of both Karkanis et al. [40] and Cardarelli et al. [41], the use of supplementary organic fertilization in the form of a side dressing did not yield remarkable increase, as its application (i.e., fertilizer side broadcasting) in a pelleted form may not have provided sufficient nutrients within the short duration of the experiments. Moreover, Rodrigues et al. [42] suggested that composted and pelleted amendments have a low N content, and the application of organic fertilization (Phenix) provided a portion of N early in the cultivation period, while the rest of the N remained available for a longer period. This is applicable to various organic amendments, as these materials release nutrients gradually, and therefore plants assimilate them more effectively due to decreased leaching [43].

Fertilization is fundamental in the synthesis of chlorophylls, which directly affects the rate of photosynthesis [44]. In the study by Chrysargyris et al. [5], the application of conventional fertilizers resulted in *Mentha spicata* (L.) plants with higher SPAD values, compared to the application of organic fertilization. Similarly, in the study of Karkanis et al. [40] it was observed that common sowthistle plants that received conventional fertilizers exhibited higher relative chlorophyll content (SPAD) values, compared to ones that received various rates of organic insect frass, which was attributed to the increased rates of N uptake by common sowthistle plants in the former case. However, in the current study both purslane and common sowthistle plants that received organic fertilization exhibited similar SPAD and chlorophylls to conventional fertilization. This could be attributed to the adequate N provided by the vinasse-based organic fertilizer within the short duration of the cultivation period, which appears to not have affected N availability, a finding which is in agreement with previous reports [41,42]. Similar results were obtained for the use of organic fertilization in the cultivation of *Pinellia ternata* (Thunb.), as SPAD values remained at similar levels compared to conventional fertilization [45]. The same researchers also reported that the increase in organic fertilizer rates improved SPAD values. The nitrogen delivered by the organic farming method is primarily organic and not completely accessible to the plants, which may explain poor plant development, a reduction in chlorophyll content and reduced photosynthetic activity [46]. Furthermore, Fontana et al. [47] showed that besides total nitrogen availability, the nitrogen form may alter the chlorophyll levels in purslane plants grown in hydroponics.

Organic farming utilizes organic fertilizers and amendments that enhance the soil's organic matter content, whilst facilitating a gradual release of nutrients, thereby improving their uptake and accumulation [48]. In the current study, the macronutrient content of purslane and common sowthistle plants was significantly influenced by the different fertilizer regimes tested. Previous studies have shown that vinasse-based organic fertilizers can support plant nutrition, especially during the initial growth and in short cultivation cycles, due to the fast mineralization and release of minerals in the post application period [41]. In the case of common sowthistle, various reports suggest that the application of organic fertilization affected the uptake of nutrients, compared to the application of conventional fertilization. Specifically, Karkanis et al. [40] reported that the use of yellow mealworm frass increased the contents of P over the application of calcium ammonium nitrate. However, in the study by Carrascosa et al. [12], decreased P contents were observed in the leaves of common sowthistle plants, compared to the application of inorganic N-P-K fertilization.

Similarly, in the current study, the common sowthistle leaves had decreased levels of P with the application of organic fertilizers, while side dressing slightly increased the P levels. Additionally, both studies of Karkanis et al. [40] and Carrascosa et al. [12] reported that macronutrients such as N, Mg, and Ca remained unaffected by the application of organic fertilizers. Similarly, the organic fertilization applied in the current study produced common sowthistle plants with a high N content in their leaves, similar to the application of conventional fertilization. Purslane was also found to have comparable N levels in both organic and conventional fertilization, while the use of a side dressing improved the uptake of N, P and K, as purslane leaves and stems had increased macronutrient levels compared to the rest of the treatments.

In terms of quality, purslane exhibited increased TSSs and sweetness index values for the application of organic fertilization, compared to conventional fertilization, and matched the results obtained with the use of side dressing with the same fertilizer. Similar findings were reported in previous studies with wild, medicinal plants. For example, Bakhtiari et al. [49] reported that the use of organic (vermicompost) fertilization, with or without additional NPK, produced *Satureja macrantha* C.A.Mey. plants with higher TSSs contents compared to conventional fertilization.

Both purslane and common sowthistle plants are valued for their diverse array of phytochemical constituents, as well as for their high content of polyphenols, which have been shown to exhibit various antioxidant, anti-inflammatory and antimicrobial properties [19,50]. When examining radical scavenging activity, a single assay may offer a limited understanding of the overall antioxidant properties of plant material. This is particularly relevant for medicinal and wild edible plants, as their complex chemical composition may lead to inconsistent results, depending on the test employed. Furthermore, the proper assessment of the antioxidant capacity from these species is crucial to promote the application of functional foods, pharmaceuticals and food additives [34]. Previous studies have reported the significant effect of organic fertilization applications on the antioxidant capacity, flavonoids and total phenolics [5,51]. In the case of purslane, a previous report suggested that the application of organic materials (waste fermentation residue after evaporation) did not affect the plants' total phenols content. Similarly, in the current study, purslane showed no significant differences in terms of total phenols, antioxidant capacity (DPPH, FRAP, ABTS•+) and flavonoids, when organic fertilization was applied compared to conventional fertilization. Similar results were obtained by Chrysargyris et al. [5], who examined the antioxidant capacity and total phenols content of *M. spicata* (L.) plants grown in conventional and organic cultivation systems. Lv et al. [52] also reported similar levels of total phenols in peppermint (*M. piperita* L.) and cinnamon (*Cinnamomum verum* L.), but the individual phenolic molecules were changed when plants grown under organic and conventional cultivation practices. In addition, in coriander (*Coriandrum sativum* L.), Serri et al. [51] reported that total phenolics and flavonoids content depended on the type of fertilizer applied, and the application of vermicompost and biophosphate produced plants with similar total phenolics and flavonoids contents compared to conventional NPK fertilization. This corroborates the notion that the fertilization applied in the current experiment adequately provided plants with balanced nutrition during the short period of cultivation. Moreover, the results indicate that the antioxidant capacity of purslane is an intrinsic property of the species, as reported previously in response to organic fertilization [53]. However, contrasting results were observed in the case of common sowthistle, as total phenolics, antioxidant capacity and flavonoids were decreased with the application of organic fertilization compared to conventional fertilization. In contrast, numerous studies have demonstrated that organic fertilizers may enhance the content of phenolics, and the antioxidant capacity in various plant species [54,55]. Interestingly, a decrease in the total phenolics, antioxidant capacity (DPPH, FRAP, ABTS•+) and total phenolics of both purslane and common sowthistle were observed with the application of OrFert + S_{OrFert}, compared to CoFert + S_{OrFert}. Similarly, in the organic cultivation of barley

(*Hordeum vulgare* L.) a decrease in phenolics and flavonoids was observed for well-fertilized plants with organic fertilization [56].

Research investigating the stress response of plants subjected to organic fertilization has yielded variable results, depending on plant species, cultivation methods and fertilizer type. Previously reported data suggest that the use of organic fertilization (e.g., manure) can alleviate oxidative damage and reduce the MDA content in beetroot plants grown under stress conditions [57]. In Chinese cabbage (*Brassica rapa* L. subsp. *pekinensis*), the application of organic fertilization led to an equal or decreased MDA content compared to treatments used conventional fertilization [58]. Similarly, in ginger (*Zingiber officinale* Rosc.), the use of vermicompost and poultry manure decreased the H_2O_2 contents of plants, compared to the application of conventional NPK fertilization [59]. In our study the application of organic fertilization in purslane had a similar effect in MDA and H_2O_2; however, H_2O_2 increased with the application of a side dressing, in both conventional and organic fertilization regimes in levels similar to the control treatment (NoFert), thus indicating the low nutrient requirements for the species which can be covered with base dressing and the negative effects of additional fertilization. In contrast, in common sowthistle, the application of organic fertilization decreased H_2O_2, a finding which is similar to the abovementioned literature reports and indicates that organic practices may trigger the defense system of plants and alleviate stress responses [60].

5. Conclusions

The current study evaluated the application of conventional and organic fertilization in purslane (*P. oleracea* L.) and common sowthistle (*S. oleraceus* L.) plants cultivated in field conditions. Regarding purslane, the application of organic fertilizers provided comparable or even enhanced plant growth traits, compared to the application of conventional fertilizers. Conventional fertilization with supplementary fertilization in the form of a side dressing positively influenced plant growth (i.e., plant height and stems FW) physiological parameters (i.e., chlorophylls content), total phenolics content and antioxidant capacity (i.e., DPPH and FRAP). Interestingly, organic fertilization presented comparable or improved results in terms of macronutrient content (i.e., P and K), quality (i.e., TSS) and ascorbic acid content. In the case of common sowthistle, organic fertilization was presented as a promising alternative to conventional fertilization. Specifically, the growth-related traits of common sowthistle plants treated with organic fertilization were comparable (i.e., leaf number and plant FW) or improved (i.e., plant height and dry matter content), compared to conventional fertilizers. Although decreased K and P contents were observed, organic fertilization provided the plants with adequate N, an element that is typically in shortage in organic cropping systems. On the other hand, total phenolics, antioxidant capacity and flavonoids were decreased with the application of organic fertilization compared to conventional fertilization. Generally, variable effects were observed regarding plant physiology, stress response and antioxidant capacity, based on the fertilization regime and the application of supplementary fertilization (e.g., side dressing). The use of organic fertilization in both purslane and common sowthistle exhibited performance similar to those of conventional fertilization, indicating that organic farming practices are ideal for crops with low input requirements. However, future studies should focus on the long-term optimization of fertilizer doses, as well as the integration of components such as biochar, and beneficial organisms such as mycorrhiza.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/horticulturae10111222/s1, Table S1: The amounts of fertilizers and nutrients applied for each treatment (kg ha^{-1}).

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