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Proceeding Paper

The Effect of Fertilization Regime on Growth Parameters of *Sonchus oleraceus* and Two Genotypes of *Portulaca oleracea* †

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Abstract: Wild edible plants of the Mediterranean represent an extraordinary food source and are basic ingredients in the "Mediterranean diet". However, there is a scarcity of information about their commercial interest or cultivation practices. This study was conducted to evaluate how different amounts of inorganic and organic fertilization affected the plant growth parameters of *Sonchus oleraceus* and *Portulaca oleracea*. The experiment was performed in greenhouse conditions in pots containing soil, sand and vermiculite in a volume ratio of 1-1-1 for 12 weeks. The control treatment had no fertilization; the inorganic fertilization (N-P-K) was 100 mL of 100-100-100 mg L^{-1}; 300-100-100 mg L^{-1}; 600-100-100 mg L^{-1}; 300-200-100 mg L^{-1}; 300-300-100 mg L^{-1}; 300-200-200 mg L^{-1}; 300-200-300 mg L^{-1}; and 100 mL of the organic compost extract to reach same equivalence as 300 mg L^{-1} of N and 100 mL of the organic compost extract + P inorg (equivalent to 300 mg L^{-1} of N and 200 mg L^{-1} of P). All treatments were applied weekly. All treatments assayed showed significantly higher leaf and stem weights compared to the control treatment; the highest values were recorded for the treatment of 600-100-100 in both plant species (*S. oleraceus* and *P. oleracea*). Treatment (600-100-100) showed a significantly higher N content, but not P and K contents, than the rest of the treatments. The plant nutrient contents of Mg, Fe, S and Ca did not differ among the tested fertilization regimes. The soil nutrient contents (N, P, K, Fe, Ca) showed no differences between treatments. We conclude that nitrogen had a main role in improving the plant growth parameters and yield in both wild plant species, the beneficial effect depending on the doses and origin (inorganic or organic) of the fertilizer applied.

Keywords: sustainable fertilization; tea compost; crop yield; nutrient assimilation

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1. Introduction

The Mediterranean basin is a biodiversity hotspot of wild plants, and many of them have been widely used in traditional culture. Wild edible plants (WEPs) have been used in traditional recipes of the Mediterranean diet, and their use has continuously increased in search of healthy sources of food. Wild plants may also be important for degraded soils, where common crops are harder to cultivate due to their natural adaptations to the soil and climate [1]. Purslane (*Portulaca oleracea* L.) is known for being a source of bio-protective compounds such as omega-3 fatty acid—mainly, α-linolenic acid—which is important in the reduction of heart diseases [2,3]. Because of its content, purslane is one of the richest plant sources for human nutrition [4]. Sow-thistle (*Sonchus oleraceus* L.) is also appreciated as an ingredient with a level of lipids higher than that in common vegetables [5].

Mediterranean soils are characterized by low contents of nitrogen (N) and organic carbon (OC), especially in semiarid Mediterranean soil [6]. In order to maintain appropriate yield levels, conventional agriculture has depended on chemical fertilizers, pesticides and herbicides, which have generated an increase in the degradation of soils, a poor development of the soil structure and, therefore, the need to increase the application of chemical treatments [7].

Tea compost (TC) is a water extract of compost that can be used as a nutrient amendment in soils to improve productivity [8,9]; it is mainly used for plant promotion through microorganisms and compounds that favor plant growth and nutrient absorption by fixing nitrogen or solubilizing other nutrients such as phosphorus [10,11].

This study was conducted to evaluate the effect of the fertilization with different amounts of N-P-K and organic compost extract on the plant growth parameters of *Sonchus oleraceus* and *Portulaca oleracea* (with two different origins, Greece and Spain).

2. Materials and Methods

Seeds of *Sonchus oleraceus* L. and *Portulaca oleracea* L. (with two different genotypes, one obtained from Greece and one from Spain) were sown in 1 L pots containing soil, sand and vermiculite (1/1/1; *w*/*w*/*w*) in April 2021. The soil was obtained from the CEBAS-CSIC Experimental Farm (Santomera, Murcia, Spain 38°06′14.0″N 1°02′00.1″W), corresponding to a semiarid climate with annual precipitations lower than 300 mm and a mean temperature of 18 °C.

The experimental design consisted of 10 fertilization treatments with 4 repetitions each: N-P-K treatments were prepared to reach a final concentration of mg L^{-1} for each of them, namely: IT1, 100-100-100 mg L^{-1}; IT2, 300-100-100 mg L^{-1}; IT3, 600-100-100 mg L^{-1}; IT4, 300-200-100 mg L^{-1}; IT5, 300-300-100 mg L^{-1}; IT6, 300-200-200 mg L^{-1}; IT7, 300-200-300 mg L^{-1}; OT1, organic compost extracts (equivalent to 300 mg L^{-1}); OT2, organic compost extract + P (equivalent to 300 and 200 mg L^{-1}); and the control treatment to which no fertilizers were added.

All treatments were applied weekly with 100 mL of the nutrient solution, starting from the fourth week since germination. The harvest took place after 12 weeks. The recorded parameters at harvest included the chlorophyll content of leaves (SPAD index) and the leaf and stem weight. Only for the *P. oleracea* plants were the nutrient content in plants and the soil carbon (N, P, K, Ca, Mg, S, Fe) analyzed using ICP-MS.

The effects of experimental factors were analyzed by a one-way ANOVA. Mean comparisons were calculated using the post hoc TUKEY's HSD (Honestly Significant Difference) test at $p < 0.05$. Both analyses were performed using R Studio (Version 2021.9.1.372, R Core Team, Vienna, Austria).

3. Results and Discussion

Plant Growth and Nutrition

The level of fertilization is a key aspect in order to establish any crop to a new situation. Nitrogen, phosphorous and potassium are the macronutrients that are more relevant, so the importance of an appropriate application of them is of great magnitude. In sustainable agriculture, the management of nutrients, especially nitrogen and phosphorous, is crucial to manage inputs [12].

The application of fertilization had a significant effect on the shoot and leaves biomass of the purslane from Greece, as is shown in Table 1. The control plants showed the lowest values of plant growth with respect to the rest of the treatments. The increase in nitrogen with other macronutrients (IT1, IT2 and IT3) showed significantly higher growth with respect to the control plants. The addition of phosphorous to nitrogen (IT4 and IT5) also showed a higher plant biomass than the control plants, both of them being similar to IT2. The tea compost treatments had similar growth rates as IT1, even though the nitrogen amount was similar to that of IT2. These data show that nitrogen increased purslane's growth, it being the treatment with the highest doses of nitrogen (IT3) and the one that produced the highest levels of plant growth. The plant growth parameters of the purslane from Spain under the different fertilization treatments were similar to those of the purslane from Greece (Table 2).

Table 1. Effects of nutritional treatments on leaves' fresh and dry weight (LFW and LDW), shoots' fresh and dry weight (SFW and SFW) and the total aerial fresh and dry weight (TFW and TDW) of the Greek purslane.

Treatment	LFW (g)	LDW (g)	SFW (g)	SDW (g)	TFW (g)	TDW (g)
Control	5.66 ± 0.69 a	0.48 ± 0.08 a	4.43 ± 1.59 a	0.4 ± 0.14 a	10.09 ± 1.92 a	0.88 ± 0.19 a
IT1	21.58 ± 2.35 bcd	1.79 ± 0.15 bc	20.36 ± 4.62 bc	1.72 ± 0.44 bcd	41.95 ± 3.31 bcd	3.51 ± 0.35 bc
IT2	28.53 ±3.60 cde	2.43 ± 0.33 cd	29.03 ± 4.59 de	2.41 ± 0.67 cd	57.56 ± 7.24 de	4.84 ± 0.98 cd
IT3	42.12 ± 12.74 f	2.93 ± 0.68 d	40.24 ± 5.80 f	2.76 ± 0.67 d	82.36 ± 17.98 f	5.68 ± 1.31 d
IT4	31.99 ± 5.12 def	2.51 ± 0.60 cd	29.62 ± 3.89 de	2.27 ± 0.51 cd	61.61 ± 6.42 e	4.78 ± 1.07 cd
IT5	25.06 ± 3.17 bcde	2.09 ± 0.14 bcd	23.10 ± 2.71 cd	1.92 ± 0.47 bcd	48.15 ± 3.02 cde	4.00 ± 0.41 bcd
IT6	33.73 ± 4.02 ef	2.76 ± 0.46 d	30.78 ± 2.64 de	2.19 ± 0.54 bcd	64.50 ± 6.43 e	4.95 ± 0.98 cd
IT7	30.41 ± 1.54 def	2.61 ± 0.13 cd	32.13 ± 2.96 ef	2.69 ± 0.57 d	62.54 ± 2.08 e	5.30 ± 0.69 cd
OT1	15.98 ± 1.80 ab	1.41 ± 0.16 b	17.12 ± 3.23 bc	1.45 ± 0.25 abc	33.10 ± 3.63 bc	2.85 ± 0.38 b
OT2	17.21 ± 1.04 abc	1.5 ± 0.09 b	12.60 ± 1.04 ab	1.06 ± 0.11 ab	29.82 ± 1.70 b	2.56 ± 0.19 ab
ANOVA (F value (p value))	18.26 (0.001)	18.61 (0.001)	34.86 (0.001)	9.79 (0.001)	34.99 (0.001)	15.53 (0.001)

For each treatment, different letters in the same column denote significant differences ($p < 0.05$) according to the Tukey HSD.

Table 2. Effects of nutritional treatments on leaves' fresh and dry weight (LFW and LDW), shoots' fresh and dry weight (SFW and SFW) and the total aerial fresh and dry weight (TFW and TDW) of the Spanish purslane.

Treatment	LFW (g)	LDW (g)	SFW (g)	SDW (g)	TFW (g)	TDW (g)
Control	4.08 ± 0.60 a	0.17 ± 0.04 a	5.63 ± 0.48 a	0.54 ± 0.07 a	9.72 ± 0.41 a	0.71 ± 0.07 a
IT1	15.24 ± 1.63 bc	0.98 ± 0.08 bc	25.83 ± 2.92 bcd	2.34 ± 0.29 bc	41.07 ± 3.51 bcd	3.32 ± 0.27 bcd
IT2	21.08 ± 2.44 cd	1.36 ± 0.37 cd	29.75 ± 3.83 cd	2.32 ± 0.55 bc	50.84 ± 5.68 cd	3.68 ± 0.80 bcd
IT3	36.01 ± 2.11 f	2.10 ± 0.14 e	44.92 ± 5.51 e	3.12 ± 0.68 c	80.93 ± 7.34 e	5.22 ± 0.69 e
IT4	23.90 ± 3.62 d	1.47 ± 0.17 cd	38.77 ± 8.13 de	3.09 ± 0.54 c	62.65 ± 11.69 d	4.55 ± 0.68 de
IT5	90.00 ± 3.13 cd	1.08 ± 0.42 bcd	29.10 ± 9.7 cd	2.22 ± 1.10 bc	48.08 ± 11.57 cd	3.30 ± 1.42 bcd
IT6	21.59 ± 4.46 d	1.05 ± 0.20 bcd	33.9 ± 3.60 de	2.62 ± 0.53 bc	55.54 ± 7.26 cd	3.67 ± 0.66 bcd
IT7	20.93 ± 1.76 cd	1.52 ± 0.13 d	33.00 ± 6.71 de	2.66 ± 0.78 bc	54.00 ± 6.33 cd	4.18 ± 0.70 cde
OT1	10.26 ± 1.27 ab	0.78 ± 0.08 b	18.40 ± 0.96 abc	1.82 ± 0.16 ab	28.66 ± 1.46 bc	2.60 ± 0.20 b
OT2	9.43 ± 2.22 ab	0.62 ± 0.16 ab	14.71 ± 5.55 ab	1.35 ± 0.50 ab	24.14 ± 7.75 b	1.97 ± 0.63 ab
ANOVA (F value (p value))	48.81 (0.001)	25.56 (0.001)	18.08 (0.001)	7.07 (0.001)	32.19 (0.001)	13.44 (0.001)

For each treatment, different letters denote significant differences ($p < 0.05$) according to the Tukey HSD.

The organic treatments with tea compost (OT1 and OT2) showed significant differences with respect to the control plants. Both organic fertilization treatments did not show significant differences with respect to the inorganic treatment IT1, although the plants growing under the OT2 treatment were a bit smaller, even with the addition of P. Therefore, the application of phosphorous seemed to not have an effect on the growth of the purslane.

In contrast to the purslane plants, the sow-thistle plants showed a stronger response to the addition of nutrients and organic fertilization. The OT1 and OT2 treatments showed the highest differences with respect to plant biomass than the control plants; they were similar to the IT2 treatment (Table 3). Treatment IT7 showed similar plant growth to IT3, despite the difference in the doses of nitrogen fertilization applied.

Table 3. Effects of nutritional treatments on leaves' fresh and dry weight (LFW and LDW), shoots' fresh and dry weight (SFW and SFW) and the total aerial fresh and dry weight (TFW and TDW) of the sow-thistle.

Treatment	LFW (g)	SFW (g)	TFW (g)
Control	1.85 ± 1.39 a	5.04 ± 3.07 a	6.88 ± 4.45 a
IT1	12.07 ± 2.72 b	14.67 ± 4.19 ab	26.74 ± 4.84 b
IT2	31.05 ± 1.07 d	22.71 ± 5.54 bcd	53.76 ± 5.72 cd
IT3	39.16 ± 5.93 e	34.39 ± 6.44 e	73.55 ± 11.47 e
IT4	25.10 ± 0.83 cd	29.06 ± 2.57 cde	54.16 ± 3.12 cd
IT5	28.33 ± 3.71 cd	25.69 ± 4.21 bcde	54.01 ± 2.58 cd
IT6	24.65 ± 3.10 cd	27.52 ± 4.69 cde	52.17 ± 7.24 cd
IT7	28.17 ± 2.75 cd	31.97 ± 0.92 de	60.14 ± 2.23 de
OT1	23.09 ± 3.35 c	20.24 ± 4.06 bc	43.33 ± 4.75 c
OT2	22.76 ± 3.47 c	22.92 ± 7.26 bcd	45.68 ± 5.39 c
ANOVA (F value (*p* value))	42.09 (<0.001)	13.88 (<0.001)	41.18 (<0.001)

For each treatment, different letters denote significant differences ($p < 0.05$) according to the Tukey HSD.

We found significant differences in the nutritional content of the leaves of the Greek purslane, especially in terms of the plant's total nitrogen content (Tables 4 and 5). The plants under the IT3 treatment showed the highest N content, which was closely related to the higher growth. The control treatment showed the highest level of phosphorous, even if we added no extra P, a fact that indicates that these plants were able to assimilate extra P. The rest of the plant nutrient contents (Mg, Fe, S and Ca) did not differ among the tested fertilization regimes.

Table 4. Effects of nutritional treatments on leaves' nutrient content: C (Carbon g/100 g), N (Nitrogen g/100 g), P (Phosphorous g/100 g) and K (Potassium g/100 g).

Treatment	N (g/Kg)	P (g/Kg)	K (g/Kg)
Control	10.9 ± 0.8 a	13.2 ± 1.3 c	41.1 ± 3
IT2	16 ± 1.6 ab	4.0 ± 1.1 ab	40.5 ± 7.1
IT3	29.9 ± 6.9 c	2.7 ± 0.4 a	36.1 ± 2.1
IT4	18.6 ± 4.2 ab	5.3 ± 2.6 ab	41.3 ± 7.5
IT6	19.2 ± 3.4 b	5.3 ± 1 ab	40.1 ± 4.9
OT1	15 ± 1 ab	5.8 ± 0.9 b	42.3 ± 7.1
ANOVA (F value (*p* value))	12.47 (<0.001)	28.57 (<0.001)	0.58 (<0.72)

For each treatment, different letters denote significant differences ($p < 0.05$) according to the Tukey HSD.

Table 5. Effects of nutritional treatments on leaves' nutrient content: K (Potassium g/100 g), Mg (Magnesium g/100 g), Fe (Iron mg/Kg), Ca (Calcium g/100 g) and S (Sulfur g/100 g).

Treatment	Mg (g/Kg)	Fe (g/Kg)	Ca (g/Kg)	S (g/Kg)
Control	7.7 ± 3.7 b	0.059 ± 0.026	9.30 ± 4.2 b	0.9 ± 0.1 a
IT2	4.2 ± 0.5 ab	0.061 ± 0.040	4.7 ± 1.1 a	1.9 ± 0.8 ab
IT3	3.56 ± 0.2 a	0.011 ± 0.054	4.7 ± 0.4 a	2.6 ± 0.4 b
IT4	3.5 ± 0.07 a	0.073 ± 0.036	4.3 ± 0.37 a	1.9 ± 0.6 ab
IT6	3.1 ± 0.3 a	0.045 ± 0.050	3.8 ± 0.6 a	2± 0.5 ab
OT1	3.5 ± 0.5 a	0.061 ± 0.027	4.3 ± 0.6 a	1.5 ± 0.4 ab
ANOVA (F value (*p* value))	4.99 (0.005)	1.60 (0.20)	5.02 (0.005)	4.83 (<0.05)

For each treatment, different letters denote significant differences ($p < 0.05$) according to the Tukey HSD.

On the other hand, the assayed fertilizer treatments did not affect the soil nutrient contents (N, P, K, Fe, Ca) (data not shown).

By comparing the purslane and the sow-thistle growth, it was demonstrated that different responses to the fertilization treatments were observed, the purslane being more dependent on nitrogen input than the sow-thistle. In conclusion, nitrogen improves the plant growth parameters and yield in both wild plant species, the beneficial effect depending on the doses and origin (inorganic or organic) of the fertilizer applied.

Supplementary Materials: The poster presentation can be downloaded at: https://www.mdpi.com/article/10.3390/IECHo2022-12515/s1.

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