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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 plant growth parameters of *Sonchus oleraceus* and *Portulaca oleracea*. The experiment was performed in greenhouse conditions, in pots containing soil, sand and vermiculite in the volume ratios of 1-1-1 during 12 weeks. The control treatment had no fertilization; inorganic fertilization (N-P-K) were 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 organic compost extract to reach same equivalence than 300 mg L^{-1} of N) and 100 mL of 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 weight compared to the control treatment, being the highest values recorded for the treatment of 600-100-100 in both plant species (*S. oleraceus* and *P. oleracea*). Treatment (600-100-100) showed significantly higher N content than the rest of treatments, but not P and K. The plant nutrients content of Mg, Fe, S and Ca did not differ among the tested fertilization regimes. Soil nutrients content (N, P, K, Fe, Ca) showed no differences between treatments. We conclude that nitrogen had a main role improving plants growth parameters and yield in both wild plant species being the beneficial effect depending on the fertilizer doses and origin (inorganic or organic) 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 be also 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 due to being a source of bioprotective compounds such as omega-3 fatty acid mainly α-linolenic acid, 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 in common vegetables [5].

Mediterranean soils are characterized by low content 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 soil structure and therefore, the need to increase the application of chemical treatments [7,8].

Tea compost (TC) is a water extract of compost that can be used as a nutrient amendment in soils to improve productivity [9,10]; but the mainly is used to plant promotion through microorganisms and compounds that favours plant growth and nutrient absorption by fixing nitrogen or solubilizing other nutrients such as phosphorus [11,12].

This study was conducted to evaluate the effect of the fertilization with different amounts of N-P-K and organic compost extract on 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 in 10 fertilization treatments with 4 repetitions each: N-P-K treatments were prepared to reach a final concentration of mg L^{-1} of each, 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 where no fertilizers were added.

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

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

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 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 [13].

The application of fertilization had a significant effect on shoot and leaves biomass of purslane from Greek as it is shown in Table 1. Control plants showed the lowest values of plant growth with respect to the rest of treatments. The increase of nitrogen with other macronutrient (IT1, IT2 and IT3) showed a significantly higher growth with respect to the control plants. The addition of phosphorous to nitrogen (IT4 and IT5) also showed higher plant biomass than control plants, being both of them similar to IT2. Tea compost treatments had similar growth rates than IT1, even though the nitrogen amount was similar to IT2. This data shows that nitrogen increased purslane's growth, being the treatment with the highest doses of nitrogen (IT3), the one which produced the highest levels of plant growth. The plant growth parameters of purslane from Spain under the different fertilization treatments were similar to 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 total aerial fresh and dry weight (TFW and TDW) of 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 significantly differences ($p < 0.05$), according to 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 total aerial fresh and dry weight (TFW and TDW) of 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 significantly differences ($p < 0.05$), according to Tukey HSD.

Organic treatments with tea compost (OT1 and OT2) showed significant differences with respect to control plants. Both organic fertilization treatments did not show significant differences with 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 do not have effect in the growth of purslane.

In contrast to purslane plants, sow-thistle plants showed a stronger response to the addition of nutrients and organic fertilization. OT1 and OT2 treatments showed the highest differences with respect to plant biomass than the control plants, being similar to IT2 treatment (Table 3). Treatment IT7 showed similar plant growth than 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 total aerial fresh and dry weight (TFW and TDW) of sow-thislte.

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 significantly differences ($p < 0.05$), according to Tukey HSD.

We found significant differences in the nutritional content in leaves of Greek purslane, especially in the plant total nitrogen content (Tables 4 and 5). Plants under the IT3 treatment showed the highest N content, which was closely related to the higher growth. Control treatment showed the highest level of phosphorous, even if we added no extra P, fact that indicates that these plants were able to assimilate extra P. The rest of plant nutrients content (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 significantly differences ($p < 0.05$), according to 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 significantly differences ($p < 0.05$), according to Tukey HSD.

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

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

Institutional Review Board Statement:

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Data Availability Statement:

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