Effect of Nutrient Solution pH on the Growth, Yield and Quality of *Taraxacum officinale* and *Reichardia picroides* in a Floating Hydroponic System

Alexios A. Alexopoulos 1, Efstatios Marandos 1, Anna Assimakopoulou 2, Nikolina Vidalis 3, Spyridon A. Petropoulos 4,5,6 and Ioannis C. Karapanos 3,*

1 Laboratoy of Agronomy, Department of Agriculture, University of the Peloponnese, Antikalamos, 241 00 Kalamata, Greece; a.alexopoulos@us.uop.gr (A.A.A.); stathis.marados@gmail.com (E.M.)
2 Laboratoy of Plant Physiology, Department of Agriculture, University of the Peloponnese, Antikalamos, 241 00 Kalamata, Greece; a.assimakopoulou@us.uop.gr
3 Laboratory of Vegetable Production, Department of Crop Science, Agricultural University of Athens, Iera Odos 75, 118 55 Athens, Greece; vidalis@aua.gr
4 Laboratory of Vegetable Production, Department of Agriculture, Crop Production and Rural Environment, University of Thessaly, Fytokou Street, 384 46 Nea Ionia, Greece
5 Correspondence: spetropoulos@uth.gr (S.A.P.); karapanos@aua.gr (I.C.K.); Tel.: +30-242-109-3196 (S.A.P.); +30-210-529-4534 (I.C.K.)

Abstract: Given the important medicinal and nutritional value of wild edible greens, the last few years there is an increasing interest for their domestication and commercial exploitation. However, information concerning their adaptation to environmental conditions and their response to modern agricultural systems are scarce. In the present study, the effect of nutrient solution pH (4.0, 5.5 and 7.0) on the growth, chemical composition and inorganic nutrition of *Taraxacum officinale* and *Reichardia picroides* plants grown indoors in a floating hydroponic system was evaluated. Both species performed better at pH 5.5 and were slightly affected by pH 7.0, whereas pH 4.0 was not prohibitive for growth for both species, although *R. picroides* was less tolerant than *T. officinale* at low pH. Moreover, pH 4.0 did not severely affect nutrients uptake and transport within the plant tissues, suggesting that *R. picroides* susceptibility to low pH should not be attributed to nutrients imbalance. Nevertheless, low pH positively enhanced the content in total soluble solids, total phenolics, chlorophylls (a, b and total) and carotenoids, and decreased nitrates in both species. In conclusion, the studied species could be successfully grown in soilless systems with nutrient solutions of varied pH. Moreover, low pH levels (pH = 4.0) seemed to be beneficial to nutritional and dietary value in both species highlighting the potential of commercial cultivation under adverse conditions, especially in sustainable farming systems.

Keywords: common brighteyes; dandelion; chemical composition; medicinal plants; wild edible greens; sustainable farming

1. Introduction

The Mediterranean basin is thriving in wild species which have been used in human diet for centuries and have great importance for the agrobiodiversity of this region [1,2]. Among the various wild species, dandelion (*Taraxacum officinale* (L.) Weber ex F.H. Wigg.) and common brighteyes (*Reichardia picroides* (L.) Roth.) are two herbs of the Asteraceae family that are traditionally consumed raw or boiled in green salads or used as medicinal plants [3,4]. They are rich in nutrients, antioxidants and numerous bioactive compounds such as organic acids, sugars, phenolics, tocopherols, fatty acids etc. [5–11], and considered basic ingredients of the Mediterranean diet [12,13]. Currently, consumers are seeking food products with health beneficial effects and of known origin, a trend which has rekindled the interest in wild edible species and is starting to increase the adherence to the

---

**Citation:** Alexopoulos, A.A.; Marandos, E.; Assimakopoulou, A.; Vidalis, N.; Petropoulos, S.A.; Marandos, E.; Assimakopoulou, A.; Vidalis, N.; Petropoulos, S.A.; Karapanos, I.C. Effect of Nutrient Solution pH on the Growth, Yield and Quality of *Taraxacum officinale* and *Reichardia picroides* in a Floating Hydroponic System. *Agronomy* 2021, 11, 1118. https://doi.org/10.3390/agronomy11061118
Mediterranean diet [12]. In this context, commercial cultivation of wild edible species under controlled conditions and following best practice guides is essential to secure food safety for consumers and to minimize the risk of irrational harvesting of wild plants [10]. Hence, similar to other wild edible species, they might have a great potential for commercial cultivation either for food production or in the food industry, as their extracts can be used as alternative preservatives or as ingredients in functional foods [10,14,15]. Considering the importance of small-scale farming in the Mediterranean countries, the introduction of new alternative/complementary species in modern farming systems is essential for the sustainability and competitiveness of the farming sector [16,17].

Modern agriculture has to face many challenges, including food security, sustainable use of natural resources and farming under extreme environmental conditions [18,19]. In this context, cultivation under controlled conditions has been a pivotal sector of farming, especially for horticultural crops which are more susceptible to adverse conditions, while providing increased crop yields with increased use efficiency of resources [20]. Among the various cropping systems, floating hydroponics has numerous advantages compared to soil cultivation or other soilless systems, especially for leafy greens production [21]. It may also produce aromatic-medicinal plants with improved phytochemical-pharmacological properties, by stimulating plant secondary metabolism through the appropriate manipulation of mineral nutrition [22,23] or the application of eustress (e.g., moderate salinity) [24,25].

The management of nutrient solution pH is an important challenge in soilless systems, since not only it may determine plant growth but also it influences dry matter production, root rhizosphere and apoplastic pH [26,27]. The optimal pH in the root zone of most crops grown hydroponically ranges from 5.5 to 6.5 [28], although values as low as 4.0 have been proposed for preventing the incidence of infections from *Pythium* and *Phytophthora* spp. [29]. Low pH in the rhizosphere poses an abiotic stress, resulting directly (i.e., high H$^+$ injury of roots) or/and indirectly (i.e., limited availability of phosphorus) to restricted plant growth and crop yield [30]. On the other hand, abiotic stressors could be elicitors of secondary metabolites, such as flavonoids, anthocyanins, phenolics, and carotenoids among other [31–36].

The aim of the present study was to evaluate the effects of nutrient solution pH on the macro- and micro-nutrients uptake of *T. officinale* and *R. picroides*, as well as on the quality of the final product (with particular reference in substances with dietary, anti-dietary and medicinal value). For this purpose, *T. officinale* and *R. picroides* plants were cultivated in a floating hydroponic system and a wide range pH in nutrient solution (from 4.0 to 7.0) was tested in order to evaluate the potential of commercial cultivation of these species.

2. Materials and Methods

2.1. Plant Material and Experimental Treatments

The experiment was conducted in an unheated glasshouse at the University of the Peloponnese (Kalamata, Messinia, Southern Greece, 37°3′22″ N, 22°1′43″ E). Two wild edible species were studied, namely *Taraxacum officinale* (L.) Weber ex F.H. Wigg. and *Reichardia picroides* (L.) Roth. Seeds of both species are part of the seed collection of the Laboratory of Agronomy, University of the Peloponnese, produced at the experimental field of the University in Kalamata in spring of 2017. Harvested seeds were stored at 4–7 °C until the start of experiment. The starting material (seeds) was collected from wild plants in the Vicinity of Kalamata, Greece. Prior to seed collections, plants were located and identified based on flower and plant morphology and with the guidance of experienced local people, since wild species usually have various common names and different species may have similar names. Sowing of seeds was performed on 10/1/2019 in polystyrene seed trays (cell dimension 5 × 5 × 5 cm) filled with white peat (pH 5.5–6.5, without fertilizers-Base Substrate, Klasmann-Deilmann GmbH, Geeste, Germany). Trays were placed in a walk-in growth chamber at 20 °C with 16 h photoperiod (fluorescent lamps, light intensity of 55 μmol m$^{-2}$ s$^{-1}$), and were regularly fertigated using a water-soluble 20-20-20 plus microelements fertilizer (Nutrileaf, Miller Chemical & Fertiliser LLC,
Hanover, PE, USA). After one month (30 days after sowing, DAS) and when seedlings reached the 2–3 true-leaf stage, seed trays were transferred to the experimental glasshouse of the University of the Peloponnese. On 6/3/2019 (55 DAS) seed trays with plants at the 6–8 leaves stage were placed into containers (length × width × height: 1 × 1 × 0.25 m, volume: 0.200 m³) filled with 0.200 m³ nutrient solution consisting of: (in mmol/L) K:9.0; Ca:4.0; Mg:1.5; N-NO₃⁻:14.0; N-NH₄⁺:1.0; H₂PO₄⁻:1.7; and (in μmol/L) Fe:30; Mn:5.0; Zn:4.0; Cu:1.0; B:30.0; Mo:0.5; with pH 7.0 and electrical conductivity (EC) of nutrient solution 2.2 mS cm⁻¹.

Nutrient solution was prepared from two stock solutions (stock solution A and stock solution B) following the procedure applied in hydroponic systems to avoid precipitation of nutrients. The composition of stock solutions is described in supplementary material (Table S1). Water composition is provided in supplementary material (Table S2). The growing conditions (temperature, relative humidity and light conditions) are described in Figures 1 and 2. The growing conditions, mean relative humidity (%) and temperatures (minimum, maximum and mean temperature; °C) throughout the experimental period. The left vertical axis presents the temperature mean values and the right vertical axis presents the relative humidity mean values; ST: start of treatments’ application.

![Figure 1](image1.png)

**Figure 1.** The growing conditions, mean relative humidity (%) and temperatures (minimum, maximum and mean temperature; °C) throughout the experimental period. The left vertical axis presents the temperature mean values and the right vertical axis presents the relative humidity mean values; ST: start of treatments’ application.

![Figure 2](image2.png)

**Figure 2.** Light intensity (μmol m⁻² s⁻¹) within the greenhouse during the experimental period. The values are the means of 10 days’ intervals for hourly recordings.

The experimental treatments consisted of three nutrient solution with varied pH values which were formulated as follows, pH 4.0 (4.0 ± 0.2), pH 5.5 (5.5 ± 0.1) and pH 7.0 (7.0 ± 0.1), by adding adequate amounts of HNO₃ (67% v/v) to the initial nutrient solution of pH 7.0 until the desired values of pH 5.5 (approx. 0.053 L per container) and 4.0 (approx. 0.061 L per container). Nutrient solution in containers was 20 cm deep and it was
permanently supplied with oxygen using common fish-tank air pumps. Plants in seed
trays were placed at distances 15 × 15 cm (44.44 plants m⁻²).

Two harvests were performed in each species, the first one when plants were reached
the harvesting stage when collected in the wild, and the second just before the appearance of
the flower stem. In dandelion, first harvest (H1) was carried out at 22/3/2019 (16 days after
the start of pH treatment-DAST) and second harvest (H2) at 4/4/2019 (29-DAST), whereas
for R. picroides the respective dates were 28/3/2019 (22-DAST) for H1 and 16/4/2019
(41-DAST) for H2. Four containers (n = 4) for each pH treatment, each harvest and each
species were used totaling to 48 containers. In each container 44 plants were grown, with
10 plants (from the center of the container) being used for each harvest.

For each plant species, a bifactorial experiment was carried out following a completely
randomized experimental design (factor 1: nutrient solution pH, factor 2: growth stage at
harvest-harvest date). In each treatment combination, four replications (n = 4) were used
comprising 10 plants each.

Throughout the experimental period, nutrient solution EC remained constant at
2.2 ± 0.1 in all the treatments without any need for readjustment. Similarly, nutrient
solution pH remained stable in all three treatments. Mean temperature of the nutrient
solution during the cultivation period of T. officinale was 16.2 °C (ranging from 14.0 to
17.2 °C) and that of R. picroides was 16.0 °C (ranging from 13.4 to 18.2 °C).

2.2. Plant Growth Parameters

At each harvesting date and pH treatment, ten plants per replication were sampled
for each species. Subsequently, plant leaf number, rosette diameter, percentage of non-
marketable leaves (not green, dried or injured), leaf SPAD index values, total plant fresh
weight (FW), root FW and marketable leaf FW were assessed. Leaves from all ten plants
per replication were grouped in one batch sample, and subsequently divided in two
identical samples for further analyses. One sample was used for the determination of dry
matter content (%DMC, by drying samples at 72 °C to constant weight), and macro and
micro-elements concentration, whereas the other sample was kept at −80 °C for chemical
composition analyses. Similarly, roots from all ten plants per each replication were grouped
in one sample, which after drying was used for the determination of dry matter content
and macro and micro-elements concentration.

2.3. Leaves and Roots Macro-and Micro-Elements Concentrations

For the determination of total N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and B concentrations
in leaves and roots, dried leaves and roots samples were ground to fine powder and dry-
ashed in a furnace at 500 °C for 6 h. 500 g of the dry-ashed material was dissolved with
10.0 mL 1.0 N HCl solution and quantitatively transferred into a 50-mL volumetric flask,
diluted to volume with deionized water for further minerals analysis. P concentration was
determined by the vanado-molybdophosphate yellow color method [37], B by azomethin-
H [38], K, Ca, Mg, Fe, Mn, Zn and Cu concentrations were determined by atomic absorption
spectrometry (SpectrAA, 240 Atomic Absorption FS; Varian, Palo Alto, CA, USA) in the dry
digest [38], while N was determined by the indophenol-blue method in the wet digest [39].
N-NO₃⁻ concentration in leaves was determined in 200 mg of dried material suspended
in 20 mL of deionized water using the colorimetric method of Cataldo et al. [40] based on
the nitration of salicylic acid. All measurements were carried out in triplicate (n = 3) and
expressed on a dry weight (DW) basis, except the leaf nitrate concentration, which was
expressed in leaf fresh weight (FW).

2.4. Chemical Composition Analyses in Leaves

2.4.1. Total Soluble Solids Content (TSSC) and Titratable Acidity (TA)

Total soluble solids content of leaves was measured in the juice of the homogenized
samples at 20 °C using a portable refractometer (model HR32B, Schmidt & Haensch GmbH
& Co., Berlin, Germany) [41]. Titratable acidity was determined by titration with NaOH in
water extracts of homogenized samples, up to pH 8.1, and results were expressed as mg malic acid 100 kg\(^{-1}\) FW [41].

2.4.2. Content in Chlorophyll and Carotenoids + Xanthophylls

Chlorophyll content of leaves was assessed using two methods:

1. By taking SPAD index readings with a SPAD-502 Chlorophyll Meter (Konica-Minolta Co. Ltd., Tokyo, Japan) at two spots on the upper surface, 0.5–1 cm right and left from the central vein of each leaf. Measurements were taken from the two youngest but fully expanded leaves, individually in all 40 plants (ten plants per replication) that were sampled in each harvesting date [42].

2. By quantifying chlorophyll a, b and total chlorophyll content of leaves in acetone extracts of homogenized samples, as described in Karapanos et al. [43]. Absorbance of the extracts at 663 and 647 nm was measured in a spectrophotometer (model Lambda 1A, PerkinElmer, Waltham, MA, USA) and the chlorophyll content was calculated according to the equations referred by Lichtenthaler and Buschmann [44].

Carotenoids + xanthophylls were quantified in the extracts previously described by measuring the absorbance at 470 nm, according to the method of Lichtenthaler and Buschmann [44]. The chlorophyll and carotenoids + xanthophylls content was expressed as mg kg\(^{-1}\) FW.

2.4.3. Total Phenolics Content

Total phenolics were quantified using the Folin–Ciocalteu method [45], in methanolic extracts, as described in Karapanos et al. [43]. In brief, the homogenized samples were mixed with 80% \((v/v)\) methanol in water, the mixtures were stirred for 2 h at room temperature and, after centrifugation, the supernatants were decanted and the pellets were resuspended in 80% methanol, following the same procedure. The combined supernatants were used for measurements according to the Folin–Ciocalteu method, and absorbance was measured in a spectrophotometer at 765 nm. Gallic acid was used as standard and the results were expressed as mg gallic acid equivalents (GAE) kg\(^{-1}\) FW.

2.5. Statistical Analysis

All data were analyzed by a two-way ANOVA in order to assess the significance of interaction between the experimental factors, namely pH value and harvesting date. Due to the statistically significant interaction between the two factors, the effect of each factor was analyzed separately. One-way ANOVA was carried out to determine the effect of nutrient solution pH on the studied parameters at each harvesting date and means were separated by the Least Significant Difference test at \(p \leq 0.05\). Accordingly, Student’s t-test at \(p \leq 0.05\) was used to compare the effect of harvesting date on the studied parameters at each nutrient solution pH level. Statistical tests were performed using the StatGraphics Centurion-XVI statistical package (StatPoint Technologies Inc., Warrenton, VA, USA).

3. Results

3.1. The Effect of Nutrient Solution pH on Taraxacum officinale

In the case of \(T. \text{officinale}\), pH treatments did not affect the leaf number, the percentage of non-marketable leaves per plant, the SPAD index values and the leaf % DMC (Table 1). Plants grown in solution with pH 4.0 had smaller rosette diameter than those grown in solution with pH 5.5 or pH 7.0, lower total FW than those grown in pH 7.0 (H1) and in pH 5.5 (H2), less marketable leaves FW than those grown in pH 5.5 and pH 7.0 (H1) and less root FW per plant than those grown in pH 5.5 (H2). Moreover, roots % of DMC (ranged between 8.3%–9.8% at H1 and 8.8%–10.1% at H2) was not affected by the pH (data not shown).
Table 1. Growth parameters of *Taraxacum officinale* plants grown under different nutrient solution pH, harvested at H1 (16-DAST) and H2 (29-DAST: Days after the Start of pH Treatment).

| pH  | H1 | H2 | H1 | H2 | H1 | H2 | H1 | H2 |
|-----|----|----|----|----|----|----|----|----|
|     | Leaf Number Plant\(^{-1}\) | Rosette Diameter (cm) | Non-Marketable Leaves (%) Plant\(^{-1}\) | SPAD Index |
| 4.0 | 18.9 a(b) | 27.9 a(a) | 24.2 b(b) | 36.7 b(a) | 12.9 a(a) | 12.0 a(a) | 33.1 a(b) | 43.2 a(a) |
| 5.5 | 18.6 a(b) | 29.9 a(a) | 27.4 a(b) | 45.8 a(a) | 12.5 a(a) | 14.7 a(a) | 35.5 a(b) | 42.1 a(a) |
| 7.0 | 24.4 a(b) | 31.1 a(a) | 30.1 a(b) | 47.5 a(a) | 9.7 a(a) | 11.8 a(a) | 35.0 a(b) | 40.7 a(a) |
| Total plant FW (g) | Root FW (g) | Marketable leaves FW (g) Plant\(^{-1}\) | Leaf DMC (%) |
| 4.0 | 8.8 b(b) | 36.3 b(a) | 1.3 a (b) | 5.8 b(a) | 7.4 b(b) | 28.4 a(a) | 9.9 a(b) | 12.7 a(a) |
| 5.5 | 11.3 a(b) | 47.3 a(a) | 1.4 a (a) | 7.9 a(a) | 9.9 a(b) | 32.9 a(a) | 11.3 a(b) | 13.3 a(a) |
| 7.0 | 12.5 a(b) | 41.1 ab(a) | 1.5 a (b) | 7.3 ab(a) | 10.9 a(b) | 31.7 a(a) | 11.0 a(b) | 13.0 a(a) |

Means in columns followed by the same letter do not differ significantly (\(p \leq 0.05\), L.S.D. test). Means in the same row followed by the same letter in parenthesis do not differ significantly (\(p \leq 0.05\), T-test); FW: fresh weight; DMC: dry matter content.

The studied pH treatments did not affect leaf concentration in N, Ca, Mg, Fe and B (H1, H2), P and Mn (H1) and Cu (H2). On the other hand, K (67.3 g kg\(^{-1}\) DW at H2) and Cu (5.0 g kg\(^{-1}\) DW at H1) were the lowest in plants grown in solution with pH 4.0. P and Zn were the lowest in pH 7.0 (16.8 g kg\(^{-1}\) DW at H2), whereas Mn was the highest in pH 4.0 (25.8 g kg\(^{-1}\) DW at H2). The time of harvest also affected leaf N concentration which was higher at H1 compared to H2, regardless of pH treatments, while P, Mn and Zn concentrations were higher at H1 compared to H2, only in the case of pH 7.0. K was higher by 9.8% at H1 compared to H2 in plants grown in pH 4.0 but lower by 8.0% at H1 compared to H2 in the case of pH 5.5 (Table 2).

Table 2. Leaf nutrient concentrations of *Taraxacum officinale* plants grown under different nutrient solution pH, harvested at H1 (16-DAST) and H2 (29-DAST: Days after the Start of pH Treatment).

| pH  | H1 | H2 | H1 | H2 | H1 | H2 | H1 | H2 | H1 | H2 |
|-----|----|----|----|----|----|----|----|----|----|----|
|     | N (g kg\(^{-1}\) DW) | P (g kg\(^{-1}\) DW) | K (g kg\(^{-1}\) DW) | Ca (g kg\(^{-1}\) DW) | Mg (g kg\(^{-1}\) DW) | Fe (mg kg\(^{-1}\) DW) | Mn (mg kg\(^{-1}\) DW) | Zn (mg kg\(^{-1}\) DW) | Cu (mg kg\(^{-1}\) DW) | B (mg kg\(^{-1}\) DW) |
| 4.0 | 50.9 a(a) | 44.2 a(b) | 11.5 a(a) | 10.8 a(a) | 62.3 b(b) | 56.2 b(b) | 9.0 a(a) | 8.5 a(a) | 3.3 a(a) | 3.4 a(a) |
| 5.5 | 51.7 a(a) | 46.2 a(b) | 11.7 a(a) | 10.3 a(a) | 62.3 b(b) | 67.7 a(a) | 8.5 a(a) | 9.3 a(a) | 3.4 a(a) | 3.5 a(a) |
| 7.0 | 53.8 a(a) | 44.9 a(b) | 10.5 a(a) | 8.9 b(b) | 67.3 a(a) | 66.1 a(a) | 8.2 a(a) | 7.4 a(a) | 3.7 a(a) | 3.4 a(a) |

Means in columns followed by the same letter do not differ significantly (\(p \leq 0.05\), L.S.D. test). Means in the same row followed by the same letter in parenthesis do not differ significantly (\(p \leq 0.05\), T-test). DW: dry weight.

Root N, Ca, Mg and B concentrations were not affected by pH treatments. P was the lowest in the case of pH 7.0 (9.2 g kg\(^{-1}\) DW; H2), K was the lowest in pH 4.0 (38.5 g kg\(^{-1}\) DW at H1; 33.5 g kg\(^{-1}\) DW at H2) and Fe was the highest in pH 4.0 (146.6 g kg\(^{-1}\) DW at H1). Moreover, Mn (23.9 g kg\(^{-1}\) DW at H1 and 29.4 g kg\(^{-1}\) DW at H2) and Cu (16.7 g kg\(^{-1}\) DW at H1) were the highest in pH 7.0, while root P, Fe and Zn concentrations were higher at H1 compared to H2 in pH 7.0 (increased by 25.2%, 9.6% and 33.7%, respectively). On the other hand, Mn in pH 5.5 and pH 7.0, Zn in pH 5.5 and Cu in pH 4.0 and pH 5.5 showed higher values at H2 compared to H1 (Table 3).
Table 3. Root nutrient concentrations of *Taraxacum officinale* plants grown under different nutrient solution pH, harvested at H1 (16-DAST) and H2 (29-DAST: Days after the Start of pH Treatment).

| pH  | N (g kg\(^{-1}\) DW) | P (g kg\(^{-1}\) DW) | K (g kg\(^{-1}\) DW) | Ca (g kg\(^{-1}\) DW) | Mg (g kg\(^{-1}\) DW) |
|-----|---------------------|---------------------|---------------------|---------------------|---------------------|
| 4.0 | 43.2 a(a)           | 45.6 a(a)           | 10.4 a(a)           | 11.1 a(a)           | 38.5 c(a)           |
| 5.5 | 45.4 a(a)           | 42.5 a(a)           | 11.4 a(a)           | 12.2 a(a)           | 46.2 b(a)           |
| 7.0 | 46.9 a(a)           | 44.5 a(a)           | 12.3 a(a)           | 9.2 b(b)            | 56.6 a(a)           |

Means in columns followed by the same letter do not differ significantly (\(p \leq 0.05\), L.S.D. test). Means in the same row followed by the same letter in parenthesis do not differ significantly (\(p \leq 0.05\), T-test). DW: dry weight.

Leaf nitrate content was lower in pH 4.0 than in pH 7.0 (reduced by 37.1% and 33.7% at H1, H2, respectively) and pH 5.5 (reduced by 38.8% at H2). Leaf content in TSS, TA, total phenolics, chlorophyll a, chlorophyll b, and total chlorophylls was the highest in pH 4.0 compared to pH 7.0 (increased by 22.9%, 29.2%, 26.9%, 13.45%, 12.8% and 13.2%, respectively) (Table 4). At H2, plants grown in pH 4.0 had higher content of total chlorophylls and chlorophyll a than in pH 7.0 (increased by 14.1% and 12.0%, respectively) and higher content of total phenolics than in pH 5.5 (increased by 16.1%). However, pH treatments did not affect the chlorophyll a/b ratio (ranged between 2.07–2.10 at H1 and 1.90–2.04 at H2, data not shown). In addition, TA was higher at H1 compared to H2 irrespective of the pH treatment, TSSC was lower at H2 compared to H1 only in the case of pH 4.0 (reduced by 17.9%) and chlorophylls a, b and total chlorophylls, as well as carotenoids + xanthophylls, were lower at H2 compared to H1 only in pH 5.5 (reduced by 11.3%, 7.1%, 10.4% and 15.5%, respectively) (Table 4).

Table 4. Total soluble solids content (TSSC), titratable acidity (TA), carotenoids + xanthophylls, total phenolics, chlorophylls (a, b and total) and nitrate content of *Taraxacum officinale* leaves grown under different nutrient solution pH, harvested at H1 (16-DAST) and H2 (29-DAST: Days after the Start of pH Treatment).

| pH  | Chlorophyll a (mg kg\(^{-1}\) FW) | Chlorophyll b (mg kg\(^{-1}\) FW) | Total Chlorophyll (mg kg\(^{-1}\) FW) | Nitrates (mg kg\(^{-1}\) FW) |
|-----|----------------------------------|----------------------------------|--------------------------------------|-----------------------------|
| 4.0 | 866.9 a(a)                       | 815.6 a(a)                       | 1279.3 a(a)                          | 2621.5 b(a)                 |
| 5.5 | 819.4 ab(a)                      | 727.1 ab(b)                      | 1215.6 ab(a)                         | 3396.8 ab(b)                |
| 7.0 | 750.3 b(a)                       | 700.4 b(a)                       | 1110.1 b(a)                          | 4170.1 a(a)                 |

Means in columns followed by the same letter do not differ significantly (\(p \leq 0.05\), L.S.D. test). Means in the same row followed by the same letter in parenthesis do not differ significantly (\(p \leq 0.05\), T-test). FW: fresh weight.

3.2. The Effect of Nutrient Solution pH on Reichardia picroides

In *R. picroides*, the percentage of non-marketable leaves per plant, the SPAD index values and the leaf % of DMC were not affected by the pH treatments (Table 5). By contrast, the leaf number, the rosette diameter, the total plant FW and the marketable leaves FW were the lowest in plants grown at pH 4.0. At H2, plants grown in pH 4.0 had lower leaf number, total FW and marketable leaves FW than those grown in other pH values. Roots
FW was the lowest in pH 4.0 (H1) but roots % of DMC (ranged between 6.1%–7.2% at H1 and 6.7%–7.5% at H2, data not shown) was not affected by the pH treatment.

Table 5. Growth parameters of Reichardia picroides plants grown under different nutrient solution pH, harvested at H1 (22-DAST) and H2 (41-DAST: Days after the Start of pH Treatment).

| pH | H1 | H2 | H1 | H2 | H1 | H2 | H1 | H2 |
|----|----|----|----|----|----|----|----|----|
|    | Leaf Number Plant⁻¹ | Rosette Diameter (cm) | Non-Marketable Leaves (%) Plant⁻¹ | SPAD Index |
| 4.0 | 21.6 b(b) | 33.8 c(a) | 22.7 b(b) | 29.1 b(a) | 13.3 a(a) | 8.6 a(a) | 47.5 a(a) | 50.7 a(a) |
| 5.5 | 27.1 a(b) | 68.9 a(a) | 32.0 a(b) | 44.0 a(a) | 12.4 a(b) | 9.8 a(a) | 50.0 a(a) | 53.7 a(a) |
| 7.0 | 29.7 a(b) | 56.9 b(a) | 30.6 a(b) | 42.2 a(a) | 12.9 a(a) | 13.1 a(a) | 49.6 a(a) | 50.2 a(a) |

Means in columns followed by the same letter do not differ significantly (p ≤ 0.05, L.S.D. test). Means in the same row followed by the same letter in parenthesis do not differ significantly (p ≤ 0.05, T-test). FW: fresh weight; DMC: dry matter content.

The studied pH treatments had no effect on leaf N, Mg and B concentrations. However, the concentrations of the rest of the macro- and micro-nutrients showed a varied response depending on the pH treatment and the harvesting time. K (51.9 g kg⁻¹ DW at H1) and Cu (3.3 g kg⁻¹ DW at H2) were the lowest in pH 4.0 and pH 5.5, respectively. P was the highest in pH 5.5 (9.8 g kg⁻¹ DW at H1), and in pH 4.0 (7.8 g kg⁻¹ DW at H2) than in pH 7.0. Ca was the highest in pH 5.5 (9.6 g kg⁻¹ DW at H1) and in pH 4.0 and pH 5.5 at H2 (7.8 g kg⁻¹ DW and 8.7 g kg⁻¹ DW, respectively). Fe was higher in pH 4.0 than in pH 5.5 (increased by 30.7% at H1 and by 26.8% at H2) and pH 7.0 (increased by 20.3% at H2), Mn was higher in pH 4.0 than in pH 7.0 (increased by 28.0% at H1 and by 70.0% at H2) and pH 5.5 (increased by 33.9% at H2), and Zn content was the highest in pH 4.0 at both harvesting stages (H1, H2). The content of N, P and Mn in pH 5.5 and pH 7.0 and Ca, Mg, Fe and Zn in pH 7.0 were higher at H1 compared to H2. On the other hand, Cu and Zn in pH 4.0 and B in pH 4.0 and pH 7.0 were higher at H2 compared to H1 (Table 6).

Table 6. Leaf nutrient concentrations of Reichardia picroides plants grown under different nutrient solution pH, harvested at H1 (22-DAST) and H2 (41-DAST: Days after the Start of pH Treatment).

| pH | H1 | H2 | H1 | H2 | H1 | H2 | H1 | H2 |
|----|----|----|----|----|----|----|----|----|
|    | N (g kg⁻¹ DW) | P (g kg⁻¹ DW) | K (g kg⁻¹ DW) | Ca (g kg⁻¹ DW) | Mg (g kg⁻¹ DW) |
| 4.0 | 38.1 a(a) | 35.8 a(a) | 6.4 b(a) | 7.8 a(a) | 51.9 b(a) | 51.5 a(a) | 7.0 b(a) | 7.8 a(a) | 1.8 a(a) | 1.8 a(a) |
| 5.5 | 43.2 a(a) | 29.1 a(b) | 9.8 a(a) | 6.0 ab(b) | 66.2 a(a) | 56.2 a(a) | 9.6 a(a) | 8.7 a(a) | 2.4 a(a) | 2.0 a(a) |
| 7.0 | 45.6 a(a) | 31.6 a(b) | 6.9 b(a) | 4.1 b(b) | 69.6 a(a) | 63.5 a(a) | 8.4 a(b) | 6.0 b(b) | 2.4 a(a) | 1.7 a(b) |

Means in columns followed by the same letter do not differ significantly (p ≤ 0.05, L.S.D. test). Means in the same row followed by the same letter in parenthesis do not differ significantly (p ≤ 0.05, T-test). DW: dry weight.

Root N, Ca, Mg and B concentrations (H1, H2), K (H2) and Mn (H1) were not affected by the pH value, whereas root P and K (H1) and Mn (H2) were the highest in pH 5.5. In contrast, pH 4.0 resulted to the highest content of Fe, Zn and Cu in roots. The content of N and Cu in pH 5.5, P and K in pH 5.5 and pH 7.0, Mn in pH 4.0 and Zn in pH 4.0 and pH 7.0 were higher at H1 compared to H2. On the other hand, Mg in pH 7.0, Mn and Zn in pH 5.5 and B in pH 4.0 were higher at H2 compared to H1 (Table 7).
Table 7. Root nutrient concentrations of Reichardia picroides plants grown under different nutrient solution pH, harvested at H1 (22-DAST) and H2 (41-DAST: Days after the Start of pH Treatment).

| pH | N (g kg⁻¹ DW) | P (g kg⁻¹ DW) | K (g kg⁻¹ DW) | Ca (g kg⁻¹ DW) | Mg (g kg⁻¹ DW) |
|----|---------------|---------------|---------------|---------------|---------------|
| 4.0 | 46.3 a(a) | 44.4 a(a) | 13.7 b(a) | 31.1 a(a) | 46.2 a(a) | 43.5 a(a) | 3.7 a(a) | 4.0 a(a) | 1.7 a(a) | 1.8 a(a) |
| 5.5 | 53.0 a(a) | 44.4 a(b) | 18.1 a(a) | 10.5 b(b) | 67.3 a(a) | 47.7 a(b) | 4.1 a(a) | 4.5 a(a) | 1.7 a(a) | 1.9 a(a) |
| 7.0 | 47.9 a(a) | 45.6 a(a) | 14.5 b(a) | 6.3 c(b) | 58.1 b(a) | 50.0 a(b) | 4.3 a(a) | 4.6 a(a) | 1.7 a(b) | 2.0 a(a) |

Means in columns followed by the same letter do not differ significantly (p ≤ 0.05, L.S.D. test). Means in the same row followed by the same letter in parenthesis do not differ significantly (p ≤ 0.05, T-test). DW: dry weight.

Leaf nitrate content was not affected by the pH treatment at H2, but it was the lowest in pH 4.0 at H1 (Table 8). pH treatments had no effect on the content of leaves in TSSC (H1), TA (H1), chlorophylls (a, b and total-H2), carotenoids + xanthophylls (H2) and on the chlorophyll a / b ratio (ranged between 1.91–2.01 at H1 and 2.15–2.25 at H2, data not shown). On the contrary, all the other parameters were similarly affected by the pH values, presenting higher values in pH 4.0. In addition, TA at H2 was lower by 24.2% in pH 7.0 compared to pH 4.0. Plants grown in pH 4.0 higher content in a, b and total chlorophylls at H1 compared to H2 (increased by 12.2%, 19.5% and 14.6%, respectively) (Table 8).

Table 8. Total soluble solids content (TSSC), titratable acidity (TA), carotenoids + xanthophylls, total phenolics, chlorophylls (a, b and total) and nitrate content of Reichardia picroides leaves grown under different nutrient solution pH, harvested at H1 (22-DAST) and H2 (41-DAST: Days after the Start of pH Treatment).

| pH | Chlorophyll a (mg kg⁻¹ FW) | Chlorophyll b (mg kg⁻¹ FW) | Total Chlorophyll (mg kg⁻¹ FW) | Nitrates (mg kg⁻¹ FW) |
|----|----------------------------|-----------------------------|-------------------------------|----------------------|
| 4.0 | 52.01 a(a) | 45.6 b(b) | 258.3 a(a) | 207.9 a(b) | 778.5 a(a) | 664.8 a(b) | 21.42b b(b) | 28.95 b(a) |
| 5.5 | 413.5 b(b) | 485.3 a(a) | 208.7 b(a) | 203.7 a(a) | 622.2 a(a) | 662.1 a(a) | 348.7 a(a) | 394.6 a(a) |
| 7.0 | 405.1 b(b) | 453.3 a(a) | 212.4 b(a) | 210.4 a(a) | 681.7 a(a) | 684.7 a(a) | 328.9 a(a) | 349.6 a(a) |

Means in columns followed by the same letter do not differ significantly (p ≤ 0.05, L.S.D. test). Means in the same row followed by the same letter in parenthesis do not differ significantly (p ≤ 0.05, T-test). FW: fresh weight.

4. Discussion

In Taraxacum officinale, the leaf number per plant was not affected by the studied pH treatments, while in Reichardia picroides it was decreased at the lower studied values (pH 4.0). However, pH did not affect the percentage of non-marketable (stressed or injured) leaves in both species, indicating that both plants were able to tolerate pH values within the tested range without severe effects. According to the literature, pH 4.0 did not also affect the leaf number per plant in Metasylon sagu [46] and Paeonia lactifolia plants [47], however, it reduced plant height and total leaf area of Paeonia lactifolia [47], suggesting a possible effect of low pH on plant morphology. This is in accordance to our results, as the rosette diameter of both species was decreased at pH 4.0, indicating a reduction of leaf length, similarly to what is reported by Roosta and Rezaei in rose plants [48]. In addition, the reduction of marketable leaves and total plant FW caused by low pH value (pH 4.0) in R. picroides at both harvests (particularly at H2) also indicates low pH induced changes on plant growth and morphology. Nevertheless, our results indicate a species-dependent
efficiency to overcome the low pH-induced stress. Even though in *T. officinale* total plant FW at pH 4.0 was lower at both harvest dates, marketable leaves FW was lower only at H1, suggesting that dandelion might have developed an adaptation mechanism to grow satisfactorily after the initial stress, whereas as stress gradually builds up the defensive mechanism cannot cope with increasing stress, thus a reduction in leaves FW is observed. In addition, DMC (%) of leaves and roots of both species was not affected by pH, indicating that the absorption and accumulation of water from plants was unaffected by the studied pH levels, as well as that the root functioning was not unbalanced due to injuries from non-optimal pH values of nutrient solution.

Several species can grow well at pH values that exceed the recommended range of 5.5 to 6.5 [20], although for most (conventional) vegetable species plant growth is impaired at pH levels above 7.0 or under 5.0 [49]. Our results showed that *T. officinale* growth was not restricted even at the lowest studied pH values (pH 4.0), whereas *R. picroides* seems to be more sensitive to changes (higher or lower than optimal) in the pH level. In comparison to the treatment of pH 5.5, *R. picroides* growth was negatively affected by pH 4.0 and to a lesser extent by pH 7.0, despite it is reported in the literature that this species is usually found in calcareous soils [50]. This contradiction in the results could be attributed to the fact that in our study the plants were grown having their roots directly immersed in nutrient solution which does not have the buffering capacity of soil [51]. Moreover, considering the wild nature of the species there are probably many other environmental factors that may define the optimal growing conditions apart from pH value of growing medium [52].

In both species, the lowest pH level (pH 4.0) reduced root FW, indicating that root growth is directly impaired by low pH levels, probably due to the restriction of root elongation caused by higher H\(^+\) concentrations at low pH in nutrient solution [53]. Limited root growth due to the restrictions of net H\(^+\) release by H\(^+\)-ATPase and the inability to properly regulate the cytoplasmic pH of root cells is related with the impaired plant growth and reduced biomass production at low soil/nutrient solution pH [54,55]. Moreover, the low soil/nutrient solution pH values (e.g., the level of pH = 4.0 tested in our study) is also reported to impair plant growth and biomass accumulation by reducing photosynthetic rate due to lower transpiration rate and closure of leaf stomata in tomato seedlings [56]. However, there is no evidence that low pH negatively affects chlorophyll content or the photosynthetic apparatus of plants. On the contrary, *Paenia lactifolia* leaves showed higher chlorophyll content at pH 4.0, which indicates a possible defense mechanism through which plants increase chlorophyll content also evidenced by the increased activity of three protective enzymes [47]. Similarly to our study, although leaf chlorophyll content expressed as SPAD index values was not affected by nutrient solution pH in both species, extractable chlorophyll a, b and total was favored by pH 4.0 in both species at H1. This finding, in relation to the unaffected chlorophyll a:b ratio by low pH value (pH = 4.0), could indicate an enhancement of the photosynthetic apparatus which allows plants to counteract the possibly impaired photosynthetic activity at low pH due to leaf stomata closure, similarly to the findings of Zhao et al. [47] who also reported an increase in leaf total soluble solids content in *Paenia lactifolia* plants. Indeed, in our study, leaf total soluble solids content (TSSC) in plants grown at pH 4.0 was higher in *T. officinale* at H1 and in *R. picroides* at H2 and tended to be higher at H2 and H1, respectively in each species, indicating different adaptation mechanisms depending on the species.

In both species, leaf and root N concentrations were not affected by pH treatments, even though plants were treated with slightly more N, in the form of nitric acid, in pH 4.0 and pH 5.5 compared to pH 7.0 level, aiming to establish the desirable pH level of nutrient solutions. Similarly, Anugoolprasert et al. [46] did not find any significant effect of pH level on N concentration in *Metaxylon sago*, whereas Findenegg [57] reported that pH 4.0 reduced total leaf N concentration in *Helianthus annuus* plants.

Leaf P concentration declined when nutrient solution pH increased to 7.0, as previously reported by Assimakopoulou et al. [58] in spinach plants grown under high pH levels in the growing medium. Moreover, the findings of our study are in accordance to
the acquired knowledge that P-PO$_4$ availability in tomato plants decreases with increasing root zone pH [59].

Leaf and root Ca and Mg concentrations of both species were not reduced at pH 4.0, except for leaf Ca concentration at H1. It has been documented that higher H$^+$ concentration in the nutrient solution inhibits Ca and Mg uptake in basil [29] and gerbera [60], leading to instability of root cells membranes [30]. Nevertheless, those responses can be alleviated by increasing Ca in the rhizosphere, since Ca is considered a base cation which does not increase acidity in nutrient solution [29,30]. In our study, the lack of effect of pH 4.0 on Ca accumulation in roots and leaves, could be ascribed to the presence of adequate Ca in the nutrient solution and/or to the proven ability of these plant species to adapt to adverse environments either due to weather extremities or to nutrient deficiencies [61].

The decrease in leaf and root K concentrations caused by the low pH level (pH 4.0) in T. officinale and R. picroides (only at H1) plants has also been reported in other species, e.g., Trifolium repens L. and Lolium perenne L. [53]. According to Alam et al. [30], this effect could be associated with the H$^+$-induced inhibition of the root cells plasma membrane function as K$^+$ movement is symplastic, as well as with the reduced ability of roots to uptake K or the increased loss of K from the root cells due to root injury caused by low Ca content. Although reduced, the K concentration of both species at pH 4.0 was at levels considered sufficient for plant growth, suggesting that this reduction may be mainly caused by a direct antagonism of K$^+$-H$^+$ uptake and to a lesser extent by reduced K uptake or increased K loss due to root injury [62].

In both species, leaf and root B concentrations were not affected by the pH values in nutrient solution, whereas the level of pH 7.0 did not affect leaf and root Cu in T. officinale, but it reduced leaf and root Cu in R. picroides at H2 and H1 harvesting dates, respectively. It is reported that increased nutrient solution pH reduces the concentration of micronutrients in several plant species [63]. A reduction in root Fe concentration was found at pH 7.0 in both species, due to the more intense oxidation of iron and thus its lower availability at higher pH [30]. Although the low pH level (pH = 4.0) favored Fe root concentration in both species, R. picroides roots accumulated Fe over three times more in pH 4.0 than in pH 7.0. Enhanced accumulation of Zn in the leaves of both species and in the roots of R. picroides was also found in pH 4.0, as it has been reported for other plant species grown in low pH [64]. Similarly, pH 4.0 increased leaf Mn in T. officinale (H2) and R. picroides (both harvests), a finding which is in agreement to reports in other plant species [58,60]. According to Gillespie et al. [29], decreasing pH values increase the solubility of nutrients such as Zn, Mn and B due the exchange of the hydronium ions with cationic nutrients from negatively charged particle in the substrate. On the other hand, at high pH values these nutrients precipitate and become unavailable for uptake from plant roots [29]. However, the same authors suggest the lack of negatively charged particles within the nutrient solution that could exchange cations with hydroniums; therefore, the effect of pH values on nutrients availability in nutrients solution differs from that in soil and substrate culture due to possible antagonistic effects between released hydroniums and cations. Finally, the higher concentration of Mn and Zn in the leaves of both species grown in pH 4.0 could be related with the higher chlorophyll content, as these elements play an important role in chlorophyll synthesis [65].

Total soluble solids content of leaves was significantly increased or showed increasing trends in plants grown at pH 4.0 in both species. This finding, along with the higher titratable acidity of T. officinale leaves at the same pH at H1, could suggest better taste and higher consumers’ acceptance due to improved quality of the final product. Moreover, similar trends were recorded in H2 for both species where the low and moderate pH values (4.0 and 5.5, respectively) increased significantly titratable acidity compared to the highest pH level. In contrast to our study, pH values did not seem to affect titratable acidity in root and shoot sap of tomato, lettuce, and bermudagrass [66].

Chlorophyll content increased in plants grown at pH 4.0 leading to a better product visual appearance and consequently to higher consumer acceptability. Apart from
its importance in photosynthesis, leaf chlorophyll content can be used to estimate the greenness of leafy vegetables [67] and plays an important role in their acceptance by consumers [28]. In addition, the decreased leaf nitrate content in plants grown at pH 4.0 contributes to final products of better quality in terms of human safety, as nitrates are significant anti-nutritional factors in leafy vegetables [68].

Leaf content in total phenolics was higher in plants grown at pH 4.0, indicating that low pH imposed an abiotic stress in both species thus eliciting the biosynthesis of secondary metabolites such as phenolic compounds [33,36,69]. This finding in turn, results in healthier products, as the dietary value and antioxidant activity of the studied species and many other wild edible greens depend to a large extent on their content and composition in phenolic and other bioactive compounds [6,7,10,70,71]. However, pH 4.0 increased more intensively the content of phenolics in the leaves of R. picroides than in T. officinale, providing additional evidence that low pH was more stressful for R. picroides plants. This is also in agreement with the increased leaf content in carotenoids + xanthophylls of R. picroides plants grown at pH 4.0 in H1. Carotenoids, except for their main role as accessory pigments and their involvement in plant photoprotective mechanisms, have also been found in higher concentrations in plants grown under abiotic stresses since they contribute to the overall defense mechanism of plants due to their antioxidative properties [53,63].

5. Conclusions

Commercial cultivation of wild edible greens is gaining increasing interest, since the current consumers trends have created marketing niches for cultivating alternative/complementary species with functional properties. The results of the present study showed the tested species showed promising characteristics and could be successfully cultivated in a floating hydroponic system. Both species showed the ability to adapt in nutrient solutions with acidic to neutral pH levels (4.0, 5.5 and 7.0), although the application of pH 5.5 was more favorable. Moreover, T. officinale showed higher adaptability to pH 4.0, compared to R. picroides, indicating the presence of an efficient defensive mechanism in the first case. However, despite the lower yields of plants under low pH values, this particular treatment enhanced most of the studied quality and dietary characteristics in both plants, a finding which is of great importance for consumers’ acceptance as novel/complementary leafy greens for human consumption and, especially, for their use in the food industry for the design of functional food products. Considering the lack of information regarding the cultivation requirements of the species, the results of the present study would provide important information regarding agronomic practices such as the nutrient solution pH and harvesting time, aiming to introduce these underexploited species in sustainable farming systems. In conclusion, the regulation of nutrient solution pH and the application of low pH values (pH = 4.0) may be beneficial to the quality of the final product, while moderate levels of pH (pH = 5.5) did not severely affect yield components in both species highlighting the potential of commercial growing of the studied species under adverse conditions.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/agronomy11061118/s1, Table S1: The composition of stock solution used for the preparation of nutrient solution, Table S2: Water composition used for the preparation of nutrient solution.

Author Contributions: Conceptualization, A.A.A.; methodology, A.A.A., E.M., A.A., N.V. and I.C.K.; software, A.A., E.M., N.V.; validation, I.C.K., A.A.; formal analysis, A.A.A. and I.C.K.; investigation, A.A.A., E.M., A.A. and N.V.; resources, A.A.A.; data curation, A.A., S.A.P. and I.C.K.; writing—original draft preparation, A.A.A., A.A. and I.C.K.; writing—review and editing, A.A.A., S.A.P., I.C.K.; visualization, A.A.A.; supervision, A.A.A.; project administration, A.A.A., I.C.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.
Data Availability Statement: The study did not report any data.

Acknowledgments: The authors are thankful to George Georgiopoulos for providing seeds and Anastasios Kotsiras for his technical advice for nutrient solution preparation.

Conflicts of Interest: The authors declare no conflict of interest.

References
1. Elia, A.; Santamaria, P. Biodiversity in vegetable crops: A heritage to save. The case of the Puglia region. *Ital. J. Agron.* 2013, 8, 21–34. [CrossRef]
2. Renna, M.; Montesano, F.; Signore, A.; Gonnella, M.; Santamaria, P. BiodiverSO: A Case Study of Integrated Project to Preserve the Biodiversity of Vegetable Crops in Puglia (Southern Italy). *Agriculture* 2018, 8, 128. [CrossRef]
3. Pieroni, A. Medicinal plants and food medicines in the folk traditions of the upper Luca Province, Italy. *J. Ethnopharmacol.* 2000, 70, 235–273. [CrossRef]
4. Garcia-Oliveira, P.; Barral, M.; Carpena, M.; Gullón, P.; Fraga-Corrá, M.; Otero, P.; Prieto, M.A.; Simal-Gandara, J. Traditional plants from Asteraceae family as potential candidates for functional food industry. *Food Funct.* 2021, 12, 2850–2873. [CrossRef]
5. Vanzani, P.; Rossetto, M.; De Marco, V.; Sacchetti, L.E.; Paoletti, M.G.; Rigo, A. Wild Mediterranean plants as traditional food: A valuable source of antioxidants. *J. Food Sci.* 2011, 76, 46–51. [CrossRef]
6. Recio, M.C.; Giner, R.M.; Hermenegildo, M.; Peris, J.B.; Iez, I.S.M.A.I.; Rios, J. Phenolics of *Reichardia* and their taxonomic implications. *Biochem. Syst. Ecol.* 1992, 20, 449–452. [CrossRef]
7. Gatto, M.A.; Ippolito, A.; Linsalata, V.; Cascarano, N.A.; Nigro, F.; Vanadia, S.; Di Venere, D. Activity of extracts from wild edible herbs against postharvest fungal diseases of fruit and vegetables. *Postharvest Biol. Technol.* 2011, 61, 72–82. [CrossRef]
8. Jeon, H.J.; Kang, H.J.; Jung, H.J.; Kang, Y.S.; Lim, C.J.; Kim, Y.M.; Park, E.H. Anti-inflammatory activity of *Taraxacum officinale*. *J. Ethnopharmacol.* 2008, 115, 82–88. [CrossRef]
9. Petropoulos, S.A.; Fernandes, A.; Tzortzakis, N.; Sokovic, M.; Ciric, A.; Barros, L.; Ferreira, I.C.F.R. Bioactive compounds content and antimicrobial activities of wild edible Asteraceae species of the Mediterranean flora under commercial cultivation conditions. *Food Res. Int.* 2019, 119, 859–868. [CrossRef]
10. Petropoulos, S.; Ntatsi, G.; Levizou, E.; Barros, L.; Ferreira, I. Nutritional profile and chemical composition of *Cichorium spinosum* ecotypes. *LWT-Food Sci. Technol.* 2016, 73, 95–101. [CrossRef]
11. Chatzopoulou, E.; Carocho, M.; Di Gioia, F.; Petropoulos, S.A. The beneficial health effects of vegetables and wild edible greens: The case of the Mediterranean diet and its sustainability. *Appl. Sci.* 2020, 10, 9144. [CrossRef]
12. Correa, R.C.G.; Gioia, F.; Ferreira, I.C.F.R.; Petropoulos, S.A. Wild greens used in the Mediterranean diet. In *The Mediterranean Diet: An Evidence-Based Approach*; Freedy, V., Watson, R., Eds.; Academic Press: London, UK, 2020; pp. 209–228. ISBN 9780128110796.
13. Sánchez-Mata, M.C.; Loera, R.D.C.; Morales, P.; Fernández-Ruiz, V.; Cámará, M.; Marqués, C.D.; Pardo-de-Santayana, M.; Tardio, J.; Cabrera Loera, R.D.; Morales, P.; et al. Wild vegetables of the Mediterranean area as valuable sources of bioactive compounds. *Genet. Resour. Crop Evol.* 2012, 59, 431–443. [CrossRef]
14. Ceccanti, C.; Landi, M.; Benvenuti, S.; Pardossi, A.; Guidi, L. Mediterranean wild edible plants: Weeds or “new functional crops”? *Molecules* 2018, 23, 2299. [CrossRef]
15. Correa, R.C.G.; Di Gioia, F.; Ferreira, I.; Petropoulos, S.A. Halophytes for future horticulture: The case of small-scale farming in the Mediterranean basin. In *Halophytes for Future Horticulture: From Molecules to Ecosystems towards Biosaline Agriculture*; Grigore, M.-N., Ed.; Springer Nature Switzerland AG: Cham, Switzerland, 2020; pp. 1–28. ISBN 9783030178543.
16. Guimarães, N.; Godinho, S.; Pinto-Correia, T.; Almeida, M.; Bartolini, F.; Bezát, P.; Biró, M.; Bjørkhaug, H.; Bojnec, Š.; Brunori, G.; et al. Typology and distribution of small farms in Europe: Towards a better picture. *Land Use Policy* 2018, 75, 784–798. [CrossRef]
17. Singh, R.; Singh, G.S. Traditional agriculture: A climate-smart approach for sustainable food production. *Energy Ecol. Environ.* 2017, 2, 296–316. [CrossRef]
18. Frison, E.A.; Cheras, J.; Hodgkin, T. Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. *Sustainability* 2011, 3, 238–253. [CrossRef]
19. Sardare, M.D.; Admane, S.A. Review on plant without soil-hydroponics. *Int. J. Res. Eng. Technol.* 2013, 02, 299–304.
20. Giménez, A.; Fernández, J.A.; Pascual, J.A.; Ros, M.; López-Serrano, M.; Egea-Gilabert, C. An agroindustrial compost as alternative to peat for production of baby leaf red lettuce in a floating system. *Sci. Hortic.* 2019, 246, 907–915. [CrossRef]
21. Mazzuoli, N.; Godinho, S.; Pinto-Correia, T.; Almeida, M.; Bartolini, F.; Bezák, P.; Biró, M.; Bjørkhaug, H.; Bojnec, Š.; Brunori, G.; et al. Typology and distribution of small farms in Europe: Towards a better picture. *Land Use Policy* 2018, 75, 784–798. [CrossRef]
56. Kang, Y.I.; Park, J.M.; Kim, S.H.; Kang, N.J.; Park, K.S.; Lee, S.Y.; Jeong, B.R. Effects of root zone pH and nutrient concentration on the growth and nutrient uptake of tomato seedlings. J. Plant Nutr. 2011, 34, 640–652. [CrossRef]
57. Findenegg, G.R. A comparative study of ammonium toxicity at different constant pH of the nutrient solution. Plant Soil 1987, 103, 239–243. [CrossRef]
58. Assimakopoulou, A. Effect of iron supply and nitrogen form on growth, nutritional status and ferric reducing activity of spinach in nutrient solution culture. Sci. Hortic. 2006, 110, 21–29. [CrossRef]
59. Dyško, J.; Kaniszewski, S.; Kowalczyk, W. The effect of nutrient solution pH on phosphorus availability in soilless culture of tomato. J. Elem. 2008, 13, 189–198.
60. Savvas, D.; Karagianni, V.; Kotsiras, A.; Demopoulos, V.; Karkamisi, I.; Pakou, P. Interactions between ammonium and pH of the nutrient solution supplied to gerbera (Gerbera jamesonii) grown in pumice. Plant Soil 2003, 254, 393–402. [CrossRef]
61. Lippmann, R.; Babben, S.; Menger, A.; Delker, C.; Quint, M. Development of wild and cultivated plants under global warming conditions. Curr. Biol. 2019, 29, R1326–R1338. [CrossRef]
62. Rietra, R.P.J.J.; Heinen, M.; Dimkpa, C.O.; Bindraban, P.S. Effects of nutrient antagonism and synergism on yield and fertilizer use efficiency. Commun. Soil Sci. Plant Anal. 2017, 48, 1895–1920. [CrossRef]
63. Assimakopoulou, A.; Holevas, C.D.; Fasseas, K. Relative susceptibility of some Prunus rootstocks in hydroponics to iron deficiency. J. Plant Nutr. 2011, 34, 1014–1033. [CrossRef]
64. Clark, M.B.; Mills, H.A.; Robacker, C.D.; Latimer, J.G. Influence of nitrate: Ammonium ratios on growth and elemental concentration in two Azalea cultivars. J. Plant Nutr. 2003, 26, 2503–2520. [CrossRef]
65. Taiz, L.; Zeiger, E. Plant Physiology, 3rd ed.; Sinauer Associates Publishers: Sunderland, MA, USA, 2002.
66. Arnon, D.I.; Johnson, C.M. Influence of hydrogen ion concentration on the growth of higher plants under controlled conditions. Plant Physiol. 1941, 5, 525–539. [CrossRef]
67. Colonna, E.; Rouphael, Y.; Barbieri, G.; De Pascale, S. Nutritional quality of ten leafy vegetables harvested at two light intensities. Food Chem. 2016, 199, 702–710. [CrossRef] [PubMed]
68. Santamaria, P. Nitrate in vegetables: Toxicity, content, intake and EC regulation. J. Sci. Food Agric. 2006, 86, 10–17. [CrossRef]
69. Petropoulos, S.A.; Fernandes, Â.; Dias, M.I.; Pereira, C.; Calhelha, R.C.; Chrysargyris, A.; Tzortzakis, N.; Ivanov, M.; Sokovic, M.D.; Barros, L.; et al. Chemical composition and plant growth of Centaurea raphanica subsp. mixta plants cultivated under saline conditions. Molecules 2020, 25, 2204. [CrossRef]
70. Petropoulos, S.; Fernandes, A.; Barros, L.; Ferreira, I. A comparison of the phenolic profile and antioxidant activity of different Cichorium spinosum L. ecotypes. J. Sci. Food Agric. 2017, 98, 183–189. [CrossRef]
71. Petropoulos, S.; Fernandes, A.; Karkanis, A.; Ntatsi, G.; Barros, L.; Ferreira, I. Successive harvesting affects yield, chemical composition and antioxidant activity of Cichorium spinosum L. Food Chem. 2017, 237, 83–90. [CrossRef]