horticulturae

MDPI

Article

Effect of Organic Fertilizer on the Growth and Physiological Parameters of a Traditional Medicinal Plant under Salinity Stress Conditions

Abdollah Beyk-Khormizi [1,2], Mohammad Reza Sarafraz-Ardakani [1,*], Siavash Hosseini Sarghein [2], Seyed Mohammad Moshtaghioun [1], Seyed Mousa Mousavi-Kouhi [3] and Mohammad Ehsan Taghavizadeh Yazdi [4,*]

[1] Department of Biology, Faculty of Science, Yazd University, Yazd 8915818411, Iran; abdollahbeyk@gmail.com (A.B.-K.); moshtaghiun@yazd.ac.ir (S.M.M.)
[2] Department of Biology, Faculty of Science, Urmia University, Urmia 5756151818, Iran; s.hosseini@urmia.ac.ir
[3] Department of Biology, Faculty of Science, University of Birjand, Birjand 9717434765, Iran; smmousavi@birjand.ac.ir
[4] Applied Biomedical Research Center, Mashhad University of Medical Sciences, Mashhad 9137913131, Iran
* Correspondence: sarafraz.ardakani@yazd.ac.ir (M.R.S.-A.); taghavizadehme971@mums.ac.ir or metyazdi@gmail.com (M.E.T.Y.)

Abstract: *Foeniculum vulgare* (fennel) is a medicinal and aromatic plant species from Apiaceae (Umbelliferae) and has been extensively used to treat digestive and pulmonary diseases. This plant is relatively sensitive to salinity. To investigate the effect of salinity stress at levels of 0, 40, and 80 mM NaCl in combination with 0 and 5% *v/v* vermicompost mixed with soil on the growth as well as the physiological and biochemical traits of two fennel landraces planted in Urmia and Shiraz areas, a factorial experiment was conducted as a randomized complete block design in three replications under greenhouse conditions. The plants were sampled in the flowering stage eleven weeks after cultivation. As the results showed, vermicompost treatment together with salinity stress could enhance the growth traits of the plants, such as the length and dry weight of shoots; leaf area and dry weight of roots; photosynthetic pigments, i.e., chlorophylls and carotenoids; membrane stability index; relative water content, soluble sugar, soluble protein, proline, total phenol, and anthocyanin in the shoots; mineral elements, i.e., phosphate, nitrate, zinc, molybdenum, magnesium, and iron in the shoots; and potassium and calcium in the shoots and roots. The interaction of vermicompost and salinity also decreased the aldehydes, total flavonoids, activity of catalase enzyme and shoot starch, soluble sugar and root proline, and sodium content of both shoots and roots. In a comparison of the two studied fennel landraces, the Shiraz landrace emerged to be less affected by salinity stress. In saline conditions, vermicompost caused a change in the physiological and biochemical parameters of both fennel landraces and improved their growth. The improvement in the growth conditions in the Urmia landrace was more obvious due to the use of vermicompost. Using vermicompost plus 40 mM NaCl salinity, the dry weight of the shoot and leaf surface of the Urmia landrace increased by about 3 and 2.5 times, respectively, and under 80 mM NaCl, the dry weight of the shoot and leaf surface increased by 2.7 and 1.2 times compared to the control. According to the experiments, it seems that vermicompost can limit the harmful effects of salinity on fennel plants by affecting photosynthetic pigments, osmolytes, phenolic compounds, antioxidants, the stability of membranes, and the availability of water and essential minerals.

Keywords: abiotic stress; availability of water and minerals; *Foeniculum vulgare* Mill; physiological traits; vermicompost

check for updates

Citation: Beyk-Khormizi, A.; Sarafraz-Ardakani, M.R.; Hosseini Sarghein, S.; Moshtaghioun, S.M.; Mousavi-Kouhi, S.M.; Taghavizadeh Yazdi, M.E. Effect of Organic Fertilizer on the Growth and Physiological Parameters of a Traditional Medicinal Plant under Salinity Stress Conditions. *Horticulturae* **2023**, *9*, 701. https://doi.org/10.3390/horticulturae9060701

Academic Editors: Deke Xing and Yanyou Wu

Received: 4 May 2023
Revised: 9 June 2023
Accepted: 11 June 2023
Published: 15 June 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Fennel (*Foeniculum vulgare* Mill), as an herbaceous and aromatic plant in the Apiaceae family, originates from the southern Mediterranean region, grows naturally, and is culti-

vated all over the world, especially in Asia, South America, and Europe [1]. A literature review demonstrates that *Foeniculum vulgare*, the most famous species of the *Foeniculum* genus, has a broad spectrum of ethnobotanical applications and has been widely used as a condiment. In Italy, the seed is employed in the preparation of salted meats and also is employed as an aromatizer for pickled olives. In Spain, the leaves and stems are consumed raw as a snack and are used in salads or stewed. It is also a well-known ethnomedicinal plant that is used in various traditional systems of the world, particularly in Asian countries. In folk medicines of Pakistan, the apical shoots are used for stress removal and as a sedative. In India, fruit powder is applied for the treatment of repeated abortions [1,2]. Furthermore, in Iranian folk medicine, it is applied for the treatment of digestive system diseases, kidney infections, bronchitis, dysentery, and toothache, and as an appetizer, antiacid, carminative, diuretic, and galactagogue [3–5].

One of the most important obstacles in the propagation of fennel is salt stress [6]. Abiotic stresses, including salinity, are a serious threat to the quantity and quality of plants in many regions of the world. Salinity stress in arid and semi-arid regions is significant due to a lack of sufficient rainfall, high temperatures, and intense evaporation and transpiration [7]. Unfortunately, the process of salinization of agricultural land will be up to 50% in 2050 and cause a sharp decrease in land suitable for cultivation [8]. Salinity may affect the growth of agricultural products by inducing toxicity in the soil, oxidative damage to different parts of the cell, and disrupting the balance of soluble nutrients [9]. Therefore, plants try to minimize the harmful effects of stress by limiting the entry of salt ions into the cytosol or intensifying the synthesis of osmolytes, antioxidants, and growth regulators [10,11]. In addition, antioxidant enzymes enable plants to cope with the excessive production of reactive oxygen species (ROS) and to survive in saline conditions [12–14].

In recent years, the excessive use of chemical fertilizers has caused the destruction of water resources and a reduction in the quality of food obtained from plants. Additionally, irreversible damage to the ecosystem is one of the complications of using chemical fertilizers [15]. The use of organic fertilizers is a common method for ameliorating abiotic stresses such as salinity. Therefore, sustainable agriculture and alternative methods based on the use of organic fertilizers can be considered as an optimal solution to overcome this problem in order to eliminate or significantly reduce chemical materials [15,16].

Vermicompost is a biological organic fertilizer produced through the conversion of organic waste by the activity of earthworms and microorganisms [16]. This fertilizer improves soil fertility by increasing organic carbon and making nitrogen, phosphorus, and potassium available for plants [17]. The use of vermicompost improves the water-holding capacity in the soil and the production of plant growth regulators and leads to improved crop growth and yield [18]. Several studies, such as those by Celikcan et al. [19] and Mousavi Kouhi et al. [20], have reported the positive effect of vermicompost on plant growth. However, just a few studies have been conducted on the effect of vermicompost on plants under salinity stress conditions. In this regard, one may refer to Shirani Bidabadi et al. [21] and BeykKhormizi et al. [22]. Vermicompost and humic acid improve the aggregate microstructure of saline soil, increase salt leaching, and inhibit nitrogen loss [23]. Feizi et al. [24] stated that vermicompost extract can neutralize the harmful effects of salinity in the saffron plant by providing the required nutrients and improving the K^+/Na^+ ratio.

In two other experiments, Beyk Khormizi et al. [25,26] investigated the effect of vermicompost extract on germination and that of vermicompost on the vegetative stage of fennel landraces in a saline environment. Since fennel is relatively sensitive to salinity and vermicompost has the potential to improve the germination and vegetative growth of this plant, and considering the different reactions of plants to environmental conditions in different life stages, in this research, the interaction effects of vermicompost organic fertilizer and salinity stress on fennel in the flowering stage were investigated. This research was carried out extensively so that different morphological parameters, photosynthetic pigments, cell membrane stability index, aldehydes, relative water content, total protein, amino acids, phenols, sugars, various mineral elements, and the activity of antioxidant

enzymes of two fennel landraces of Urmia and Shiraz were measured in order to understand the effect mechanism of vermicompost, salinity, and their interaction on the fennel plant in the flowering stage.

2. Materials and Methods

2.1. Experimental Design, Plant Culture, and Treatment

In this research, an investigation was conducted on the effects of 0 and 5% vermicompost mixed with loam-clay soil (*v*/*v*) at different salinity levels, which were produced by adding sodium chloride to distilled water (0, 40, and 80 mM NaCl), on two fennel landraces planted in Urmia and Shiraz areas. The experiment was carried out as a factorial randomized complete block design with three replications. This experiment was conducted in the research greenhouse of Yazd University in Iran, with temperature conditions of 25–28 °C, relative humidity of 60–70%, and 16/8 h of light/darkness. Some of the characteristics of the vermicompost and soil used in the experiment are reported in Table 1.

Table 1. Some characteristics of the vermicompost and soil used in the experiment (available forms): EC—electrical conductivity, OC—organic carbon.

Sample	EC (dS m^{-1})	OC (%)	Mo (ppm)	Zn (ppm)	Fe (ppm)	Na (ppm)	Mg (ppm)	Ca (ppm)	K (ppm)	P (ppm)	N (ppm)
VC	7.68	15.87	150	127	15,100	4200	18,900	52,000	15,900	22,200	15,400
Soil	3.81	0.015	0.37	0.14	0.08	547	91.7	216.4	136.4	4.3	10
A mixture of VC and Soil	4.87	0.099	o.49	0.22	0.36	554	131.2	368.7	390	15.62	90

After being soaked in water for 24 h, the seeds of two fennel landraces were planted in plastic pots (with an opening size of 18.5, a height of 17 cm, and a capacity of 4 kg of soil) and irrigated according to the crop capacity. The pots were irrigated with distilled water (i.e., water with no salinity) for three weeks and then according to experimental treatments (i.e., 40 and 80 mM NaCl). Irrigation was conducted once a week, and in order to keep the amount of salinity in the pots constant, the electrical conductivity of the drainage of the pots was measured and controlled.

After eleven weeks of planting (flowering stage), the shoots were separated from the roots, and the length and the dry weight of the shoots and the roots were measured. The surface of the leaves was also determined by using a leaf area meter.

2.2. Photosynthetic Pigments

The amounts of chlorophyll and carotenoids were measured after the fresh leaves were homogenized with 80% acetone, the homogenate was centrifuged at 3000 rpm for five minutes, and the absorbance of the supernatant solution was read by an Analytic Jena 210 spectrophotometer at 647, 663, and 470 nm [27].

2.3. Aldehydes

The concentration of malondialdehyde [28] and other aldehydes [29] was measured after 0.2 g of the fresh tissue of the plant was extracted with 0.1% Trichloroacetic acid (TCA) and reacted with Thiobarbituric acid (TBA) 0.5%. The resulting solution was absorbed at 532 nm (in the case of malondialdehyde) and 455 nm (in the case of the other aldehydes).

2.4. Membrane Stability Index (MSI)

To determine MSI, 0.1 g of the leaves was put in two sets of test tubes containing 10 mL of distilled water. One set of tubes was placed in a bath at 40 °C for 30 min, and the other set was kept in a bath at 100 °C for 10 min. After the temperature of the tubes was reduced

to an ambient value, the electrical conductivity of the samples was measured with an EC meter, and then, MSI was obtained from the following equation [30]:

$$MSI = [1 - (C_1/C_2)] \times 100$$

MSI: membrane stability index; C_1: the electrical conductivity of the sample at 40 °C for 30 min; C_2 is the electrical conductivity of the sample at 100 °C for 10 min.

2.5. Relative Water Content (RWC)

To determine the RWC in the leaves, a given amount of them (FW) was immersed in distilled water. After 48 h, the leaves were removed from the water, their surface was dried with a paper napkin, and their weight was measured (TW). Then, the leaves were dried in an oven at 70 °C for 48 h (DW), their weight was determined, and, finally, RWC was obtained according to the following formula [31]:

$$RWC = (FW - DW/TW - DW) \times 100$$

2.6. Carbohydrate Content

First, 1.5 mL ethanol (80%) was added to 0.03 g of a powdered plant sample, and then, it was vortexed for 5 min and centrifuged at 3000 rpm for 10 min. A supernatant solution was used to measure the dissolved sugars after the evaporation of the alcohol and the addition of 10 mL of distilled water, 0.47 mL of 0.3 normal barium hydroxide, and 0.5 mL of 5% zinc sulfate. Pellets were also used to measure the starch content after it was dried and 4.5 mL of distilled water and 6 mL of 52% perchloric acid were added. Both soluble sugar and starch content were measured based on their reaction with 5% phenol and 98% sulfuric acid. The amount of light absorption of the samples was determined at a wavelength of 485 nm. Finally, the concentration of each sample was determined using a standard curve.

2.7. Proline

The amount of proline was measured using the method of Bates et al. [32]. At first, 200 mg of plant tissue was ground in 10 mL of 3% sulfosalicylic acid solution, and the resulting extract was centrifuged for 5 min at 10,000 rpm. Then, 2 mL of the liquid solution was mixed with 2 mL of ninhydrin reagent and 2 mL of glacial acetic acid in a test tube. The test tubes were placed in a water bath at 100 °C for one hour. Then, the tubes containing the mixture were immediately transferred to a container containing ice. After that, 4 mL of toluene was added to the contents of the test tube and mixed vigorously for 30 s. By keeping the tubes still for 15 to 20 s, two separate layers were formed. The amount of light absorption of the upper colored layer (containing toluene and proline) was read at 518 nm. The amount of proline was calculated using a standard curve.

2.8. Total Phenol

An amount of 0.1 g of the plant tissue was ground in 5 mL of 95% methanol and left in the dark for 24 h. Then, 450 µL of distilled water and 250 µL of Fulin reagent were added to 50 µL of this extract. This was followed by the addition of 1.25 mL of 20% sodium carbonate solution. The resulting mixture was kept at 25 °C for 20 min and then centrifuged at 2000 rpm for 10 min. The absorption of the supernatant occurred at 735 nm. Finally, the amount of the total phenolic compounds was calculated with a standard curve [33].

2.9. Total Flavonoid

Total flavonoid was determined based on the method reported by Chang et al. [34]. To this end, 0.1 g of the plant tissue was ground with 1 mL of distilled water, and then, 1.5 mL of 95% ethanol, 0.1 mL of 10% aluminum chloride, 0.1 mL of 1 M potassium acetate, and 2.8 mL of distilled water were added to 0.5 mL of the ground sample. The resulting mixture was kept at 25 °C for 45 min and then centrifuged at 2000 rpm for 10 min. The absorbance

of the supernatant was read at 415 nm. Finally, using a standard curve, the amount of total flavonoids was calculated.

2.10. Anthocyanins

To determine the amount of anthocyanins, 0.1 g of the plant tissue was ground with 10 mL of acidic methanol (pure methanol and pure hydrochloric acid at a ratio of 1:99) and placed in the dark at a temperature of 25 °C for 24 h. Then, it was centrifuged at 4000 rpm for 10 min, and the absorbance of the supernatant was recorded at 550 nm. The concentration of anthocyanins was calculated using an extinction coefficient of 33,000 mol/cm^2 [35].

2.11. Total Protein and Antioxidant Enzymes

Fresh tissue (0.5 g) was ground by the addition of 50 mg of Poly Vinyl Pyrrolidone (PVP) and 3 mL of an extraction buffer solution containing 50 mM potassium phosphate (pH = 7) and 1 mM Sodium Metabisulfite. The resulting homogenate was centrifuged at 14,000 rpm for 30 min. The supernatant, or protein extract, was used to determine the total protein concentration [36] and the activity of catalase [37] and guaiacol peroxidase [38] enzymes. The CAT enzyme reaction mixture included 3 mL of a 50 mM potassium phosphate buffer (pH = 7), 0.4 mL of 15 mM hydrogen peroxide (H_2O_2), and 20 µL of the enzyme extract. The GPX enzyme reaction mixture included 2.65 mL of a 50 mM phosphate buffer (pH = 7.4), 300 µL of 3% hydrogen peroxide, 30 µL of 99% guaiacol, and 20 µL of the enzyme extract. The curve of the absorbance changes at 240 nm for CAT and 470 nm for GPX was traced for 3 min, and the activity of the enzymes was calculated.

2.12. Phosphate Measurement

For phosphate extraction, 5 mL of 0.01 N hydrochloric acid was added to 0.5 g of crushed plant tissue. The resulting mixture was vortexed for 90 s and then filtered. An amount of 2 mL of ammonium molybdate–vanadate solution was added to 2 mL of the extract, and the volume was brought to 15 mL with distilled water. Finally, the absorbance of the resulting solution was read at 470 nm, and the phosphate concentration was determined using a standard curve [39].

2.13. Nitrate Measurement

An amount of 2 g of crushed plant tissue was placed in a test tube containing 10 mL of distilled water and placed in a 100 °C water bath for 30 min. After cooling, the sample was filtered and made up to 25 mL with distilled water. Then, 0.4 mL of 5% salicylic acid in 96% (*w*/*v*) sulfuric acid was added to 0.1 mL of this solution. After cooling the solution, 9.5 mL of 8% sodium hydroxide was added to it, and the absorbance of the resulting solution was read at 410 nm. Nitrate concentration was determined using a standard curve [40].

2.14. Concentration of Minerals

One gram of the plant dry matter was burned into ash in an electric furnace at a temperature of 550 °C. Then, 10 mL of 2 M hydrochloric acid was added to the ash, and the mixture was slowly heated until the extract was reduced to one-third of its initial volume. The remaining extract was filtered and reached 100 mL with distilled water [41]. Finally, the concentrations of zinc, molybdenum, magnesium, and iron were measured using a NOVAA 300 atomic absorption device.

To measure sodium, potassium, and calcium, 3 mL of concentrated nitric acid was added to 0.05 g of powdered dry matter. After 48 h, the resulting mixture was slowly heated. The emission of white smoke and the discoloration of the acid solution marked the end of the digestion process. The volume of the remaining solution reached 50 mL with distilled water [42]. The concentration of these cations was determined using a flame photometry device model PFP7 and using a standard curve.

2.15. Statistical Analyses

The significant differences (at $p \leq 0.05$) and the comparative means were determined through two-way ANOVA followed by Duncan's multiple-range test using Mstat-C software (version 1.1.0).

3. Results and Discussion

3.1. Morphological Traits

The results of the variance analysis table show a significant effect of the interaction of vermicompost and salinity stress on the morphological parameters of fennel (Table 2).

Table 2. Results of variance analysis of morphological traits of two fennel landraces: DW—dry weight.

Sources of Variation	Degrees of Freedom	Plant Height (cm)	Shoot DW (mg)	Leaf Area (mm^2)	Root Length (mm)	Root DW (mg)
Landrace	1	** 311.993	** 0.142404	** 84,625.62	** 23.831	** 0.029884
Salinity	2	** 218.579	** 0.259129	** 58,083.64	** 36.727	** 0.017791
Landrace × salinity	2	** 20.14	** 0.013889	ns 665.093	** 5.452	ns 0.000068
Vermicompost	1	** 109.063	** 0.850694	** 481,979.1	** 23.088	** 0.045788
Landrace × vermicompost	1	ns 0.0001	** 0.025	** 17,109.3	** 2.794	** 0.000321
Salinity × vermicompost	2	ns 0.766	** 0.114597	** 30,423.42	** 12.341	ns 0.000101
Landrace × salinity × vermicompost	2	* 2.005	** 0.009003	** 1504.115	** 1.798	** 0.000614
Error	22	0.686	0.000072	203.66	0.148	0.000034

ns: non-significant; * and **: significant at $\alpha = 0.05$ and $\alpha = 0.01$, respectively.

As the results showed, salinity stress significantly decreased the length and the dry weight of the roots and shoots in both Urmia and Shiraz landraces of plants, as well as the leaf area of the Urmia landrace. The effect of salinity stress on these traits was stronger in the Urmia landrace than in the Shiraz landrace. In the treatment of the plants with vermicompost alone and its interaction with salinity stress, the morphological traits were enhanced significantly. This was more evident in the landrace of Urmia than in that of Shiraz. Vermicompost usage at 40 mM NaCl in both Urmia and Shiraz landraces caused an increase in the length of the shoot by about 22%. Additionally, the parameters of the dry weight of the shoot and the leaf area increased by about 3 and 2.5 times, respectively. In the salinity of 80 mM NaCl, the length of the shoot increased by 64% and the dry weight of the shoot and the leaf area increased more than twice in the landrace of Urmia, while in the landrace of Shiraz, the length of the shoot increased by about 30% and the dry weight of the shoot and the leaf area increased less than two-fold (Table 3).

Other studies, such as those by Abou El-Magd et al. [43] and Semiz et al. [44], reported a reduction in fennel growth under salt stress. As Cucci et al. [45] stated, sodium-induced salinity affects the growth of fennel, probably due to the side effects of sodium on the plant (i.e., toxicity and competition to absorb nutrients) and on the soil (i.e., a reduction in physical and chemical fertility). According to the results of the present research, vermicompost has beneficial effects on plant growth in conditions without salinity stress and in interaction with salinity stress, which has also been reported by Mousavi Kouhi et al. [20], Kiran [46], Shirani Bidabadi [21], and Beyk Khurmizi et al. [22]. Arancon et al. [47] found that humic acid, fulvic acid, and other organic acids in vermicompost and those produced by microorganisms can stimulate and improve plant growth and performance. The positive effect of vermicompost on plant growth is due to one or more useful ingredients, such as nutrients, plant growth regulators (PGRs), and microorganisms. Vermicompost can also change soil structure and positively affect plant growth [48]. Vermicompost causes a decrease in the harmful effects of salinity stress on the growth parameters of fennel plants

due to its structural features, such as porosity and high water-holding capacity, as well as having plant growth regulators and macro and micronutrients.

Table 3. Mean comparison of the effects of vermicompost and salinity stress interaction on the morphological traits of two fennel landraces: DW—dry weight, Conc.—concentration.

Fennel Landraces	VC Conc.	Salinity Conc. (mM NaCl)	Plant Height (cm)	Shoot DW (mg)	Leaf Area (mm^2)	Root Length (mm)	Root DW (mg)
Urmia	0	0	14.11 d	4.900 i	142.5 g	5.867 e	3.100 h
		40	11.67 e	3.200 k	116.4 h	9.500 b	1.867 k
		80	4.33 g	2.033 l	90.08 i	4.167 f	0.9667 l
	5%	0	19.11 b	18.70 c	423.2 c	10.00 b	5.567 c
		40	14.33 d	10.10 d	289.5 d	8.167 cd	3.900 f
		80	7.110 f	5.500 h	199.7 e	4.500 f	2.667 i
Shiraz	0	0	19.00 b	7.267 e	182.9 ef	7.750 d	5.100 d
		40	16.11 c	5.900 g	167.8 fg	8.607 c	3.400 g
		80	12.66 e	3.900 j	158.3 fg	6.387 e	2.333 j
	5%	0	22.11 a	24.77 a	561.9 a	11.28 a	6.900 a
		40	19.66 b	19.40 b	466.4 b	9.667 b	6.300 b
		80	16.44 c	7.067 f	305.9 d	8.277 cd	4.967 e

In each column, the averages that have at least one letter in common are not significantly different according to Duncan's multiple-range test ($p \leq 0.05$).

3.2. Photosynthetic Pigments

Salinity stress, vermicompost, and the interaction between them had a significant effect on the photosynthetic pigments of fennel (Table 4). Different salinity levels caused a significant decrease in chlorophylls and carotenoids in both of the studied fennel landraces (except for chlorophyll *a* and carotenoids at 40 mM NaCl salinity in the Urmia landrace). Vermicompost treatment alone significantly increased the photosynthetic pigments in both fennel landraces (except for chlorophyll *a* in the Urmia landrace). In saline conditions, the use of vermicompost caused a significant increase in photosynthetic pigments. Using vermicompost treatment in 40 mM NaCl salinity, the amount of chlorophyll *b* and carotenoids increased by 5.5% and 9.6%, respectively, in Urmia landrace. While in the same conditions and in the landrace of Shiraz, the amount of chlorophyll *b* (10.2%) and total chlorophyll (5.4%) increased significantly. In 80 mM NaCl salinity, the amount of chlorophyll *a*, total chlorophyll, and carotenoids increased by 13.9%, 8%, and 68% in the Urmia landrace and by 21%, 23%, and 12% in the Shiraz landrace, respectively. Additionally, the amount of chlorophyll *b* in the fennel plants of the Shiraz landrace increased by 28% (Figure 1).

Table 4. Analysis of variance of photosynthetic pigments, malondialdehyde (MDA), other aldehydes, and cell membrane stability index (MSI) of two fennel landraces.

Sources of Variation	Degrees of Freedom	Chl *a* (mg g^{-1})	Chl *b* (mg g^{-1})	Total Chl (mg g^{-1})	Carot (mg g^{-1} FW)	MDA (Nm/gFW)	Other Aldehydes (Nm/gFW)	MSI (%)
Landrace	1	** 0.139	** 0.04	** 0.029	** 0.052	** 657.452	** 191,525.7	** 213.194
Salinity	2	** 0.225	** 0.094	** 0.595	** 0.023	** 1976.924	** 671,031.7	** 2829.979
Landrace × salinity	2	** 0.086	* 0.0001	** 0.073	** 0.004	ns 41.093	* 10,214.61	* 25.624
Vermicompost	1	** 0.044	** 0.013	** 0.104	** 0.01	** 3086.451	** 715,880.4	** 757.506
Landrace × vermicompost	1	* 0.005	ns 0.001	** 0.01	** 0.001	** 223.727	** 65,172.03	ns 8.146
Salinity × vermicompost	2	* 0.006	** 0.001	** 0.008	** 0.001	ns 31.955	ns 5479.736	** 44.851
Landrace × salinity × vermicompost	2	* 0.001	** 0.002	* 0.001	** 0.001	* 31.962	** 28,303.53	* 22.781
Error	22	0.001	0.0001	0.001	0.0001	19.818	1826.999	7.006

ns: non-significant; * and **: significant at $\alpha = 0.05$ and $\alpha = 0.01$, respectively.

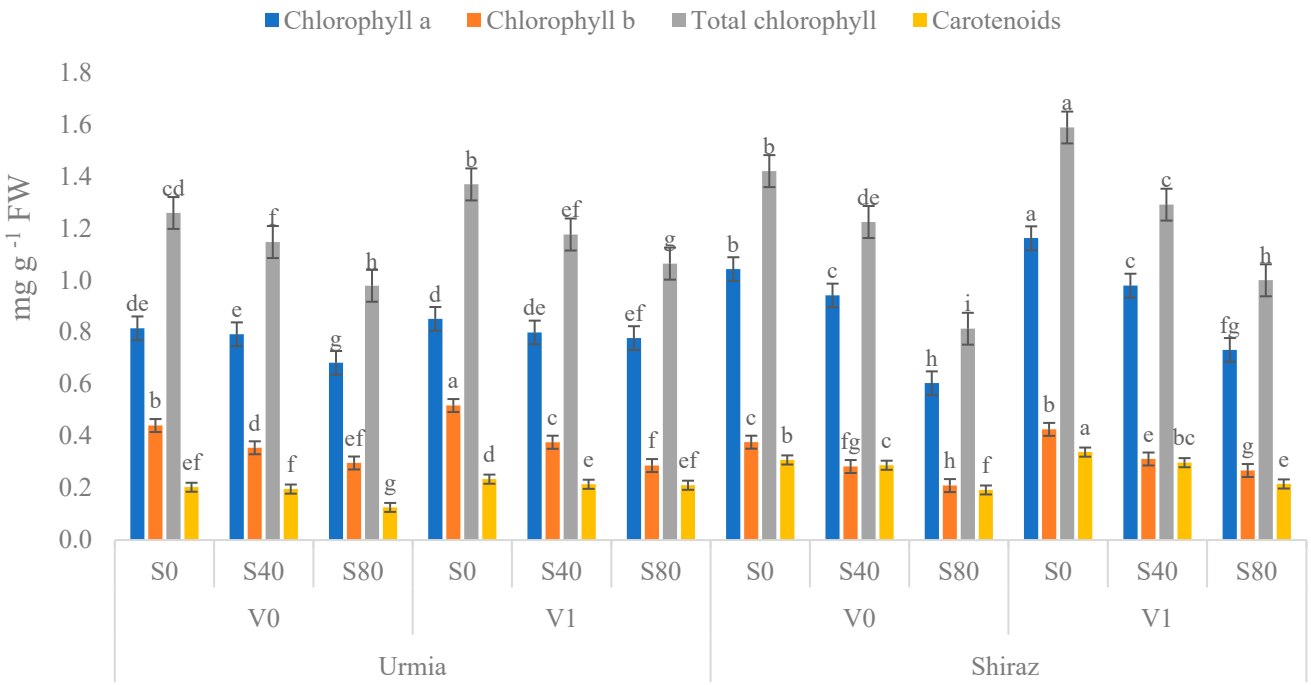

Figure 1. Mean comparison of the effects of vermicompost and salinity stress interaction on the photosynthetic pigments of the two fennel landraces. In each column, the averages that have at least one letter in common are not significantly different according to Duncan's multiple-range test ($p \leq 0.05$). (S0: control; S40: 40 mM NaCl; S80: 80 mM NaCl; V0: without vermicompost; V1: with 5% vermicompost; FW: fresh weight).

A reduction in plant photosynthetic pigments under saline conditions has been reported in other studies, such as those by Banakar et al. [49] and Grzeszczuk et al. [50]. Reactive oxygen species (ROS) cause peroxidation and, as a result, destroy chlorophyll pigments [51]. Photosystem proteins are highly sensitive to oxidative damage [52]. The loosening of chlorophyll connections with the related proteins, an increase in chlorophyllase enzyme activity, and an increase in stress regulators such as abscisic acid and ethylene account for the reduction in chlorophylls under saline conditions [53]. Another reason for the decrease in chlorophylls in salt stress conditions can be the competition of glutamine kinase enzyme with glutamate ligase enzyme during salt stress, which causes the consumption of more glutamate (i.e., the precursor of chlorophyll and proline) in proline production pathways. This actually results in limited chlorophyll biosynthesis [54].

According to the results of the present study, the amount of chlorophylls and carotenoids in peas was increased under vermicompost treatment. This can be attributed to the existence of nutrients in this organic fertilizer, including potassium and nitrogen, which play a role in the regulation of osmotic pressure [55]. Hosseinzadeh et al. [56] related this effect to microelements, such asiron, in vermicompost. Since iron serves as a prosthetic group in hemoproteins such as catalase, peroxidase, and superoxide dismutase [57], the ability to destroy ROS in plants treated with vermicompost is increased. Moreover, the amount of chlorophyll is proportional to that of carotenoids that protect it [58]. Therefore, an increase in the carotenoid content during vermicompost treatment can be related to the increase in chlorophyll synthesis [55].

3.3. Aldehydes (Malondialdehyde and Other Aldehydes) and MSI

According to Table 4, the amount of aldehydes and MSI of two fennel landraces were significantly affected by the interaction of salinity and vermicompost. The amount of aldehydes in the shoots increased significantly with exposure to the studied salinity levels in both Urmia and Shiraz fennel landraces. In contrast, different levels of salinity

caused a significant decrease in the MSI of the leaf cell membrane in both fennel groups. In this regard, at 80 mM NaCl salinity, the MSI of the cell membrane in the Urmia and Shiraz landraces decreased by 2.2 times and 89.5%, respectively. With vermicompost alone and its interaction with salt stress, the aldehydes in both studied fennel landraces decreased drastically, but the MSI increased. In the interaction of vermicompost with 40 mM NaCl salinity, the amount of malonaldehyde in the landrace of Urmia was more affected compared to Shiraz, while in the case of the amount of other aldehydes, the reverse was true. In this situation, MSI increased by 15% in the landrace of Urmia and 13.8% in the landrace of Shiraz. With vermicompost and 80 mM NaCl salinity, malondialdehyde and other aldehydes in the Urmia landrace reduced by 55% and 16%, respectively. In the Shiraz landrace, this reduction was 41% and 93%, respectively. Under these conditions, the MSI increased by 59% and 26% in Urmia and Shiraz landraces, respectively (Table 5).

Table 5. Mean comparison of the effects of vermicompost and salinity stress interaction on the malondialdehyde (MDA), other aldehydes, cell membrane stability index (MSI), relative water content (RWC), and proline content of the two fennel landraces. Conc.—concentration.

Fennel Landraces	VC Conc.	Salinity Conc. (mM NaCl)	MDA (Nm/gFW)	Other Aldehydes (Nm/gFW)	MSI (%)	RWC (%)	Shoot Proline (µmol/gFW)	Root Proline (µmol/gFW)
Urmia	0	0	34.19 de	561.6 d	65.79 c	63.16 e	12.54 h	28.24 g
		40	57.69 b	751.3 c	49.45 e	59.17 f	15.08 f	88.50 c
		80	66.24 a	1036.a	29.71 g	48.16 h	16.93 cd	101.3 b
	5%	0	17.09 g	306.3 f	70.89 b	84.40 b	15.62 ef	11.00 h
		40	27.78 ef	561.6 d	57.10 d	70.71 d	19.09 b	71.38 d
		80	42.73 c	889.9 b	47.34 e	59.77 f	20.85 a	89.08 c
Shiraz	0	0	27.78 ef	452.2 e	68.73 bc	76.14 c	11.58 h	29.90 g
		40	38.46 cd	714.8 c	57.42 d	71.49 d	13.81 g	100.3 b
		80	51.28 b	999.3 a	36.26 f	57.21 g	16.51 de	106.5 a
	5%	0	14.96 g	240.7 f	76.01 a	88.34 a	14.97 f	12.47 h
		40	25.64 f	306.3 f	65.36 c	77.31 c	16.39 de	43.87 f
		80	36.32 cd	517.9 de	45.71 e	64.12 e	17.74 c	50.14 e

In each column, the averages that have at least one letter in common are not significantly different according to Duncan's multiple-range test ($p \leq 0.05$).

According to the literature in this field, other researchers, such as Banakar et al. [49], have also reported that malondialdehyde and other aldehydes (which are the products of lipid peroxidation and indicators of membrane damage) significantly increase in plants under osmotic stress. A decrease in leaf water content and an increase in osmotic potential, along with an increase in sodium ion concentration, cause lipid peroxidation and disrupt the function and structure of cell membranes [59]. A reduction in malondialdehyde by the use of vermicompost has also been shown in lettuce [46]. Similarly, Shirani Bidabadi et al. [21] found that, under salinity stress, malondialdehyde and electrolyte leakage of two pomegranate cultivars increased, while the use of vermicompost leachate in these conditions decreased the two features. Bandeoglu et al. [60] stated that a change in the activity of hydrogen-peroxide-producing enzymes leads to a reduction in gibberellin in cells, which, in turn, reduces lipid peroxidation and membrane ion leakage. In addition, it has been shown that the structure and function of plant cell membranes are strongly affected by zinc deficiency [61]. Studies have shown that zinc nutrition by the increased concentration of sulfhydryl in the roots lowers the permeability of the root membrane, and reduces the lipid peroxidation induced by free radicals [62]. Therefore, it is possible that vermicompost with high amounts of minerals, such as zinc, and plant hormones, such as gibberellins, can reduce lipid peroxidation and increase the membrane stability of fennel leaf cells.

3.4. RWC

Salinity stress, vermicompost, and the interaction between them significantly affected the RWC of two fennel landraces (Table 6). The RWC of the leaves of both fennel landraces significantly decreased when exposed to different levels of salinity. In contrast, vermicom-

post treatment alone significantly increased RWC in the Urmia (33%) and Shiraz (16%) fennel landraces. The interaction of vermicompost and salinity stress caused an increase in the RWC of both fennel landraces. This increase was greater under 80 mM NaCl compared to 40 mM NaCl. In the presence of vermicompost at 80 mM NaCl salinity, the amount of this trait increased by 24 and 12% in the Urmia and Shiraz landraces, respectively, and by 19 and 8% at 40 mM NaCl salinity (Table 5).

Table 6. Analysis of variance of relative water content (RWC), proline, and sugars of two fennel landraces.

Sources of Variation	Degrees of Freedom	RWC (%)	Shoot Proline (µmol/gFW)	Root Proline (µmol/gFW)	Shoot Soluble Sugar (mg/gFW)	Shoot Starch (mg/gFW)	Root Soluble Sugar (mg/gFW)	Root Starch (mg/gFW)
Landrace	1	605.833 **	20.737 **	538.488 **	4.31 **	5.686 **	0.023 ns	32.418 **
Salinity	2	1300.854 **	56.385 **	15,219.31 **	4.204 **	0.056 ns	9.33 **	1.295 **
Landrace × salinity	2	5.846 **	1.174 ns	255.343 **	0.022 ns	0.002 ns	0.981 **	4.764 **
Vermicompost	1	1201.061 **	82.771 **	7812.262 **	3.089 **	23.25 **	124.096 **	105.576 **
Landrace × vermicompost	1	94.537 **	3.603 **	1746.181 **	0.921 **	2.945 **	1.23 **	19.044 **
Salinity × vermicompost	2	60.38 *	0.478 ns	335.614 **	0.998 **	0.316 **	5.79 **	2.289 *
Landrace × salinity × vermicompost	2	3.863	1.696 *	434.979 **	0.212 **	0.223 **	0.375 **	0.182 *
Error	22	0.939	0.38	2.5	0.008	0.003	0.047	0.086

ns: non-significant; * and **: significant at $\alpha = 0.05$ and $\alpha = 0.01$, respectively.

Under salinity stress, water absorption is difficult, and the decrease in RWC can be attributed to the decrease in leaf water potential and the decrease in water absorption by the roots [63]. An increase in the tissue sodium concentration is also one of the possible reasons for the reduction in RWC and the potential of leaf water under salinity stress conditions [63]. As Rafiq and Nusrat [64] reported, osmotic potential and water potential decreased significantly with an increase in the salt concentration in sunflower leaves, but they increased with the application of organic fertilizers. The researchers stated that organic fertilizers cause the accumulation of K^+ and some organic ions in cells, resulting in an increase in osmotic activity and, subsequently, a decrease in the water potential and the movement of water into the cells. Beyk Khurmizi et al. [22] also reported a reduction in RWC in the face of salinity stress and its improvement in the presence of vermicompost in bean plants. They stated that vermicompost can improve the water potential of leaves due to having plant hormones, a porous structure, and a high water-holding capacity.

3.5. Proline of Shoots and Roots

The proline in the shoots and roots of both fennel landraces increased significantly when exposed to certain levels of salinity. The increase in proline in the roots of both landraces was much higher than that in the shoots. In the treatment of the fennel landraces with vermicompost alone and along with salt stress, the amount of proline significantly increased in the shoots, but it decreased sharply in the roots. Vermicompost induced an increase in the proline of the shoots under 40 mM NaCl and 80 mM NaCl by 26% and 21% in the landrace of Urmia and by 18% and 7% in the landrace of Shiraz, respectively. The root proline decreases in salinities of 40 and 80 mM NaCl were 24% and 13% in the Urmia landrace and 2.2 and 2.1 times in the Shiraz landrace, respectively (Tables 5 and 6).

An increase in proline under saline conditions has been reported in other studies, such as those by Dejampour et al. [65] and Abdel Rahman et al. [66]. Bian and Jiang [31] stated that proline plays a role in maintaining the structure of the membrane, creating osmotic compatibility, and maintaining the structure of enzymes in the cell. Additionally, due to its hydrophilic nature, proline may replace water molecules around nucleic acids, proteins, and membrane molecules, thus reducing the effects of destructive ions on these compounds to protect them and the structure of the membrane.

An increase in the amount of proline due to the use of vermicompost has been reported [55]. Additionally, according to Atik [57], owing to the microorganisms existing in

it, the vermicompost added to the soil increases the nitrogen available for plants. This, in turn, raises the amount of free amino acids, including proline in the plants.

3.6. Soluble Sugar and Starch in the Shoots and Roots

The interaction of salinity stress and vermicompost had a significant effect on the amount of soluble sugar and starch in the shoot of fennel (Table 6). The results showed a significant decrease in the soluble sugar and starch of the shoots as well as the starch of the roots in the face of salinity stress, with some exceptions. Additionally, at the studied salinity levels, the root soluble sugar significantly increased in both landraces. In the vermicompost treatment alone, the soluble sugar in the shoots and the starch in the roots increased significantly, but the starch in the shoots and the soluble sugar in the roots decreased significantly. The interaction of salinity and vermicompost led to a significant decrease in the starch and soluble sugar of the shoots and the starch of the roots as well as a significant increase in the soluble sugar of the shoots. With vermicompost under saline conditions of 80 mM NaCl, the amount of shoot starch in the Urmia and Shiraz landraces decreased by 51% and about 2.7 times, respectively. The soluble sugar and starch of the roots in these two landraces also decreased by 3 and 2 times and 82% and 2.2 times, respectively. However, the soluble sugar in the shoots of these two landraces increased by 16% and 12%, respectively. Under salinity of 40 mM NaCl, there was a significant reduction in shoot starch (about 51% and 4 times), root soluble sugar (about 3 and 2 times), and root starch (40% and 2.2 times), and a significant increase in shoot soluble sugar (about 12 and 36%) was observed in the landraces of Urmia and Shiraz, respectively (Figure 2).

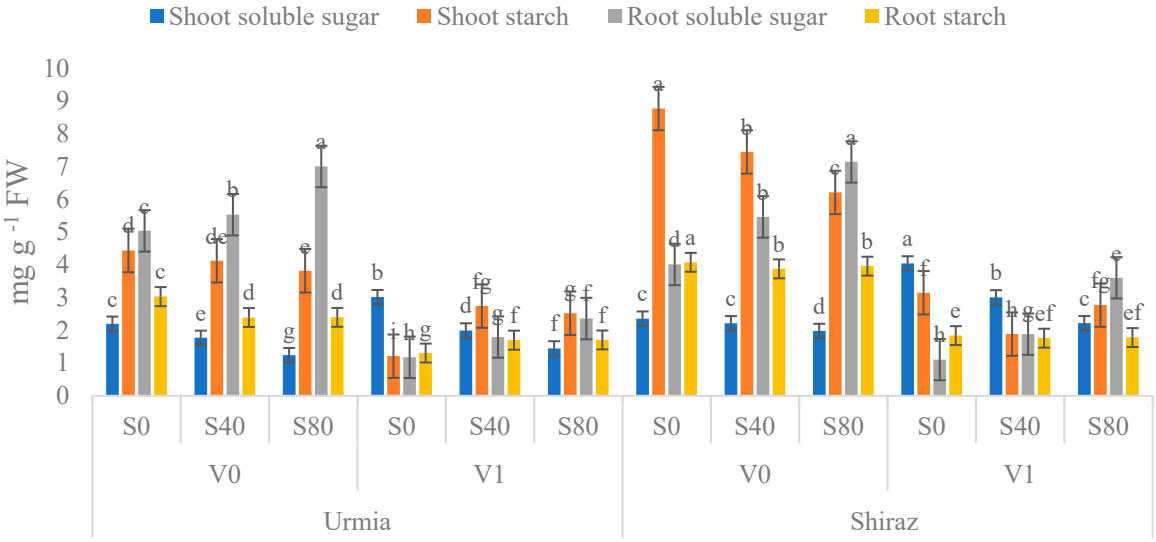

Figure 2. Mean comparison of the effects of vermicompost and salinity stress interaction on the amount of soluble sugar and starch in the shoots and roots of the two fennel landraces. In each column, the averages that have at least one letter in common are not significantly different according to Duncan's multiple-range test ($p \leq 0.05$). (S0: control; S40: 40 mM NaCl; S80: 80 mM NaCl; V0: without vermicompost; V1: with 5% vermicompost; FW: fresh weight).

Salinity stress causes a decrease in cell growth and, thus, a decrease in the leaf area and photosynthesis due to the limited absorption of nutrients, the lack of usable water, and the toxicity of some elements. These can induce a reduction in the production of carbohydrates and plant growth [67]. In the present study, this was related to the reduction in the soluble sugar and starch of the shoots as well as the root starch in the face of salt stress.

The results also showed a rise in the soluble sugar of the roots in saline conditions. In addition to regulating the osmosis inside the cell and controlling the osmotic potential and water potential [68], soluble sugars have a role in detoxification as chelating agents to trap Na^+ [69].

An increase in the content of soluble sugars is a result of the destruction and hydrolysis of larger molecules such as starch and their conversion into sugar compounds, such as sucrose, and then into smaller molecules, such as glucose and fructose, which causes more negative water potential in cells, osmotic regulation, and increased resistance to salinity stress in plants [70,71]. According to the results, the interaction of salinity and vermicompost led to decreased soluble sugar in the roots and starch in both shoots and roots and increased soluble sugar in the shoots.

Ashok et al. [72] stated that potassium is involved in some biological processes such as the production and movement of sugars and cell division in plants. It seems that the use of vermicompost makes the environmental conditions of plant roots favorable in terms of water and nutrient absorption; as a result, there is less need for sugar in the roots to maintain the osmotic potential. This is why the amount of root sugar reduces in the presence of vermicompost.

Regarding the amount of sugar in the shoots, vermicompost can increase the photosynthesis and metabolism of the plant owing to some characteristics, such as containing potassium as a nutrient. More photosynthesis means the production of more sugar to participate in various reactions, the result of which is a reduction in the shoot starch content.

3.7. Phenolic Compounds (Total Phenol, Total Flavonoid, and Anthocyanin)

An analysis of variance showed a significant effect of vermicompost interaction with salinity stress on fennel phenolic compounds (Table 7). At different levels of salinity, the amount of total phenol and total flavonoid significantly increased in the shoots of the fennel landraces of Urmia and Shiraz, but the amount of anthocyanin decreased sharply. With the application of vermicompost in saline and non-saline conditions, the amount of total phenol and anthocyanin in both studied fennel landraces increased significantly. Under the same conditions, total flavonoid in the fennel landrace of Urmia had no change, but it was significantly reduced in the Shiraz landrace. Vermicompost caused an increase in total phenol and anthocyanin by 40% and 97% in the Urmia landrace and by 18% and 29% in the Shiraz landrace, respectively. Under these conditions, the total flavonoid of the Urmia landrace was not affected, but it decreased by 75% in the landrace of Shiraz. At 80 mM NaCl salinity in the presence of vermicompost, the total phenol content increased by 15.7% and 3.7% and the anthocyanin content increased by 86% and 37% in the Urmia and Shiraz landraces, respectively. In these conditions, the amount of flavonoids in the landrace of Shiraz decreased by 64% (Table 8).

Table 7. Results of analysis of variance on the phenolic metabolites, total protein (TPC), activities of catalase (CAT) and peroxidase (POX) enzymes, and the amount of phosphate and nitrate in the shoots of the two landraces of fennel.

Sources of Variation	Degrees of Freedom	Total Phenol (mg/gFW)	Total Flavonoid (µg/gFW)	Anthocyanin (M/gFW)	TPC (mg/g FW)	CAT Activity (U Protein^{-1})	POX Activity (U Protein^{-1})	Phosphate (mg/kgFW)	Nitrate (mg/kgFW)
Landrace	1	** 322.083	** 1.329	** 8.313	** 11,085.28	** 10.569	* 1.905	** 37.21	** 37.088
Salinity	2	** 142.958	** 0.444	** 18.75	** 22,685.56	** 26.257	ns 0.726	** 29.765	** 2622.273
Landrace × salinity	2	** 40.002	** 0.027	** 1.553	** 1512.943	** 2.189	ns 0.107	** 15.017	* 9.585
Vermicompost	1	** 29.304	** 1.787	** 5.61	** 5845.112	** 25.182	ns 0.087	** 18.674	** 777.109
Landrace × vermicompost	1	** 0.846	** 1.335	ns 0.009	** 128.142	ns 0.0001	ns 0.232	ns 0.17	** 118.592
Salinity × vermicompost	2	** 1.639	** 0.02	** 1.448	** 368.278	** 2.553	ns 0.612	** 0.515	** 70.999
Landrace × salinity × vermicompost	2	* 0.001	** 0.013	* 0.026	** 355.366	** 3.631	ns 0.37	** 0.56	** 59.309
Error	22	0.096	0.001	0.014	2.773	0.013	0.256	0.052	2.079

ns: non-significant; * and **: significant at $\alpha = 0.05$ and $\alpha = 0.01$, respectively.

Table 8. Mean comparison of the effects of vermicompost and salinity stress interaction on the phenolic metabolites, total protein (TPC), activities of catalase (CAT) and peroxidase (POX) enzymes, and the amount of phosphate and nitrate in the shoots of the two landraces of fennel. Conc.—concentration.

Fennel Landraces	VC Conc.	Salinity Conc. (mM NaCl)	Total Phenol (mg/gFW)	Total Flavonoid (µg/gFW)	Anthocyanin (M/gFW)	TPC (mg/g FW)	CAT activity (U Protein^{-1})	POX Activity (U Protein^{-1})	Phosphate (mg/kgFW)	Nitrate (mg/kgFW)
Urmia	0	0	4.533 i	0.7567 h	2.181 d	53.13 e	0.9675 f	0.1606 ab	7.929 b	64.47 c
		40	5.033 i	1.112 ef	0.3737 hi	15.70 i	3.525 d	0.7257 ab	5.227 de	53.93 e
		80	8.267 fg	1.182 d	0.2927 i	11.53 j	4.844 a	1.066 a	3.319 i	36.13 h
	5%	0	6.833 h	0.6783 i	3.838 b	101.0 c	0.1406 i	1.047 a	10.40 a	70.60 b
		40	7.767 g	1.062 fg	0.7370 g	50.40 ef	0.3827 h	0.1045 ab	6.421 c	59.50 d
		80	9.567 e	1.129 de	0.5450 gh	16.73 i	3.793 c	0.9877 ab	4.386 g	41.42 g
Shiraz	0	0	6.967 h	1.708 c	2.636 c	127.5 b	0.5046 gh	0.07173 ab	3.999 h	59.40 d
		40	11.73 d	1.778 b	2.030 d	47.70 f	1.495 e	0.2600 ab	3.912 h	52.67 e
		80	18.00 b	1.874 a	0.9690 f	21.73 h	4.083 b	0.7222 ab	2.877 j	37.67 h
	5%	0	8.693 f	0.7086 hi	4.151 a	147.6 a	0.1144 i	0.02713 b	5.312 d	83.03 a
		40	13.83 c	1.016 g	2.615 c	72.03 d	0.3044 hi	0.08487 ab	4.877 ef	61.03 d
		80	18.67 a	1.142 de	1.333 e	42.43 g	0.6485 g	0.1653 ab	4.508 fg	44.43 f

In each column, the averages that have at least one letter in common are not significantly different according to Duncan's multiple-range test ($p \leq 0.05$).

Phenolic compounds play an essential role as a non-enzymatic defense mechanism in plants and are considered indicators sensitive to environmental changes. They are also biochemical indicators of plant defense against environmental stresses, and they help to accumulate hydrogen peroxide in plant cells [73]. The antioxidant activity of phenolic compounds is mainly due to their redox properties, which play an important role in absorbing and neutralizing free radicals [74]. Like in the present study, other researchers, such as Rezazadeh et al. [75] and Bourgou et al. [76], have reported an increase in phenolic and flavonoid compounds in different plants under saline conditions. Nevertheless, the present study showed a decrease in the amount of anthocyanins when faced with salinity. In this regard, Ahmed et al. [77] stated that a reduction in anthocyanins during salinity stress may allow more photosynthetically active rays to reach mesophyll cells. The use of vermicompost in the face of salinity stress caused an increase in total phenol and anthocyanin in both fennel landraces, but the amount of total flavonoids was decreased in the Shiraz landrace. Phenolic compounds are also synthesized in plant cells under favorable environmental conditions, but different environmental stresses change their amount in the cell [73]. Wang and Lin [78] reported that in the presence of compost, the amount of anthocyanin in strawberries was increased. Connor et al. [79] considered the availability of nutrients as one of the important factors in the production of anthocyanin and total phenol. Suthar [80] stated that vermicompost contains high amounts of macro and micronutrients. Therefore, in the presence of this organic fertilizer, the production of anthocyanin and total phenol increases.

On the other hand, the amount of total flavonoids was decreased in vermicompost treatment. It seems that the reduction in total flavonoid is related to other types of these compounds including flavonol. In this regard, Pollastr and Tattini [81] reported that flavonol is the most abundant type of flavonoid in plants, which plays an important role in plants coping with stress.

3.8. Total Protein

The total protein of both studied fennel landraces was significantly affected by salinity stress, vermicompost, and the interaction between them (Table 7). The amount of the total protein in the shoots of both fennel landraces significantly decreased when exposed to different levels of salinity, but it rose significantly in the presence of vermicompost alone and its interaction with salt stress. In the Urmia and Shiraz fennel landraces, the total protein increased by 3.2 times and 51% as vermicompost was used with 40 mM NaCl and by 45% and 95% with 80 mM NaCl (Table 8).

Manna et al. [82] reported a decrease in the soluble proteins of tomatoes under saline conditions. In a plant that is under stress conditions, protein synthesis stops and its decomposition accelerates. Following salinity stress, secondary stresses such as oxidative

stress also occur, through which the production and accumulation of reactive radicals lead to the oxidation of proteins, lipids, and, ultimately, cell death [83,84]. Amiri et al. [55] attributed the increase in pea plant protein in vermicompost treatment to the availability and absorption of more nitrogen. Salama [85] reported that the total protein in corn and chickpea plants was limited under the condition of zinc deficiency. Therefore, owing to its characteristics, vermicompost not only increases protein production but also prevents damage to proteins due to the decrease in the production of ROS.

3.9. The Activity of Antioxidant Enzymes (CAT and GPX)

Under different levels of salinity, the CAT activity of the shoots increased significantly in both the Urmia and Shiraz fennel landraces. The activity level of this enzyme was greatly reduced by the application of vermicompost alone and in its interaction with salinity stress in both studied fennel landraces. Vermicompost caused a reduction in CAT activity under 40 and 80 mM NaCl in the Urmia (about 9 and 5 times, respectively) and Shiraz landraces (27.7% and about 6 times, respectively). As it emerged, vermicompost, salinity stress, and their interaction did not affect the GPX activity in the Urmia and Shiraz landraces (Tables 7 and 8).

An increase in CAT activity under salinity stress has also been reported in other plants [86,87]. Sorkheh et al. [88] stated that salinity stress disturbs the homeostasis of water potential and ion distribution at both the cell level and the whole plant level and causes osmotic stress. This lack of water causes the creation of ROS, which disturbs metabolism through oxidative damage to lipids, proteins, and nucleic acids and increases the activity of antioxidant enzymes under stress. Under saline conditions, antioxidant defense mechanisms are activated to protect the root membrane structure from oxidation [61]. The increase in the activities of antioxidant enzymes (CAT, GPX, and superoxide dismutase) and the accumulation of proline are part of the defense against oxidative stress [89].

According to the results of the present study, vermicompost treatment and its interaction with salinity stress decrease the CAT activity but do not change the activity of GPX. These results are in contrast to the findings of Hosseinzadeh et al. [90], who observed that vermicompost treatment had no effect on the CAT activity in pea plants but significantly reduced peroxidase. On the other hand, Kiran et al. [46] showed that the CAT activity in lettuce increased with the use of vermicompost. Therefore, according to the observations in the present study and the results of other researchers, the effect of vermicompost on the activity of antioxidant enzymes is different in different plants. As Chakrabarti and Mukharji [91] reported, the activity of CAT and peroxidase enzymes increased in *Vigna radiate* under salt stress, but the external application of gibberellin decreased the CAT activity in saline conditions. It can, therefore, be claimed that, owing to its physicochemical and biological properties, especially the existence of gibberellin, vermicompost improves the plant growth environment, where the probable lower production of ROS lowers the CAT activity.

3.10. Phosphate, Nitrate, Zinc, Molybdenum, Magnesium, Iron, Sodium, Potassium, and Calcium

According to the data analysis of variance, salinity stress, vermicompost, and their interaction had a significant effect on the amount of phosphate, nitrate, and mineral elements (Tables 7 and 9). In this study, salinity stress significantly decreased the phosphate, nitrate, zinc, molybdenum, magnesium, and iron contents in the shoots of the fennel landraces of Urmia and Shiraz. Additionally, vermicompost alone and its interaction with salt stress significantly increased the amounts of these elements in the shoots of the fennel plants. Vermicompost treatment in 40 mM NaCl caused increased amounts of phosphate (by 22.8% and 24.6% in the Urmia and Shiraz fennels), nitrate (Urmia, 10.3%; Shiraz, 15.8%), zinc (Urmia, 12.6%; Shiraz, 20.1%), molybdenum (Urmia, 26%; Shiraz, 68.3%), magnesium (Urmia, 13.7%; Shiraz, 26.6%), and iron (Urmia, 70.9%; Shiraz, 40.4%). It also induced an increase in phosphate (Urmia, 32.1%; Shiraz, 56.6%), nitrate (Urmia, 14.6%; Shiraz, 17.9%), zinc (Urmia, 20.9%; Shiraz, 74.2%), molybdenum (Urmia, 21.8%; Shiraz, 58.8%), magnesium

(Urmia, 26%; Shiraz, 25.8%), and iron (Urmia, 59.6%; Shiraz, 40%) under 80 mM NaCl, compared to the control group (Table 8, Figure 3).

Table 9. Analysis of variance of some elements of two fennel landraces.

Sources of Variation	Degrees of Freedom	Shoot Zn (mg kg $^{-1}$ DW)	Shoot Mo (mg kg $^{-1}$ DW)	Shoot Mg (mg kg $^{-1}$ DW)	Shoot Fe (mg kg^{-1} DW)	Shoot Na (%)	Shoot K (%)	Shoot Ca (%)	Root Na (%)	Root K (%)	Root Ca (%)
Landrace	1	** 1855.312	** 2983.709	** 154,291.9	** 2817.84	** 0.902	** 5.112	** 0.481	** 9.879	** 5.951	* 0.026
Salinity	2	** 4371.429	** 7150.278	** 1,494,829	** 197,377.1	** 64.375	** 37.022	** 2.105	** 37.016	** 8.431	** 1.192
Landrace × salinity	2	** 105.022	** 70.817	** 20,567.36	** 129.722	** 3.629	** 0.814	ns 0.019	** 2.664	** 0.664	ns 0.008
Vermicompost	1	** 3034.541	** 7652.167	** 262,280.5	** 87,428.64	** 9.203	** 18.855	** 0.968	** 8.754	** 5.179	** 1.839
Landrace × vermicompost	1	** 189.521	** 121.073	** 5241.762	** 624.167	ns 0.289	** 0.86	ns 0.0001	ns 0.017	** 0.661	ns 0.001
Salinity × vermicompost	2	** 564.889	** 1173.674	** 1742.007	** 6346.17	* 0.358	** 0.836	* 0.033	ns 0.175	* 0.135	** 0.08
Landrace × salinity × vermicompost	2	** 22.474	** 350.342	** 4749.172	** 223.214	* 0.49	** 0.702	** 0.052	* 0.283	* 0.113	* 0.003
Error	22	0.344	0.863	295.864	9.732	0.088	0.072	0.006	0.146	0.031	0.004

ns: non-significant; * and **: significant at $\alpha = 0.05$ and $\alpha = 0.01$, respectively.

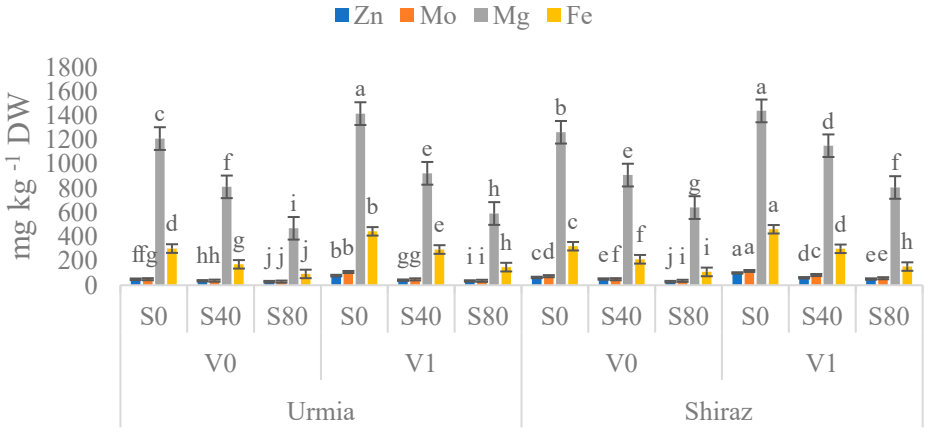

Figure 3. Mean comparison of the effects of vermicompost and salinity stress interaction on some elements in the shoots of the two fennel landraces. In each column, the averages that have at least one letter in common are not significantly different according to Duncan's multiple-range test ($p \leq 0.05$). (S0: control; S40: 40 mM NaCl; S80: 80 mM NaCl; V0: without vermicompost; V1: with 5% vermicompost; DW: dry weight).

Salinity stress caused a significant increase in the amount of sodium and a significant decrease in the potassium and calcium of the shoots and roots of both fennel landraces. With vermicompost alone, the sodium concentration in the roots of the Urmia landrace and the shoots of both landraces decreased significantly. Potassium and calcium concentrations also increased considerably in the shoots of both landraces. With the use of vermicompost under saline conditions, the sodium concentration decreased significantly in the shoots and roots of the fennel landrace of Shiraz at the levels of 40 (shoot, 10.6%; root, 21.5%) and 80 mM NaCl (shoot, 7%; root, 16.4%) and in the fennel landrace of Urmia at 80 mM NaCl (shoot, 12.7%; root, 12.1%). Moreover, with the interaction of salinity and vermicompost, the potassium and calcium concentrations considerably increased in the shoots and roots. With the application of vermicompost and 40 mM NaCl salinity, potassium increased in the shoot and root of the Urmia landrace by 26.3% and 19.2%, respectively, and by 25.25% and 46% in the landrace of Shiraz. The amount of calcium in the shoot and root increased by 56 and 71% in the Urmia landrace and by 65.6 and 75.7% in the Shiraz landrace. Under a salinity of 80 mM NaCl, with the use of vermicompost, the amount of potassium in the roots of both the Urmia and Shiraz landraces increased by about 28%, while it increased in the shoot of the Shiraz landrace by 20.67% (Figure 4).

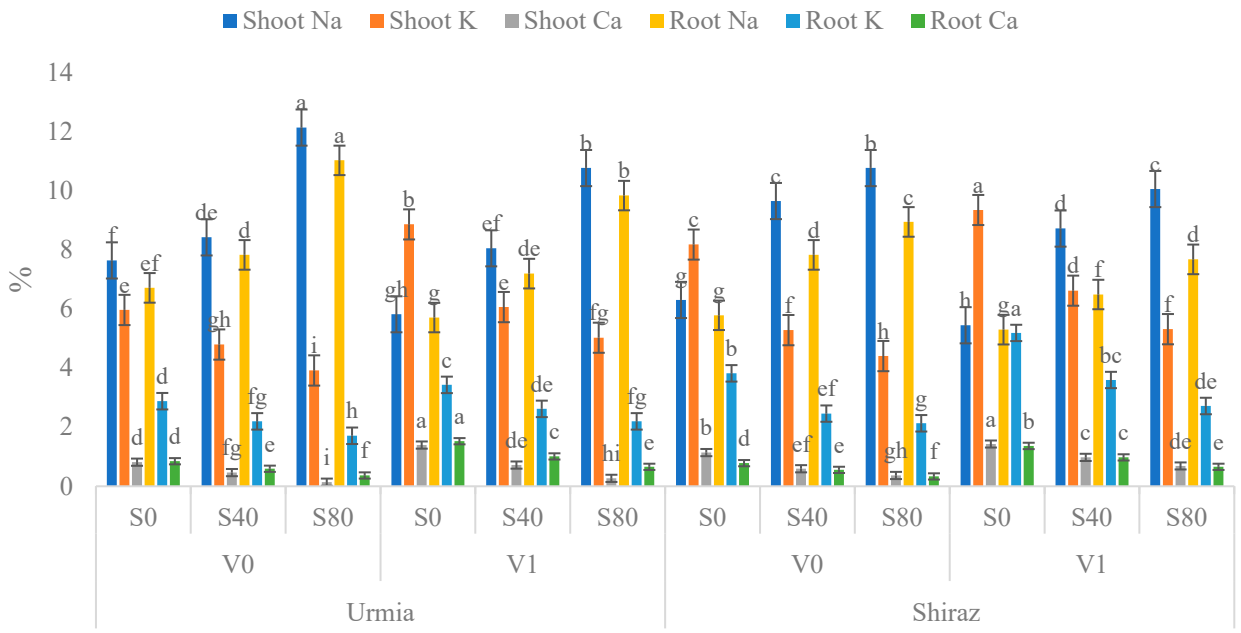

Figure 4. Mean comparison of the effects of vermicompost and salinity stress interaction on the concentration of sodium, potassium, and calcium in the shoots and roots of the two fennel landraces. In each column, the averages that have at least one letter in common are not significantly different according to Duncan's multiple-range test ($p \leq 0.05$). (S0: control, S40: 40 mM NaCl, S80: 80 mM NaCl, V0: without vermicompost, V1: with 5% vermicompost).

The increased absorption and accumulation of sodium and chloride ions cause a decrease in the absorption of essential elements [92]. There are reports on the role of salinity stress in decreasing the concentrations of magnesium [44] and potassium [26] in fennel; the concentrations of iron, magnesium, phosphorus, and nitrogen in chickpea [93]; zinc concentrations in wheat [94]; and calcium and magnesium concentrations in spinach [95].

According to the results, under saline conditions, the vermicompost treatment decreased sodium but increased the other elements in the fennel landraces. In this regard, Abou El-Magd et al. [43] reported that an organic fertilizer increased the amount of nitrogen, phosphorus, and potassium in fennel but decreased the amount of sodium in this plant. Bachman and Metzger [96] reported that vermicompost increased the supply of nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium, which led to improved plant growth. While salinity stress affected nitrate absorption due to the competition of chloride and nitrate and the change in the plasma membrane, the use of vermicompost under salinity increased the amount of nitrate in sunflowers [97]. Salt stress inhibits ammonium assimilation [98], but the use of vermicompost increases the activity of nitrate reductase, nitrite reductase, glutamine synthetase, and glutamate synthase when exposed to salinity [97]. In a study by Beyk Khormizi et al. [22], salt stress reduced the potassium and calcium in the leaves and roots of beans and increased sodium in these organs. With the use of vermicompost, however, the potassium and calcium contents of the leaves and roots increased while sodium decreased. The researchers attributed this issue to abundant nutrients; plant hormones such as cytokinin, which can increase potassium absorption; and the high water-storing capacity of vermicompost.

4. Conclusions

According to the results, salinity stress decreased chlorophylls, carotenoids, soluble proteins, carbohydrates, relative water content, membrane stability index, and essential macro and microelements. However, it increased sodium, proline, phenolic compounds, and CAT activity, resulting in a decrease in the growth in both Urmia and Shiraz fennel landraces. In this context, vermicompost was found to improve plant growth. Of the two

landraces, Urmia plants were more evidently affected by salinity and vermicompost. It can be concluded that the use of 5% vermicompost improves plant growth conditions, such as the availability of water and essential minerals, and positively affects the amount of photosynthetic pigments, enzymatic and non-enzymatic antioxidants, mineral elements, and osmotic compounds while limiting the adverse effects of salt stress on the growth of fennel. Salinity stress increases the production of ROS, which causes damage to other biomolecules, such as proteins, lipids, and pigments, and generally changes plant metabolism, which results in reduced growth. It was demonstrated in this research that vermicompost application leads to reduced oxidative damage, so plant metabolism was adjusted to reduce the side effect of salinity on plant growth.

Author Contributions: Conceptualization, A.B.-K., M.R.S.-A., S.H.S., S.M.M. and S.M.M.-K.; methodology, A.B.-K., M.R.S.-A., S.M.M., S.H.S. and S.M.M.-K.; software, A.B.-K., M.R.S.-A., S.H.S. and S.M.M.-K.; investigation, A.B.-K., M.R.S.-A., S.H.S. and S.M.M.-K.; writing—original draft preparation, A.B.-K., M.R.S.-A. and M.E.T.Y.; writing—review and editing, M.R.S.-A. and M.E.T.Y.; supervision, M.R.S.-A. and M.E.T.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Urmia University (grant number A2/1189).

Data Availability Statement: The authors declare that the data supporting the findings of this study are available within the article.

Acknowledgments: The authors thank Urmia University and Yazd University for their helpful support.

Conflicts of Interest: The authors declare no conflict of interest regarding this research.

References

1. Badgujar, S.B.; Patel, V.V.; Bandivdekar, A.H. Foeniculum vulgare Mill: A review of its botany, phytochemistry, pharmacology, contemporary application, and toxicology. *BioMed Res. Int.* **2014**, *2014*, 842674. [CrossRef]
2. Amiri, M.S.; Yazdi, M.E.T.; Rahnama, M. Medicinal plants and phytotherapy in Iran: Glorious history, current status and future prospects. *Plant Sci. Today* **2021**, *8*, 95–111. [CrossRef]
3. Amiri, M.S.; Joharchi, M.R. Ethnobotanical knowledge of Apiaceae family in Iran: A review. *Avicenna J. Phytomedicine* **2016**, *6*, 621.
4. Mehrnia, M.; Akaberi, M.; Amiri, M.; Nadaf, M.; Emami, S. Ethnopharmacological studies of medicinal plants in central Zagros, Lorestan Province, Iran. *J. Ethnopharmacol.* **2021**, *280*, 114080. [CrossRef]
5. Emami, S.; Nadjafi, F.; Amine, G.; Amiri, M.; Khosravi Mt, N.M. Les espèces de plantes médicinales utilisées par les guérisseurs traditionnels dans la province de Khorasan, nord-est de l'Iran. *J. Ethnopharmacol.* **2012**, *48*, 48–59.
6. Mohammadi, M.; Pouryousef, M.; Farhang, N. Study on germination and seedling growth of various ecotypes of fennel (*Foeniculum vulgare* Mill.) under salinity stress. *J. Appl. Res. Med. Aromat. Plants* **2023**, *34*, 100481. [CrossRef]
7. Faisal, M.; Faizan, M.; Tonny, S.H.; Rajput, V.D.; Minkina, T.; Alatar, A.A.; Pathirana, R. Strigolactone-Mediated Mitigation of Negative Effects of Salinity Stress in Solanum lycopersicum through Reducing the Oxidative Damage. *Sustainability* **2023**, *15*, 5805. [CrossRef]
8. Bahmani, K.; Darbandi, A.I.; Ramshini, H.A.; Moradi, N.; Akbari, A. Agro-morphological and phytochemical diversity of various Iranian fennel landraces. *Ind. Crops Prod.* **2015**, *77*, 282–294. [CrossRef]
9. Hafsi, C.; Lakhdhar, A.; Rabhi, M.; Debez, A.; Abdelly, C.; Ouerghi, Z. Interactive effects of salinity and potassium availability on growth, water status, and ionic composition of Hordeum maritimum. *J. Plant Nutr. Soil Sci.* **2007**, *170*, 469–473. [CrossRef]
10. Kumar, J.; Singh, S.; Singh, M.; Srivastava, P.K.; Mishra, R.K.; Singh, V.P.; Prasad, S.M. Transcriptional regulation of salinity stress in plants: A short review. *Plant Gene* **2017**, *11*, 160–169. [CrossRef]
11. Es-sbihi, F.Z.; Hazzoumi, Z.; Aasfar, A.; Amrani Joutei, K. Improving salinity tolerance in Salvia officinalis L. by foliar application of salicylic acid. *Chem. Biol. Technol. Agric.* **2021**, *8*, 25. [CrossRef]
12. Shamili, M.; Esfandiari Ghalati, R.; Samari, F. The impact of foliar salicylic acid in salt-exposed guava (*Psidium Guajava* L.) seedlings. *Int. J. Fruit Sci.* **2021**, *21*, 323–333. [CrossRef]
13. Nadaf, M.; Amiri, M.S.; Joharchi, M.R.; Omidipour, R.; Moazezi, M.; Mohaddesi, B.; Taghavizadeh Yazdi, M.E.; Mottaghipisheh, J. Ethnobotanical Diversity of Trees and Shrubs of Iran: A Comprehensive Review. *Int. J. Plant Biol.* **2023**, *14*, 120–146. [CrossRef]
14. Nadaf, M.; Halimi Khalil Abad, M.; Gholami, A.; Taghavizadeh Yazdi, M.E.; Iriti, M.; Mottaghipisheh, J. Phenolic content and antioxidant activity of different Iranian populations of *Anabasis aphylla* L. *Nat. Prod. Res.* **2022**, 1–5. [CrossRef]
15. Gholami, H.; Saharkhiz, M.J.; Fard, F.R.; Ghani, A.; Nadaf, F. Humic acid and vermicompost increased bioactive components, antioxidant activity and herb yield of Chicory (*Cichorium intybus* L.). *Biocatal. Agric. Biotechnol.* **2018**, *14*, 286–292. [CrossRef]

16. Joshi, R.; Singh, J.; Vig, A.P. Vermicompost as an effective organic fertilizer and biocontrol agent: Effect on growth, yield and quality of plants. *Rev. Environ. Sci. Bio. Technol.* **2015**, *14*, 137–159. [CrossRef]
17. Chatterjee, D.; Dutta, S.K.; Kikon, Z.J.; Kuotsu, R.; Sarkar, D.; Satapathy, B.; Deka, B.C. Recycling of agricultural wastes to vermicomposts: Characterization and application for clean and quality production of green bell pepper (*Capsicum annuum* L.). *J. Clean. Prod.* **2021**, *315*, 128115. [CrossRef]
18. Gupta, C.; Prakash, D.; Gupta, S.; Nazareno, M.A. Role of vermicomposting in agricultural waste management. In *Sustainable Green Technologies for Environmental Management*; Springer: Berlin/Heidelberg, Germany, 2019; pp. 283–295.
19. Celikcan, F.; Kocak, M.Z.; Kulak, M. Vermicompost applications on growth, nutrition uptake and secondary metabolites of *Ocimum basilicum* L. under water stress: A comprehensive analysis. *Ind. Crops Prod.* **2021**, *171*, 113973. [CrossRef]
20. Mousavi Kouhi, S.M.; Sarafraz Ardakani, M.R.; Beykkhormizi, A. Irrigation of Helianthus annuus with Pb-polluted water: Improvement of phytoremediation using vermicompost. *J. Plant Process Funct.* **2019**, *8*, 77–83.
21. Bidabadi, S.S.; Dehghanipoodeh, S.; Wright, G.C. Vermicompost leachate reduces some negative effects of salt stress in pomegranate. *Int. J. Recycl. Org. Waste Agric.* **2017**, *6*, 255–263. [CrossRef]
22. Beykkhormizi, A.; Abrishamchi, P.; Ganjeali, A.; Parsa, M. Effect of vermicompost on some morphological, physiological and biochemical traits of bean (*Phaseolus vulgaris* L.) under salinity stress. *J. Plant Nutr.* **2016**, *39*, 883–893. [CrossRef]
23. Liu, M.; Wang, C.; Liu, X.; Lu, Y.; Wang, Y. Saline-alkali soil applied with vermicompost and humic acid fertilizer improved macroaggregate microstructure to enhance salt leaching and inhibit nitrogen losses. *Appl. Soil Ecol.* **2020**, *156*, 103705. [CrossRef]
24. Feizi, H.; Moradi, R.; Pourghasemian, N.; Sahabi, H. Assessing saffron response to salinity stress and alleviating potential of gamma amino butyric acid, salicylic acid and vermicompost extract on salt damage. *S. Afr. J. Bot.* **2021**, *141*, 330–343. [CrossRef]
25. Beyk-Khormizi, A.; Hosseini Sarghein, S.; Sarafraz-Ardakani, M.R.; Moshtaghioun, S.M.; Mousavi-Kouhi, S.M.; Ganjeali, A. Ameliorating effect of vermicompost on Foeniculum vulgare under saline condition. *J. Plant Nutr.* **2022**, *46*, 1601–1615. [CrossRef]
26. Beykkhormizi, A.; Sarghein, S.H.; Sarafraz Ardakani, M.R.; Moshtaghioun, S.M.; Mousavi Kouhi, S.M. Alleviation of salinity stress by vermicompost extract: A comparative study on five fennel landraces. *Commun. Soil Sci. Plant Anal.* **2018**, *49*, 2123–2130. [CrossRef]
27. Lichtenthaler, H.K. Chlorophylls and carotenoids: Pigments of photosynthetic biomembranes. In *Methods in Enzymology*; Elsevier: Amsterdam, The Netherlands, 1987; pp. 350–382.
28. Heath, R.L.; Packer, L. Photoperoxidation in isolated chloroplasts: I. Kinetics and stoichiometry of fatty acid peroxidation. *Arch. Biochem. Biophys.* **1968**, *125*, 189–198. [CrossRef]
29. Meir, S.; Philosoph-Hadas, S.; Aharoni, N. Ethylene-increased accumulation of fluorescent lipid-peroxidation products detected during senescence of parsley by a newly developed method. *J. Am. Soc. Hortic. Sci.* **1992**, *117*, 128–132. [CrossRef]
30. Sairam, R.; Saxena, D. Oxidative stress and antioxidants in wheat genotypes: Possible mechanism of water stress tolerance. *J. Agron. Crop. Sci.* **2000**, *184*, 55–61. [CrossRef]
31. Bian, S.; Jiang, Y. Reactive oxygen species, antioxidant enzyme activities and gene expression patterns in leaves and roots of Kentucky bluegrass in response to drought stress and recovery. *Sci. Hortic.* **2009**, *120*, 264–270. [CrossRef]
32. Bates, L.; Waldren, R.; Teare, I. Rapid determination of free proline for water-stress studies. *Plant Soil* **1973**, *39*, 205–207. [CrossRef]
33. Yazdi, T.; Ehsan, M.; Housaindokht, M.R.; Sadeghnia, H.R.; Esmaeilzadeh Bahabadi, S.; Amiri, M.S.; Darroudi, M. Assessment of phytochemical components and antioxidant activity of Rheum turkestanicum Janisch. *Stud. Med. Sci.* **2020**, *31*, 75–81.
34. Chang, C.-C.; Yang, M.-H.; Wen, H.-M.; Chern, J.-C. Estimation of total flavonoid content in propolis by two complementary colorimetric methods. *J. Food Drug Anal.* **2002**, *10*, 3. [CrossRef]
35. Wagner, G.J. Content and vacuole/extravacuole distribution of neutral sugars, free amino acids, and anthocyanin in protoplasts. *Plant Physiol.* **1979**, *64*, 88–93. [CrossRef] [PubMed]
36. Bradford, M.M. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal. Biochem.* **1976**, *72*, 248–254. [CrossRef] [PubMed]
37. Hugo, A.; Lester, P. Catalase in vitro. *Methods Enzym.* **1984**, *105*, 121–126.
38. Bergmeyer, H. Determination with glucose oxidase and peroxidase. *Methods Enzym. Anal.* **1974**, 1205–1215.
39. Minocha, R.; Shortle, W.C.; Long, S.L.; Minocha, S.C. A rapid and reliable procedure for extraction of cellular polyamines and inorganic ions from plant tissues. *J. Plant Growth Regul.* **1994**, *13*, 187–193. [CrossRef]
40. Xiong, Z.-T.; Liu, C.; Geng, B. Phytotoxic effects of copper on nitrogen metabolism and plant growth in Brassica pekinensis Rupr. *Ecotoxicol. Environ. Saf.* **2006**, *64*, 273–280. [CrossRef]
41. Walsh, L.M.; Douglas, L.A. Instrumental methods for analysis of soils and plant tissue. *Soil Sci.* **1972**, *114*, 500. [CrossRef]
42. Chapman, H.; Pratt, P. *Methods of Plant Analysis. I. Methods of Analysis for Soils, Plants and Wate*; Chapman Publishers: Riverside, CA, USA, 1982.
43. El-Magd, A.; Zaki, M.; Abou-Hussein, S. Effect of organic manure and different levels of saline irrigation water on growth, green yield and chemical content of sweet fennel. *Aust. J. Basic Appl. Sci.* **2008**, *2*, 90–98.
44. SEMİZ, G.; Ünlükara, A.; Yurtseven, E.; Suarez, D.; Telci, I. Salinity impact on yield, water use, mineral and essential oil content of fennel (*Foeniculum vulgare* Mill.). *J. Agric. Sci.* **2012**, *18*, 177–186.
45. Cucci, G.; Lacolla, G.; Boari, F.; Cantore, V. Yield response of fennel (*Foeniculum vulgare* Mill.) to irrigation with saline water. *Acta Agric. Scand. Sect. B Soil Plant Sci.* **2014**, *64*, 129–134.

46. Kiran, S. Effects of vermicompost on some morphological, physiological and biochemical parameters of lettuce (*Lactuca sativa* var. crispa) under drought stress. *Not. Bot. Horti Agrobot.* **2019**, *47*, 352–358. [CrossRef]
47. Arancon, N.Q.; Edwards, C.A.; Babenko, A.; Cannon, J.; Galvis, P.; Metzger, J.D. Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. *Appl. Soil Ecol.* **2008**, *39*, 91–99. [CrossRef]
48. Xu, L.; Yan, D.; Ren, X.; Wei, Y.; Zhou, J.; Zhao, H.; Liang, M. Vermicompost improves the physiological and biochemical responses of blessed thistle (Silybum marianum Gaertn.) and peppermint (Mentha haplocalyx Briq) to salinity stress. *Ind. Crops Prod.* **2016**, *94*, 574–585. [CrossRef]
49. Banakar, M.H.; Amiri, H.; Ardakani, M.R.S.; Ranjbar, G.H. Susceptibility and tolerance of fenugreek (*Trigonella foenum-graceum* L.) to salt stress: Physiological and biochemical inspections. *Environ. Exp. Bot.* **2022**, *194*, 104748. [CrossRef]
50. Grzeszczuk, M.; Salachna, P.; Meller, E. Changes in photosynthetic pigments, total phenolic content, and antioxidant activity of Salvia coccinea Buc'hoz Ex Etl. induced by exogenous salicylic acid and soil salinity. *Molecules* **2018**, *23*, 1296. [CrossRef]
51. Ramírez, D.; Yactayo, W.; Gutiérrez, R.; Mares, V.; De Mendiburu, F.; Posadas, A.; Quiroz, R. Chlorophyll concentration in leaves is an indicator of potato tuber yield in water-shortage conditions. *Sci. Hortic.* **2014**, *168*, 202–209. [CrossRef]
52. Muhammad, A.; Muhammad, Q.; Rafiq, A. Effect of sea salt irrigation on plant growth, yield potential and some biochemical attributes of Carissa carandas. *Pak. J. Bot.* **2016**, *48*, 853–859.
53. Orabi, S.; Salman, S.; Shalaby, M.A. Increasing resistance to oxidative damage in cucumber (*Cucumis sativus* L.) plants by exogenous application of salicylic acid and paclobutrazol. *World J. Agric. Sci.* **2010**, *6*, 252–259.
54. Bybordi, A.; Tabatabaei, S.J.; Ahmadev, A. Effect of salinity on the growth and peroxidase and IAA oxidase activities in canola. *J. Food Agric. Env.* **2010**, *8*, 109–112.
55. Amiri, H.; Ismaili, A.; Hosseinzadeh, S.R. Influence of vermicompost fertilizer and water deficit stress on morpho-physiological features of chickpea (*Cicer arietinum* L. cv. karaj). *Compos. Sci. Util.* **2017**, *25*, 152–165. [CrossRef]
56. Hosseinzadeh, S.; Amiri, H.; Ismaili, A. Effect of vermicompost fertilizer on photosynthetic characteristics of chickpea (*Cicer arietinum* L.) under drought stress. *Photosynthetica* **2016**, *54*, 87–92. [CrossRef]
57. Atik, A. Effects of planting density and treatment with vermicompost on the morphological characteristics of oriental beech (Fagus orientalis Lipsky.). *Compos. Sci. Util.* **2013**, *21*, 87–98. [CrossRef]
58. Ebrahimi, M.; Khajehpour, M.; Naderi, A.; Nassiri, B.M. Physiological responses of sunflower to water stress under different levels of zinc fertilizer. *Int. J. Plant Prod.* **2014**, *8*, 483–504.
59. Farooq, S.; Azam, F. The use of cell membrane stability (CMS) technique to screen for salt tolerant wheat varieties. *J. Plant Physiol.* **2006**, *163*, 629–637. [CrossRef]
60. Bandeoğlu, E.; Eyidoğan, F.; Yücel, M.; Avni Öktem, H. Antioxidant responses of shoots and roots of lentil to NaCl-salinity stress. *Plant Growth Regul.* **2004**, *42*, 69–77. [CrossRef]
61. Daneshbakhsh, B.; Khoshgoftarmanesh, A.H.; Shariatmadari, H.; Cakmak, I. Effect of zinc nutrition on salinity-induced oxidative damages in wheat genotypes differing in zinc deficiency tolerance. *Acta Physiol. Plant.* **2013**, *35*, 881–889. [CrossRef]
62. Sanaeiostovar, A.; Khoshgoftarmanesh, A.H.; Shariatmadari, H.; Afyuni, M.; Schulin, R. Combined effect of zinc and cadmium levels on root antioxidative responses in three different zinc-efficient wheat genotypes. *J. Agron. Crop. Sci.* **2012**, *198*, 276–285. [CrossRef]
63. Colom, M.; Vazzana, C. Photosynthesis and PSII functionality of drought-resistant and drought-sensitive weeping lovegrass plants. *Environ. Exp. Bot.* **2003**, *49*, 135–144. [CrossRef]
64. Ahmad, R.; Jabeen, N. Demonstration of growth improvement in sunflower (*Helianthus annuus* L.) by the use of organic fertilizers under saline conditions. *Pak. J. Bot.* **2009**, *41*, 1373–1384.
65. Dejampour, J.; Aliasgarzad, N.; Zeinalabedini, M.; Niya, M.R.; Hervan, E.M. Evaluation of salt tolerance in almond [*Prunus dulcis* (L.) Batsch] rootstocks. *Afr. J. Biotechnol.* **2012**, *11*, 11907–11912.
66. Rahman, R.A.; Gomaa, S.E.; Abdelsalam, N.R.; El-Wakil, H.; Khaled, A.; Hassan, H. Effect of Sodium Chloride on Tropane Alkaloids Accumulation and Proline content in Datura metel and D. stramonium callus cultures. *Int. J. Adv. Biol. Biomed. Res.* **2013**, *1*, 197–210.
67. Ali, A.; Salim, M.; Ahmad, I.; Mahmood, I. Nutritional role of calcium on the growth of Brassica napus under salineconditions. *Pak. J. Agric. Sci.* **2003**, 40.
68. Cha-Um, S.; Charoenpanich, A.; Roytrakul, S.; Kirdmanee, C. Sugar accumulation, photosynthesis and growth of two indica rice varieties in response to salt stress. *Acta Physiol. Plant.* **2009**, *31*, 477–486. [CrossRef]
69. Kanai, M.; Higuchi, K.; Hagihara, T.; Konishi, T.; Ishii, T.; Fujita, N.; Nakamura, Y.; Maeda, Y.; Yoshiba, M.; Tadano, T. Common reed produces starch granules at the shoot base in response to salt stress. *New Phytol.* **2007**, *176*, 572–580. [CrossRef] [PubMed]
70. Bartels, D.; Sunkar, R. Drought and salt tolerance in plants. *Crit. Rev. Plant Sci.* **2005**, *24*, 23–58. [CrossRef]
71. Mousavi, A.; Lessani, H.; Babalar, M.; Talaei, A.; Fallahi, E. Influence of salinity on chlorophyll, leaf water potential, total soluble sugars, and mineral nutrients in two young olive cultivars. *J. Plant Nutr.* **2008**, *31*, 1906–1916. [CrossRef]
72. Ashok, P.; Carlos, R.; Christian, L. *Current Developments in Solid-State Fermentation*; Asiatech Publishers, Inc.: New Delhi, India, 2008; 517p.
73. Vogt, T. Phenylpropanoid biosynthesis. *Mol. Plant* **2010**, *3*, 2–20. [CrossRef]

74. Pennycooke, J.C.; Cox, S.; Stushnoff, C. Relationship of cold acclimation, total phenolic content and antioxidant capacity with chilling tolerance in petunia (Petunia× hybrida). *Environ. Exp. Bot.* **2005**, *53*, 225–232. [CrossRef]
75. Rezazadeh, A.; Ghasemnezhad, A.; Barani, M.; Telmadarrehei, T. Effect of salinity on phenolic composition and antioxidant activity of artichoke (*Cynara scolymus* L.) leaves. *Res. J. Med. Plant* **2012**, *6*, 245–252. [CrossRef]
76. Bourgou, S.; Kchouk, M.; Bellila, A.; Marzouk, B. Effect of salinity on phenolic composition and biological activity of Nigella sativa. In *International Symposium on Medicinal and Aromatic Plants-SIPAM2009 853*; International Society for Horticultural Science: Leuven, Belgium, 2009.
77. Ahmed, N.; Maekawa, M.; Noda, K. Anthocyanin accumulation and expression pattern of anthocyanin biosynthesis genes in developing wheat coleoptiles. *Biol. Plant.* **2009**, *53*, 223–228. [CrossRef]
78. Wang, S.Y.; Lin, H.-S. Compost as a soil supplement increases the level of antioxidant compounds and oxygen radical absorbance capacity in strawberries. *J. Agric. Food Chem.* **2003**, *51*, 6844–6850. [CrossRef]
79. Connor, A.M.; Luby, J.J.; Tong, C.B.; Finn, C.E.; Hancock, J.F. Genotypic and environmental variation in antioxidant activity, total phenolic content, and anthocyanin content among blueberry cultivars. *J. Am. Soc. Hortic. Sci.* **2002**, *127*, 89–97. [CrossRef]
80. Suthar, S. Impact of Vermicompost and Composted Farmyard Manure on Growth and Yield of Garlic (Allium stivum L.) Field Crop. *Int. J. Plant Prod.* **2009**.
81. Pollastri, S.; Tattini, M. Flavonols: Old compounds for old roles. *Ann. Bot.* **2011**, *108*, 1225–1233. [CrossRef]
82. Manaa, A.; Mimouni, H.; Wasti, S.; Gharbi, E.; Aschi-Smiti, S.; Faurobert, M.; Ahmed, H.B. Comparative proteomic analysis of tomato (Solanum lycopersicum) leaves under salinity stress. *Plant Omics* **2013**, *6*, 268–277.
83. Molassiotis, A.; Sotiropoulos, T.; Tanou, G.; Diamantidis, G.; Therios, I. Boron-induced oxidative damage and antioxidant and nucleolytic responses in shoot tips culture of the apple rootstock EM 9 (Malus domestica Borkh). *Environ. Exp. Bot.* **2006**, *56*, 54–62. [CrossRef]
84. Khan, M.N.; Siddiqui, M.H.; Mohammad, F.; Khan, M.; Naeem, M. Salinity induced changes in growth, enzyme activities, photosynthesis, proline accumulation and yield in linseed genotypes. *World J Agric Sci* **2007**, *3*, 685–695.
85. Salama, Z.A.; El-Fouly, M.M.; Lazova, G.; Popova, L.P. Carboxylating enzymes and carbonic anhydrase functions were suppressed by zinc deficiency in maize and chickpea plants. *Acta Physiol. Plant.* **2006**, *28*, 445–451. [CrossRef]
86. Carrasco-Ríos, L.; Pinto, M. Effect of salt stress on antioxidant enzymes and lipid peroxidation in leaves in two contrasting corn, 'Lluteno' and 'Jubilee'. *Chil. J. Agric. Res.* **2014**, *74*, 89–95. [CrossRef]
87. Esfandiari, E.; Shekari, F.; Shekari, F.; Esfandiari, M. The effect of salt stress on antioxidant enzymes'activity and lipid peroxidation on the wheat seedling. *Not. Bot. Horti Agrobot.* **2007**, *35*, 48.
88. Sorkheh, K.; Shiran, B.; Rouhi, V.; Khodambashi, M.; Sofo, A. Salt stress induction of some key antioxidant enzymes and metabolites in eight Iranian wild almond species. *Acta Physiol. Plant.* **2012**, *34*, 203–213. [CrossRef]
89. Eraslan, F.; Inal, A.; Savasturk, O.; Gunes, A. Changes in antioxidative system and membrane damage of lettuce in response to salinity and boron toxicity. *Sci. Hortic.* **2007**, *114*, 5–10. [CrossRef]
90. Hosseinzadeh, S.R.; Amiri, H.; Ismaili, A. Nutrition and biochemical responses of chickpea (*Cicer arietinum* L.) to vermicompost fertilizer and water deficit stress. *J. Plant Nutr.* **2017**, *40*, 2259–2268. [CrossRef]
91. Chakrabarti, N.; Mukherji, S. Alleviation of NaCl stress by pretreatment with phytohormones in Vigna radiata. *Biol. Plant.* **2003**, *46*, 589–594. [CrossRef]
92. Tester, M.; Davenport, R. Sodium tolerance sodium transport in higher plants. *Ann. Bot.* **2003**, *91*, 503–527. [CrossRef] [PubMed]
93. Nenova, V. Growth and mineral concentrations of pea plants under different salinity levels and iron supply. *Gen Appl Plant Physiol* **2008**, *34*, 189–202.
94. Khoshgoftarmanesh, A.; Shariatmadari, H.; Karimian, N.; Kalbasi, M.; Khajehpour, M. Zinc efficiency of wheat cultivars grown on a saline calcareous soil. *J. Plant Nutr.* **2005**, *27*, 1953–1962. [CrossRef]
95. Yousif, B.S.; Nguyen, N.T.; Fukuda, Y.; Hakata, H.; Okamoto, Y.; Masaoka, Y.; Saneoka, H. Effect of salinity on growth, mineral composition, photosynthesis and water relations of two vegetable crops; New Zealand spinach (Tetragonia tetragonioides) and water spinach (Ipomoea aquatica). *Int. J. Agric. Biol.* **2010**, *12*, 211–216.
96. Bachman, G.; Metzger, J. Growth of bedding plants in commercial potting substrate amended with vermicompost. *Bioresour. Technol.* **2008**, *99*, 3155–3161. [CrossRef] [PubMed]
97. Jabeen, N.; Ahmad, R. Foliar application of potassium nitrate affects the growth and nitrate reductase activity in sunflower and safflower leaves under salinity. *Not. Bot. Horti Agrobot.* **2011**, *39*, 172–178. [CrossRef]
98. Debouba, M.; Maâroufi-Dghimi, H.; Suzuki, A.; Ghorbel, M.H.; Gouia, H. Changes in growth and activity of enzymes involved in nitrate reduction and ammonium assimilation in tomato seedlings in response to NaCl stress. *Ann. Bot.* **2007**, *99*, 1143–1151. [CrossRef] [PubMed]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.