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KNO_3, Nano-Zn, and Fe Foliar Application Influence the Growth and Physiological Responses of *Aloe vera* under Salinity

Asghar Ebrahimzadeh [1], Soraya Ghorbanzadeh [1], Lamia Vojodi Mehrabani [2], Erika Sabella [3,*], Luigi De Bellis [3] and Mohammad Bagher Hassanpouraghdam [1,*]

[1] Department of Horticultural Science, Faculty of Agriculture, University of Maragheh, Maragheh 55181-83111, Iran
[2] Department of Agronomy and Plant Breeding, Faculty of Agriculture, Azarbaijan Shahid Madani University, Tabriz 53751-71379, Iran
[3] Department of Biological and Environmental Sciences and Technologies, University of Salento, Piazza Tancredi, 7, 73100 Lecce, Italy
* Correspondence: erika.sabella@unisalento.it (E.S.); hassanpouraghdam@gmail.com (M.B.H.)

Abstract: *Aloe vera* L. is a perennial drought-tolerant plant that is commonly used in the pharmaceutical, food, and cosmetic industries. To evaluate the effects of the foliar application of KNO_3, nano-Zn, and Fe (0 and 2 mgL^{-1}) on *Aloe vera* plants under NaCl salinity stress (0, 50, 100 mM), a factorial experiment was conducted based on a completely randomized design. The results revealed that foliar applications influenced the root dry weight. The chlorophyll b content was affected by the salinity plus the foliar application. The total soluble solids content, chlorophyll a, phenolics, and flavonoids of the leaves, the gel content, catalase and superoxide dismutase activity, malondialdehyde, proline, and mineral nutrients content were impacted by the treatments as well. The highest values for the gel content (0.37 g per leaf) and plant dry weight (13.1 g per pot) were recorded at 0 mM NaCl + KNO_3 + nano-Fe. The top K/Na ratio (35.2), and the largest K (69 g kg^{-1}), P (6.6 g kg^{-1}), Ca (31 g kg^{-1}), and Mg (2.5 g kg^{-1}) contents were recorded after the 0 mM NaCl + KNO_3 treatment. The highest Fe content (383 g kg^{-1}) was observed with 0 mM NaCl + nano-Fe treatment, and the maximum Zn content (37.6 mg kg^{-1}) was measured after the 0 mM NaCl + nano Zn treatment. One hundred mM NaCl increased the malondialdehyde and Na contents. The largest amount of catalase activity was measured after the 50 mM NaCl + KNO_3 + nano-Zn treatment. Salinity stress had adverse effects on the growth and physiological responses of *Aloe vera*. However, the foliar application of KNO_3, nano-Zn and Fe mitigated the damaging effects of salinity. The results from more detailed studies would be advisable for pioneer farmers and the agricultural sector.

Keywords: minerals content; malondialdehyde; proline; chlorophyll; catalase

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1. Introduction

Salinity is a major environmental stressor affecting plant growth and productivity [1]. Accumulating ions such as sodium, magnesium, and chloride in the root zone imposes a salinity stress on plants [2]. Under saline conditions, with an increasing degree of sodium entry into the cell, the plants' potassium uptake and potassium/sodium ratio considerably decline [3]. Salinity stress causes a disturbance in the plant's energy metabolism by inducing the over-generation of oxygen free radicals in the chloroplasts and the mitochondria, thereby drastically impacting the growth potential and crop yield (as a result of damage that occurs to the proteins, lipids, and the disruption of normal cell metabolism) [4]. Under stress conditions, crosstalk must be addressed between the energy that is generated from the mitochondria and the chloroplasts, the demand for water, ion transfer, and osmotic adjustment in the plants [5]. The appropriate nutrition of plants, especially in terms of

micronutrients, is essential in increasing the plant's resistance to stress factors. Nanofertilizers have found widespread applications in the agricultural sector due to the rapid effectiveness of these particles and the corresponding reduction of environmental pollution arising from the significant inputs of their common forms [6].

Moreover, the cations' foliar application is reported to increase the antioxidant activity and detoxify the oxidative stress products/effects through the increased enzymatic activities and proline accumulation [7]. Fe is an essential element that is required by the plant that plays a critical role in the chloroplasts' function, photosynthesis, enzymatic activity, nitrogen metabolism, and plant respiration [7,8]. Zinc is also another essential micronutrient that plays crucial actions in the metabolism of nucleic acids, cell division, carbohydrate metabolism, and tryptophan biosynthesis [9]. Under salt stress, zinc significantly reduces sodium chloride's negative effect by preventing the absorption or transfer of those toxic ions [3,9]. Potassium is crucial in regulating stomata opening, keeping the correct K^+/Na^+ ratio, photosynthesis, osmotic adjustment, and activating antioxidant enzymes [10]. In *Mentha spicata*, a foliar treatment with Zn and K under a salinity condition reduced the stress depression on plants. The salinity conditions reduced the stomatal conductance, photosynthesis rate, yield, and the K and Ca contents. Foliar Zn and K application improved all of the before-mentioned traits by mitigating the salinity effects [7]. The nano-Fe foliar treatment of salinity-exposed grapevine plants along with soil-based graphene oxide use revealed, that the Fe treatment improved the catalase activity yield and nutrients uptake in the plants [11].

Aloe vera L. is an evergreen plant from the Liliaceae family that is widely used in traditional medicine and the pharmaceutical, cosmetic, hygienic, and food industries. The therapeutic importance of this plant is, in the main part, due to a gel-like substance that is inside leaves which contains polysaccharides such as glucomannan, galactan, and aloin [12] sugars, lipids, proteins, amino acids, organic acids, lignins, saponins, and phenolic compounds [13–15]. Since salt stress has become one of the most critical problems in the world's arid and semi-arid regions, mitigating the salinity depressions on the neighboring plants and retaining their yield and quality attributes is crucial. The present study evaluated the foliar application of potassium nitrate, Zn, and Fe nanoparticles on *Aloe vera* plants' growth and physiological responses under saline-sodic conditions.

2. Materials and Methods

2.1. Plant Materials

This experiment was conducted during the spring and summer of 2020 at the Research Greenhouse of Azarbaijan Shahid Madani University, Tabriz, Iran. The greenhouse growing conditions were as follows: lighting period: 16:8, day and night; temperature regime: 30 °C and 25 °C in the daytime and nighttime, respectively; relative humidity of approximately 65 ± 5%. Homogenous *Aloe vera* plants (25–30 cm height) that had 4–5 leaves were planted in pots (5 L) that were filled with medium-sized perlite and cocopeat (1:1). The plants were nourished with half-strength Hoagland's nutrient solution during the early establishing growth stage. Afterward, following a period of 3 weeks, the salinity treatments were imposed. The salinity levels were 0, 50, and 100 mM NaCl. The addition of salts began at 25 mM and gradually increased to reach the final level within ten days. Half-strength Hoagland's nutrient solution with NaCl treatments (300 mL/pot) was applied every two days. The pots were regularly washed with tap water once weekly to avoid salinity standup on the pot surfaces. Following the salinity application, the ECs of the nutrient solutions were 2.1 mS cm^{-1} (0 mM NaCl), 6.0 mS cm^{-1} (50 mM NaCl), and 12.0 mS cm^{-1} (100 mM NaCl). Two repeated foliar treatments with zero and 2 mg L^{-1} of KNO_3, magnetized nano-Fe, and nano–Zn (10–30 nanometer-sized from US-Nano Company, Houston, TX, USA) were applied onto the plants. The first foliar treatment occurred simultaneously with the salinity initiation, and the second one occurred two weeks later. Distilled water was employed as a control treatment. Fifty days after the second foliar spray (plants had 7–8 leaves), the leaf samples were taken for morphological and biochemical assays. The

full-sized leaves from the middle part of the plants were employed for sampling and traits analyses. The leaves were wrapped in aluminum foil and incubated in liquid nitrogen until the measurements were taken.

2.2. Synthesis and Characterization of Fe_3O_4 Magnetic Nanoparticles (Fe_3O_4 MNPs)

The Fourier transform infrared (FTIR) spectrum of the Fe_3O_4 nanoparticles was recorded using a Vector 22 (Bruker, Ettlingen, Germany) Fourier transform infrared spectrometer, using KBr as the mulling agent. An x-ray diffraction analysis (XRD) of the Fe_3O_4 nanoparticles was carried out using a Bruker D8 Advance (Bruker AXS, Karlsruhe, Germany) instrument with a Cu-Kα radiation source (1.54 Å) between 8 and 80 °C generated at 40 kV and 35 mA at room temperature. An electronic analytical balance (PFB300-3, Kern, Germany) was used for weighing the solid materials. A heater (IKA, model RHB2) was employed to synthesize the nanomaterials. The ultrasonic treatment was carried out using an ultrasonic bath (DSA100-SK2-4.0 L Fuzhou Desen Precision Instruments Co., Ltd., Fuzhou, China).

Fe (III) chloride hexahydrate (99%), Fe (II) sulfate heptahydrate (99.5%), and ammonia solution (25%, d = 0.91 Kg L^{-1}) were purchased from Merck (Darmstadt, Germany). Deionized water (Ghazi Company, Tabriz, Iran) was used to prepare aqueous solutions.

For Fe_3O_4 MNPs, 50 mL deionized water was degassed into an ultrasonic bath for 10 min, and then 4.86 g $FeCl_3$ 6H2O and 3.34 g $FeSO_4$ 7H2O were added. The solution was heated at 100 °C and vigorously stirred to dissolve the Fe salts. Then, 12 mL of concentrated ammonia solution was rapidly added under a vigorous stirring condition. After the reaction (2 h), the solution containing black Fe oxide MNPs was cooled at room temperature. The precipitate was collected using a magnet and washed with a mixture of ethanol: water (50:50, v/v). Finally, the MNPs were washed with ethanol and dried in an oven at 80 °C for five hours [16].

2.3. Plant Fresh and Dry Weight

The fresh weight was recorded immediately after the harvest, and the dry weight was measured after machine drying at 35 °C until a constant weight was achieved (BBI41, Beco, Geesthacht, Germany).

2.4. Total Chlorophyll Content

According to Arnon, the chlorophylls content of the outer part of *Aloe vera* leaf was determined from the acetone extract [17]. The absorbance was read spectrophotometrically at 663 and 645 nm (T80, Shanghai, China).

2.5. Total Soluble Solids Content (TSS)

The filtered leaf extracted juice of *Aloe vera* was used to determine the TSS (in °Brix) using a digital refractometer (Erma, Tokyo, Japan).

2.6. Total Phenolics and Flavonoids Content

The total phenolic content was determined according to the Folin-Ciocalteu procedure. Furthermore, the flavonoids were measured by the colorimetric method ($AlCl_3$) that was proposed by Kim et al. [18]. The content of the total phenolics and the flavonoids were expressed as gallic acid (mg of GAE g^{-1} dry weight) and rutin equivalents (mg rutin g^{-1} dry weight), respectively.

2.7. Malondialdehyde (MDA) Content

The MDA was measured by the thiobarbituric acid (TBA) method that was described by Sevengor et al. [1]. A frozen leaf sample (0.2 g) was homogenized in 5 mL of trichloroacetic acid (TCA) (1% v/m) and centrifuged at 12,000× g for 5 min. One ml of the supernatant was mixed with 5 mL of TBA (0.5%) + TCA (4%) and warmed at 95 °C for 30 min. The reaction was placed on ice to stop the enzyme activity. After centrifugation

(10,000× *g* for 10 min at 4 °C), the supernatant absorbance was read using a spectrophotometer (T80+, China) at 532 nm, and the values corresponding to nonspecific absorption (600 nm) were subtracted. The lipid peroxidation products were measured as the content of the TBA-reactive substances. The MDA content was calculated using the molar extinction coefficient of 155/(mM cm).

2.8. Superoxide Dismutase (SOD) Activity

The SOD activity was traced by recording the enzyme's inhibition of nitroblue tetrazolium (NBT) photoreduction. The reaction mixture contained 50 mM sodium phosphate buffer (pH 7.6), 0.1 mM EDTA, 50 mM sodium carbonate, 12 mM L-methionine, 50 µM NBT, 10 µM riboflavin, and 100 µL of plant sample extract in a final volume of 3.0 mL. The SOD activity was recorded at 560 nm using a spectrophotometer (T80+, China). One unit (U) of SOD activity was defined as the amount of enzymes causing 50% inhibition of the photochemical reduction of NBT [19].

2.9. Catalase Activity

For the CAT activity, one g of frozen leaf sample was grinded in 10 mL buffer (0.1 M phosphate buffer, pH 7.5, 0.5 mM EDTA) to prepare the extract. After filtration, the samples were centrifuged at 4 °C for 20 min at 15,000× *g*. The supernatant was collected and used for an assay of the catalase activity. Half of a mL of 75 mM H_2O_2 was added to 1.5 mL of 0.1 M phosphate buffer (PH 7) and 50 µL of diluted enzyme extract in a 3 mL reaction mixture. The decrease in absorption was recorded at 240 nm for 60 s. The enzyme activity was computed by calculating the amount of H_2O_2 that was decomposed [20].

2.10. Proline Content

The proline content was quantified by the method that was described by Bates et al. [21]. A fresh leaf sample (0.2 g) was powdered in a cold mortar with liquid nitrogen, then 5 mL of homogenized sulfosalicylic acid (SSA) (3%) was added. Two mL of the filtered sample were mixed with 2 mL of glacial acetic acid and 2 mL of acid-ninhydrin. The sample was incubated at 100 °C water bath for 1 h. After one hour, the reaction was stopped by putting the tube in an ice bath. Four mL toluene was added to each tube and vortexed for 15–20 s. The absorption reduction was recorded at 520 nm, and the results were expressed as µmol g^{-1} DW.

2.11. Minerals Analysis

The contents of Na and K of the leaves were quantified by the flame photometric method (Corning, 410, London, UK). The nitrogen content was measured by Kjeldahl digestion. Zn, Fe, and P were recorded by atomic absorption spectroscopy (Shimadzu, AA6300, Tokyo, Japan) according to the method that was described by Honarjoo et al. [22].

2.12. Experimental Design and Data Analysis

The experiment was arranged as factorial based on a completely randomized design with three replications. The data were subjected to a standard analysis of variance. The values of the LSD were calculated at 1 and 5% levels of significance.

3. Results and Discussion

3.1. Characterization of Fe_3O_4 Magnetic Nanoparticles (Fe_3O_4 MNPs)

The FT-IR spectrum (Figure 1) shows a strong peak at around 582 cm^{-1}, which is attributed to the Fe–O bond in Fe_3O_4. This peak was shifted to a higher wavenumber than the Fe–O bond peak of bulk magnetite at 570 cm^{-1} due to the NP's sizes [16]. Therefore, it indicates that Fe_3O_4 MNPs have been successfully synthesized.

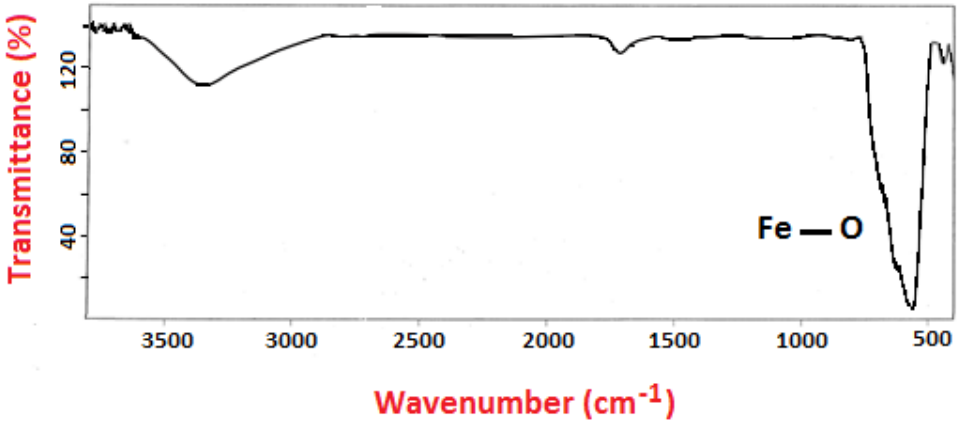

Figure 1. FT-IR spectrum of Fe_3O_4 MNPs.

Figure 2 shows the X-ray diffraction pattern (XRD) of Fe_3O_4 MNPs. The diffraction peaks in 2θ region of 5–80° (30.007, 35.601, 43.239, 53.782, 57.372, and 63.058°), which are marked by their indices (220, 311, 400, 422, 511, and 440), confirmed the formation of Fe_3O_4 MNPs [16].

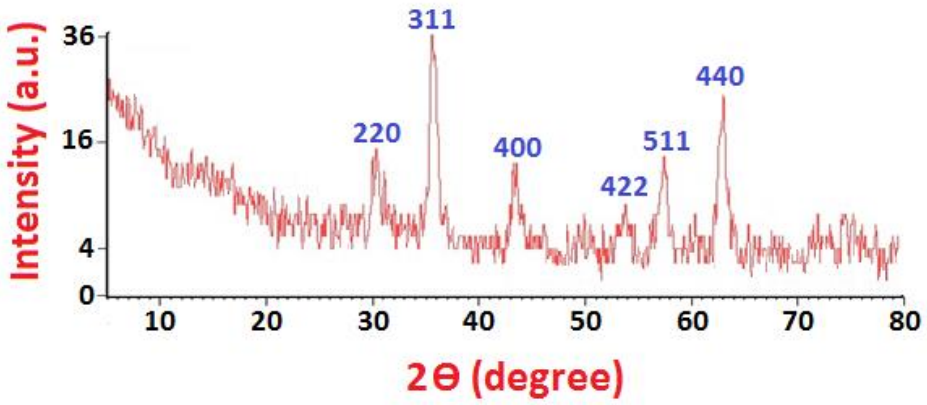

Figure 2. XRD pattern of Fe_3O_4 MNPs.

3.2. Fresh and Dry Weight of the Leaves

The interactions that occurred due to the experimental treatments affected the fresh and dry weights of the leaves (Table 1). The highest fresh and dry weight was obtained in the unstressed plants that were treated with nano-Fe + KNO_3, thereby indicating a 49% increase in the plant dry weight compared to the control (Table 2). Ullah et al. [23] and Moghbeli et al. [24] reported reductions in the dry weight of *Aloe vera* under salinity stress. The foliar application of Zn and Fe nanoparticles increased the rosemary yield by improving the photosynthetic rate and reducing the sodium ion accumulation in the plants [25]. Salinity adversely affected the plant yield due to the decreased amount of photosynthesis and the disorders caused by toxic ion accumulation. The photosynthesis inhibition reduced the plant's energy for essential metabolites' biosynthesis, ultimately reducing the plant growth [26,27]. The foliar application of potassium nitrate positively affected coriander yield [28]. Under stress conditions, the increase in the expression of the NAC genes (a special group of transcription factors) played a key action in the function of the AhNAC4 gene in peanut plants, and by closing the stomata and improving the water-use efficiency during the stress period, it improved the plant's growth and the product quality [29].

Table 1. ANOVA for the effects of salinity stress (0, 50, and 100 mM NaCl) and foliar applications (without spraying, potassium nitrate, ZnO, and Fe nanoparticles) on some growth-related traits and gel content of *Aloe vera* plants.

S.o.V	DF	Root Fresh Weight	Root Dry Weight	Leaf Fresh Weight	Leaf Dry Weight	Gel Fresh Weight	Gel Dry Weight
Salinity	2	280 **	0.046 ns	18,468 **	64.8 **	40.6 **	0.1 **
Treatments	6	164 **	0.22 *	6589 **	18.8 **	170.1 **	0.03 **
Salinity × Treatments	12	18.4 **	0.019 ns	2347 **	3.48 **	23.8 *	0.003 *
Error	42	2.2	0.021	79	0.64	1.3	0.00
CV		10.2	15.2	6.17	10.53	6.7	9.3

ns, * and ** indicate no significant difference and significant differences at 5 and 1% probability levels, respectively. S.o.V: source of variation; DF: degrees of freedom.

Table 2. Effect of salinity levels and foliar applications on plant weight, gel weight, proline content, and TSS content of *Aloe vera* plants.

NaCl (mM)	Treatments (g L^{-1})	Root FW (g)	Leaf FW (g)	Leaf DW (g)	Gel DW (g)	Gel FW (g)	Proline (µmol g^{-1} DW) Content	TSS (°Brix)
0	Control	9.3 ± 0.29 ji	121.8 ± 4.8 ij	6.4 ± 0.45 ik	0.11 ± 0.03 h	6.5 ± 3.3 k	35 ± 0.57 j	1.2 ± 0.14 hi
	Fe-NPs	15.3 ± 0.28 df	165.0 ± 19.5 d	8.4 ± 0.78 eg	0.18 ± 0.03 e	15.3 ± 1.5 i	50 ± 0.66 i	1.8 ± 0.12 ef
	Zn-NPs	11.6 ± 0.26 hi	135.0 ± 26.7 eg	8.0 ± 1.02 eh	0.17 ± 0.03 ef	15.4 ± 2.3 i	53 ± 0.48 i	1.9 ± 0.00 df
	KNO_3	20.0 ± 0.23 b	215.0 ± 43.8 b	10.2 ± 1.93 bc	0.27 ± 0.04 b	15.4 ± 1.7 i	62 ± 1.02 fh	2.1 ± 0.16 ce
	Fe-NPs + Zn-NPs	19.0 ± 0.09 bc	181.0 ± 25.9 e	9.2 ± 1.45 ce	0.24 ± 0.03 c	16.1 ± 1.5 hi	56 ± 0.41 gi	**3.1 ± 0.41 a**
	Fe-NPs + KNO_3	**25.0 ± 0.08 a**	**257.0 ± 36.6 a**	**13.1 ± 1.76 a**	**0.37 ± 0.04 a**	**27.0 ± 5.3 a**	70 ± 0.68 ce	**2.9 ± 0.29 a**
	Zn-NPs + KNO_3	**26.3 ± 0.08 a**	170.0 ± c30.9 d	10.9 ± 1.67 b	0.29 ± 0.01 b	18.1 ± 4.5 dg	64 ± 1.17 eg	2.5 ± 0.26 b
50	untreated	8.0 ± 0.27 jk	95.0 ± l10.1 m	4.8 ± 0.51 mn	0.06 ± 0.01 j	7.4 ± 3.4 k	50 ± 1.44 i	1.1 ± 0.21 i
	Fe-NPs	13.1 ± 0.21 f–h	134.0 ± 22 eg	6.8 ± 1.05 hj	0.10 ± 0.04 hi	15.0 ± 6.0 i	66 ± 0.91 df	2.0 ± 0.65 ce
	Zn-NPs	12.0 ± 0.12 gh	125.0 ± 17.6 fi	6.1 ± 0.79 j-m	0.11 ± 0.01 h	18.8 ± 4.5 de	55 ± 0.93 hi	2.0 ± 0.45 ce
	KNO_3	14.2 ± 0.21 eg	139.0 ± 22.6 ef	8.6 ± 1.11 d-f	0.17 ± 0.01 ef	19.5 ± 6.1 cd	**83 ± 0.42 ab**	2.2 ± 1.11 c
	Fe-NPs + Zn-NPs	13.3 ± 0.37 fh	129.0 ± 40 eh	8.3 ± 2.05 e–g	0.16 ± 0.04 ef	16.5 ± 1.9 gi	61 ± 0.88 fh	1.5 ± 0.87 gh
	Fe-NPs + KNO_3	14.3 ± 0.41 eg	116.0 ± 35 hk	7.5 ± 1.82 f–i	0.22 ± 0.06 d	18.6 ± 2.4 df	**80 ± 0.43 a**	2.1 ± 0.45 cd
	Zn-NPs + KNO_3	16.5 ± 0.12 de	200.0 ± 43.0 b	9.8 ± 2.16 b–d	0.22 ± 0.06 d	22.6 ± 3.6 b	60 ± 0.08 fh	1.7 ± 0.01 fg
100	untreated	5.7 ± 0.30 k	89.0 ± 7.8 m	4.3 ± 0.41 n	0.04 ± 0.01 k	9.4 ± 2.7 j	**86 ± 0.82 a**	1.0 ± 0.05 i
	Fe-NPs	7.8 ± 0.43 jk	113.0 ± 31.7 i–k	6.8 ± 1.72 h–j	0.06 ± 0.02 j	18.2 ± 2.7 dg	**80 ± 0.62 a**	1.2 ± 0.29 hi
	Zn-NPs	8.0 ± 0.43 jk	109.0 ± 14.9 jl	5.1 ± 0.77 l–n	0.09 ± 0.02 i	21.2 ± 4.6 bc	**88 ± 0.90 a**	1.1 ± 0.09 hi
	KNO_3	9.0 ± 0.46 j	130.0 ± 28.6 e–h	6.0 ± 1.56 i–k	0.08 ± 0.01 i	**22.0 ± 6.3 b**	**85 ± 0.88 a**	1.7 ± 0.16 fi
	Fe-NPs + Zn-NPs	14.9 ± 0.51 df	106.0 ± 6.2 kl	5.4 ± 0.21 k–n	0.11 ± 0.01 gh	16.8 ± 1.9 fi	**87 ± 0.74 a**	1.0 ± 0.376 i
	Fe-NPs + KNO_3	14.0 ± 0.38 eh	160.0 ± 17.0 d	7.2 ± 0.79 g–j	0.12 ± 0.00 g	17.5 ± 0.5 eh	73 ± 1.38 cd	1.9 ± 0.25 df
	Zn-NPs + KNO_3	17.0 ± 0.51 cd	141.0 ± 13.4 e	6.2 ± 0.79 i–l	0.15 ± 0.03 f	18.2 ± 3.9 dg	76 ± 0.97 bc	1.1 ± 0.22 hi
L.S.D.		2.4	14.7	1.3	0.01	1.8	0.8	0.3

Different letters within each column indicate significant differences based on LSD test ($p < 0.05$), and the **bold** data are the treatments that received the significance level of a.

3.3. Root Fresh and Dry Weight

The foliar application of nano-Fe + potassium nitrate and nano-Zn + potassium nitrate increased the root fresh weight when the plant was under no salinity conditions (Table 2). The roots' dry weight was also affected by the foliar applications (Table 1). The least root dry weight was observed in the no-foliar application (0.68 g) and foliar-treated ones with Zn nanoparticles (0.82 g) (Figure 3). An earlier study that was conducted on *Aloe vera* found that salinity stress reduced the root dry weight [24]. As known, supplying sufficient amounts of K, Fe, and Zn increases the rate of photosynthesis and declines the stressors' effects on plants. Photosynthesis stimulation improves the plant's growth, especially root growth and development. Maintaining a proper K^+/Na^+ ratio in the growing medium or cellular level is essential for normal plant growth and a suitable crop yield [28,30,31].

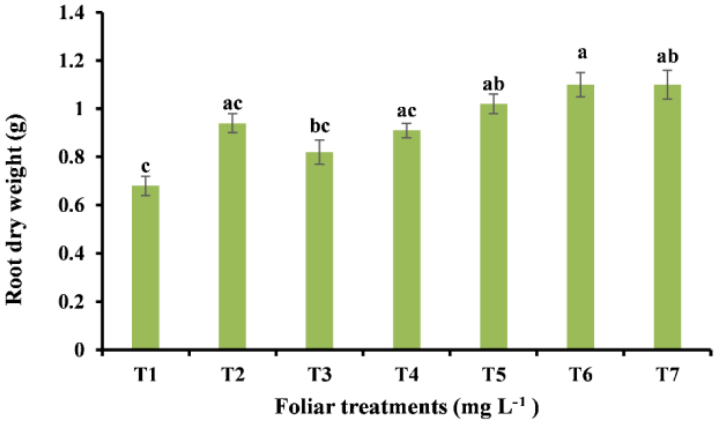

Figure 3. Effects of different foliar treatments on root dry weight of *Aloe vera*. Different letters on bars indicate significant differences among foliar treatments at $p < 0.05$ by LSD test. T1: control, T2: Magnetic Fe nanoparticle, T3: Zn nanoparticle, T4: KNO_3, T5: Fe + Zn nanoparticles, T6: Fe nanoparticle+ KNO_3, T7: Zn nanoparticle+ KNO_3.

3.4. The Fresh and Dry Weight of the Gel

The interactions of experimental treatments affected the gel's fresh and dry weights (Table 1). According to the results, the gel's highest fresh and dry weights were observed in the 0 mM NaCl + nano Fe + KNO_3 treatment (Table 2).

A notable decrease in the *Aloe vera* gel content was reported by Moghbeli et al. [24]. Potassium deficiency in plants drastically impacts the stomatal conductance. Disturbances in stomatal closure result in a reduced photosynthesis rate and a lower crop yield [28]. Fe is one of the essential nutrient elements that is required by plants, which plays a crucial role in the activity of several enzymes and is a vital element in enhancing the chlorophyll content. Fe enhances the plants' photosynthesis and secondary metabolites production [31]. Increasing the chlorophyll content due to the above-mentioned treatments improves the plant's photosynthesis potential and increases the gel content.

3.5. Phenolics and Flavonoids Content of Leaves and Gel

Fifty mM NaCl + nano Fe + Zn, 50 mM NaCl + nano Fe + KNO_3 and, 50 mM NaCl + KNO_3 increased the phenolics content of the leaves. The gel phenolic content is influenced by the 50 mM NaCl + nano Fe + Zn; 50 mM NaCl + nano Zn + KNO_3 treatment and the no salinity + nano Fe + KNO_3 treatment (Table 4).

The leaf flavonoids content was affected by the 50 mM NaCl + nano Fe + Zn treatment and the 50 mM NaCl + nano Zn + KNO_3 treatment. The gel flavonoid content was responsive to the 50 mM NaCl + nano Fe + Zn treatment and the 50 mM NaCl + nano Fe + KNO_3 treatment (Table 4). In a study that was conducted on *Aloe vera* under salinity conditions, the phenolic content in the leaves was higher than it was in the gel. A study on rosemary showed that the flavonoid content of the whole plant was affected by the independent effects of salinity stress and foliar treatments. The foliar spraying with zinc nanoparticles increased the flavonoid content of the plant [26]. Probably, the leaves' photosynthetic cells offered more carbohydrates for the biosynthesis of the phenolic compounds [32]. Furthermore, the phenolic content of *Aloe vera* plants was increased under the salinity stress condition [33]. The foliar application with potassium nitrate under salinity increased the grapes' total phenolic and flavonoid content [34]. The phenolics and flavonoid compounds are the most important secondary metabolites that are produced in plants under stress conditions, having dominant roles in plant survival by eliminating free radicals [34,35].

3.6. Proline Content

The fifty mM NaCl + nano Fe + KNO_3, 50 mM NaCl + KNO_3, 100 mM NaCl + nano Fe, Zn and KNO_3, and the 100 mM NaCl + nano Fe + Zn and 100 mM NaCl + without foliar

spray treatments had the top proline content. The lowest proline content was observed in the control treatment (Table 2). A study on mint plants under a salinity condition showed that the foliar application of magnetic Fe increased the proline content of the plants [36]. Another research found that the foliar application of Zn and Fe nanoparticles increased the proline content in rosemary plants that were under salt stress conditions [25]. The biosynthesis of organic compounds such as proline and proteins under a stress condition is the primary defense mechanism that helps in their osmotic adjustment and maintains the cell membranes' integrity [36,37]. When a plant was under salinity stress, applying potassium nitrate increased the rate of proline biosynthesis [38]. Proline reduces the harmful effects of the hydroxyl free radicals and protects the macro-molecules like DNA and cell membrane-anchored proteins [38].

3.7. Total Soluble Solids Content

The treatment combinations affected the total soluble solids content (Table 3). The no salinity + nano Fe + KNO_3 treatment and the 0 mM NaCl + nano Fe + Zn treatment increased the leaf TSS content. The lowest total soluble solids content was observed in the plants that were grown under a 100 mM salt treatment without a foliar application (Table 2). Zn foliar application improved the net photosynthesis in *Pelargonium graveolens* and increased the availability of carbon structures for secondary metabolites biosynthesis [39]. In *Aloe vera* plants that were irrigated with seawater, the salinity declined the availability of N, K, and Ca and even reduced the photosynthesis potential and greatly diminished the yield and carbon skeletons that are essential for secondary metabolism [40]. Other studies on *Moringa peregrine* [41] showed that the foliar application of Fe sulfate increased the TSS content of the tested plants under salinity conditions. In the survey on maize, it was found that the foliar application of Zn and Fe under salinity conditions increased the photosynthetic rate and TSS content [42]. The osmolytes that are produced under stress conditions regulate the osmotic potential of the cytoplasm and partially reduce the sodium accumulation in the vacuole, thereby helping the plants to survive under harsh stressful environments [42,43].

Table 3. ANOVA for the effects of salinity and foliar applications (without spraying, potassium nitrate, Zn, and Fe nanoparticles) on the gel and leaf phenolics, gel and leaf flavonoids, TSS, and proline content of *Aloe vera* plants.

S.o.V	DF	Gel Phenolics Content	Gel Flavonoids Content	Leaf Phenolics Content	Leaf Flavonoids Content	TSS Content	Proline Content
Salinity	2	23,031 **	2624 **	19,018 **	9007 **	4.36 **	38.30 **
Treatments	6	3737 **	1395 **	4321 **	1656 **	1.13 **	5.20 **
Salinity × Treatments	12	1743 **	269 *	516 **	439 **	0.46 **	3.90 **
Error	42	79	28	116	53	0.03	0.24
CV		6.2	12.8	4.2	10.0	9.0	7.0

ns, * and ** indicate non-significant and significant differences at 5 and 1% probability levels, respectively. S.o.V: source of variation; DF: degrees of freedom.

3.8. Chlorophyll Content

The chlorophyll a content was affected by the interactions of the salinity condition and foliar applications. The highest chlorophyll a content was observed in the nano-Zn + KNO_3 and nano-Fe + KNO_3 under no salinity condition (Table 4). The chlorophyll b content was influenced by the independent effects of the foliar applications and the salinity stress conditions (Table 5). Salinity decreased the chlorophyll b content. The highest value for chlorophyll b was observed in the control plants (no-salinity) (Figure 4). The foliar application of Zn nanoparticles+ KNO_3, Fe nanoparticles + KNO_3, and Zn + Fe nanoparticles increased the chlorophyll b content (Figure 5). Under the salinity stress, the chlorophyll content of rosemary plants was decreased [26]. Similar results about a decreasing chlorophyll content under salinity stress conditions were reported in a pumpkin seedling [1]. A decrease in the chlorophyll content in response to the salinity stress may be due to the

chloroplast structural demolition [42–44]. Foliar treatments, by improving photosynthesis, ionic balance, relative water content, proteins biosynthesis, pH modulation in photosystem II, and cellular turgor regulation, positively influence the growth and yield under salinity conditions [28–31].

Table 4. The effect of salinity and foliar treatments on the chlorophyll a content, CAT and SOD activity, MDA content, and leaf and gel phenolics content of *Aloe vera* plants.

NaCl (mM)	Treatments (g L^{-1})	Chlorophyll a Content (mg g^{-1}FW)	Leaf Phenolics Content (mg g^{-1} DW)	Gel Phenolics Content (mg g^{-1} DW)	Leaf Flavonoids Content (mg g^{-1} DW)	Gel Flavonoids Content (mg g^{-1} DW)	SOD Activity (U mg^{-1} protein)	MDA Content (µmol g^{-1} FW)	CAT Activity (µmol H_2O_2 mg^{-1} Protein min^{-1})
0	Control	1.3 ± 0.05 ij	209 ± 28.24 jk	125 ± 9.10 f	51.3 ± 5.88 jk	29.3 ± 13.27 eg	19 ± 1.63 i	16.6 ± 4.5 g	29.4 ± 3.21 k
	Fe-NPs	2.3 ± 0.24 c	275 ± 17.93 ce	166 ± 20.41 c	81.6 ± 9.41 df	36.0 ± 19.01 ce	27 ± 2.16 h	19.0 ± 2.8 g	40.0 ± 2.57 ij
	Zn-NPs	1.8 ± 0.21 fh	255 ± 22.95 fg	153 ± 19.77 cd	69.6 ± 10.14 fh	30 ± 17.74 dg	26 ± 2.14 h	18.0 ± 3.2 g	37.0 ± 1.77 j
	KNO_3	1.9 ± 0.36 eg	267 ± 2.05 ef	168 ± 30.21 c	89.0 ± 9.89 bd	32.0 ± 18.92 cg	26 ± 3.39 h	17.0 ± 4.0 g	40.0 ± 2.49 fj
	Fe-NPs + Zn-NPs	2.8 ± 0.05 b	289 ± 34.70 be	188 ± 7.78 b	84.0 ± 2.05 de	61.0 ± 34.92 b	33 ± 1.41 g	14.6 ± 1.6 g	44.0 ± 2.7 eg
	Fe-NPs + KNO_3	**3.1 ± 0.41 a**	282 ± 29.87 be	**196 ± 9.03 ab**	92.0 ± 11.1 bd	62.0 ± 8.17 b	35 ± 2.82 fg	15.6 ± 4.1 g	47.0 ± 1.2 bd
	Zn-NPs + KNO_3	**2.9 ± 0.26 ab**	280 ± 36.00 bc	158 ± 15.62 c	85.0 ± 10.66 ce	59.0 ± 22.79 b	31 ± 5.35 g	14.6 ± 1.6 g	43.0 ± 1.2 f–h
50	Control	1.1 ± 0.29 jk	232 ± 9.89 hi	107 ± 3.29 gh	60 ± 4.18 hj	29 ± 4.54 dg	27 ± 2.12 b	31 ± 5.76 e	40 ± 2.56 hj
	Fe-NPs	1.9 ± 0.22 e–g	280 ± 9.80 be	132 ± 29.26 ef	97 ± 5.73 bc	38 ± 12.83 cd	35 ± 0.81 fg	29 ± 4.54 ef	48 ± 4.48 bc
	Zn-NPs	1.7 ± 0.17 gh	245 ± 15.76 gh	122 ± 18.19 fg	73 ± 4.18 eg	40 ± 6.54 c	33 ± 2.44 g	29 ± 3.29 ef	45 ± 3.03 cf
	KNO_3	1.8 ± 0.14 fgh	**291 ± 35.83 ac**	143 ± 40.40 de	66 ± 4.78 gi	35 ± 8.21 cf	32 ± 0.94 g	29 ± 4.41 ef	50 ± 2.16 b
	Fe-NPs + Zn-NPs	2.2 ± 0.21 cd	**295 ± 12.35 ab**	**208 ± 24.09 a**	**122 ± 8.16 a**	**68 ± 21.31 ab**	38 ± 3.29 df	29 ± 3.77 ef	42 ± 1.66 gi
	Fe-NPs + KNO_3	2.7 ± 0.21 b	**287 ± 4.94 ad**	186 ± 36.62 b	99 ± 8.64 b	**69 ± 11.29 ab**	30 ± 0.92 cf	30 ± 5.65 ef	**53 ± 2.88 a**
	Zn-NPs + KNO_3	2.1 ± 0.19 c–e	271 ± 16.57 df	**195 ± 33.52 ab**	**113 ± 3.68 a**	60 ± 18.06 b	**43 ± 2.05 ac**	25 ± 1.69 f	47 ± 1.68 c–e
100	Control	1.0 ± 0.18 k	193 ± 23.09 k	109 ± 25.31 gh	38 ± 5.65 l	20 ± 2.94 h	37 ± 2.13 ef	**67 ± 4.71 a**	39 ± 3.72 ij
	Fe-NPs	1.6 ± 0.29 hi	224 ± 23.79 ij	102 ± 37.02 hi	51 ± 7.84 jk	27 ± 4.92 fh	**43 ± 7.13 ac**	59 ± 1.24 bc	42 ± 2.85 gi
	Zn-NPs	2.0 ± 0.53 d–f	213 ± 24.68 g	103 ± 20.72 hi	53 ± 5.88 j	31 ± 7.93 dg	38 ± 1.14 ef	61 ± 4.32 b	44 ± 1.02 d–g
	KNO_3	1.8 ± 0.37 fh	210 ± 26.53 jk	89 ± 15.17 i	41 ± 9.41 kl	28 ± 3.09 eh	39 ± 2.49 ef	54 ± 3.29 cd	47 ± 0.094 bc
	Fe-NPs + Zn-NPs	2.1 ± 0.41 ce	236 ± 28.89 hi	106 ± 3.29 h	57 ± 11.71 ij	26 ± 2.94 gh	**46 ± 1.88 a**	50 ± 1.41 d	42 ± 2.49 gi
	Fe-NPs + KNO_3	2.2 ± 0.41 cd	211 ± 26.62 j	103 ± 28.53 hi	60 ± 3.77 hj	31 ± 4.18 dg	**44 ± 3.55 ab**	52 ± 4.71 d	48 ± 1.24 bc
	Zn-NPs + KNO_3	1.8 ± 0.21 fh	240 ± 15.08 gi	130 ± 7.76 ef	50 ± 4.71 jl	35 ± 1.94 cg	41 ± 2.21 be	51 ± 7.48 d	46 ± 2.05 cf
L.S.D.		0.3	17.8	14.6	12.0	8.7	4.1	5.7	2.9

Different letters within each column indicate significant differences based on LSD test ($p < 0.05$), and the **bold** data are the treatments that received the significance level of a.

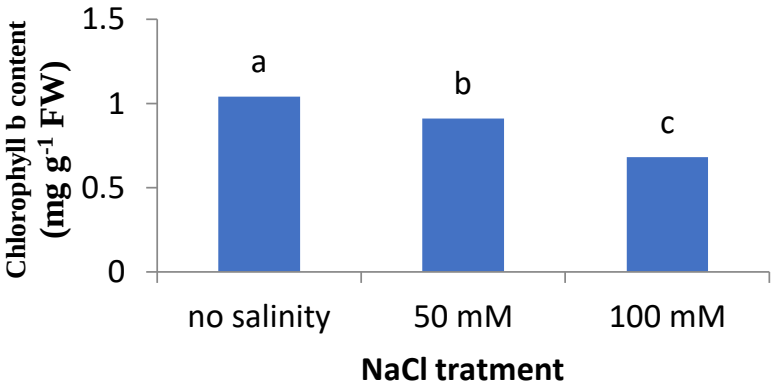

Figure 4. Effects of salinity (mM of NaCl) on chlorophyll b content of *Aloe vera*. Different letters on bars indicate significant differences at $p < 0.05$ by LSD test.

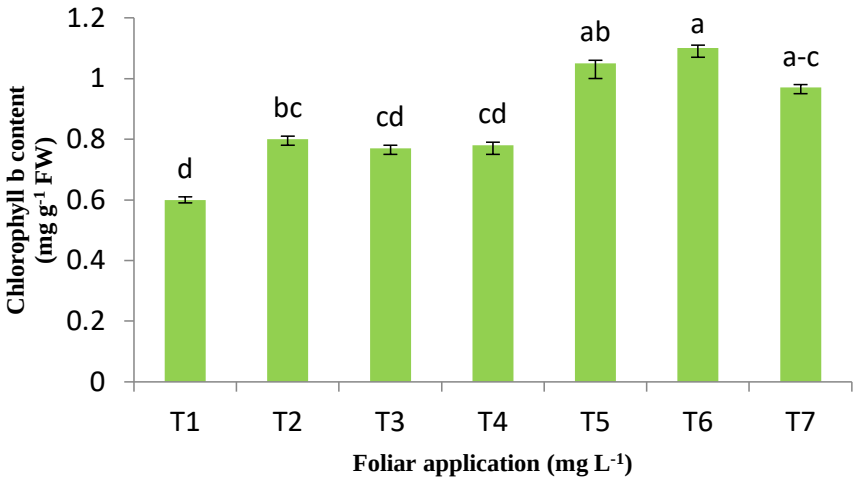

Figure 5. Effects of foliar treatments on chlorophyll b content of *Aloe vera*. Different letters on bars indicate significant differences among foliar treatments at $p < 0.05$ by LSD test. T1: control, T2: Magnetic Fe nanoparticle, T3: Zn nanoparticle, T4: KNO_3, T5: Fe + Zn nanoparticles, T6: Fe nanoparticle + KNO_3, T7: Zn nanoparticle+ KNO_3.

Moreover, the foliar application of potassium nitrate under salinity conditions modulates the cell polarity and regulates the cells' osmotic potential and nitrogen metabolism [28]. The foliar application of Fe nanoparticles under salinity conditions increased *Moringa peregrine* chlorophyll content [41]. Fe is inevitable in chlorophyll development and thylakoid synthesis [31]. However, when they were under salinity stress conditions, the chlorophyll content decreased via the reduced Fe and magnesium uptake, and consequently, the photosynthesis potential dramatically declined in the plants [25,26]. In the present study, Fe foliar application positively improved the rate of chlorophyll biosynthesis. The foliar Zn nanoparticle treatment enhanced the chlorophyll content in rosemary under stress conditions [25]. Zn plays dominant actions in activating the enzymes that are involved in the biosynthesis of sugars and cell membrane integrity, thereby mitigating the effects of ROSs and improving the crop yield and quality [31].

Table 5. ANOVA for the effects of salinity stress and foliar application (without spraying, potassium nitrate, and Zn and Fe nanoparticles) on chlorophyll a and b content, CAT and SOD activity, and MDA and minerals (NPK) content of *Aloe vera* plants.

S.o.V	Chl. a	Chl. b	CAT	MDA	SOD	K	P	N
Salinity	1.48 **	0.70 **	214.2 **	8808.0 **	975 **	1240.6 **	25.80 **	403.4 **
Foliar treatments	2.32 **	0.29 **	150.8 **	78.3 **	172 **	551.0 **	2.30 **	171.0 **
Salinity × treatments	0.15 **	0.015 ^{ns}	22.1 *	30.3 *	18.5 *	41.8 *	0.52 *	5.6 *
error	0.03	0.015	3.2	12.1	6.4	7.6	0.22	1.9
CV	8.7	13.7	4.1	10.2	7.2	6.7	11.8	7.5

ns, * and ** indicate non-significant and significant differences at 5 and 1% probability levels, respectively. S.o.V: source of variation.

3.9. Catalase Activity

The fifty mM NaCl and nano Fe + KNO_3 treatment increased the catalase activity (53 µmol H_2O_2 mg^{-1} protein min^{-1}), indicating that there was a 3.7% increase compared to that of the control (Table 4). In grapevines, the foliar treatment with iron nanoparticles under salinity stress increased the catalase activity in the plants [11]. In a study that was conducted on sunflowers, it was found that the foliar application of potassium sulfate under salinity stress improved the growth, photosynthesis, water relations, stability of the cell membrane, and even increased the rate of the absorption of nutrients (potassium,

magnesium, phosphorus and calcium) [27]. It seems that maintaining the integrity of the cell membrane plays a vital role in reducing the overgeneration of oxygen free radicals in the plant [27]. Catalase plays an essential role in neutralizing oxygen free radicals. In the study that was conducted on grapes, a potassium foliar treatment improved catalase activity at all levels of salinity stress (50 and 100 mM) [34]. Under stress conditions, polyamines enter the apoplastic space due to the loss of the polarity of the cell membranes, they are oxidized by amine oxidases which are attached to the cell wall and produce hydrogen peroxide. Hydrogen peroxide enters the cell through aquaporins or diffusion, thereby reducing the ROS radicles' adverse effects [45,46]. The application of Fe nanoparticles increased the catalase activity in grapes that were under salinity stress conditions. Fe plays a vital role in the activity of antioxidant enzymes such as catalase, and the foliar treatment with Fe reduced the hydrogen peroxide genesis in those plants [47]. The availability of antioxidant enzymes (catalase and superoxide dismutase) contributes to the plants' survival under stress conditions. Superoxide dismutase reduces the effects of free radicals by converting superoxides into hydrogen peroxide and oxygen [48].

3.10. Superoxide Dismutase Activity

The superoxide dismutase activity increased in the 50 mM NaCl + nano Zn + KNO_3 treatment, the 100 mM NaCl + nano Fe treatment, the 100 mM NaCl + nano Fe + Zn treatment and the 100 mM NaCl + nano Fe + KNO_3 treatment (Table 4). The over-production of free radicals in plants under stress conditions increases the activity of successive MAP kinases signaling pathways and regulates downstream stress-related hormone-producing genes [49]. Zn and Fe play dominant roles in catalase and superoxide dismutase, carbohydrates and nucleic acids metabolism, photosynthesis, light-dependent respiration, and protein biosynthesis [50,51]. A previous study on lavender showed that the foliar application of zinc increased the rate of superoxide dismutase activity in the plant [50]. In another research study that was conducted on grapes, a foliar Fe nanoparticles treatment increased the activity of the superoxide dismutase and catalase [47].

3.11. MDA Content

The malondialdehyde content was responded to the treatments (Table 5). The one hundred mM NaCl salinity treatment attained the highest MDA content when it was performed with no foliar application (Table 4). Based on the results, foliar applications prevented the accumulation of malondialdehyde in plants, reflecting their influential role in controlling salinity stress. An increase in the content of hydrogen peroxide and malondialdehyde has been reported in grapevine (11) and rosemary (26) when they are under salt stress, and also the ion leakage was hugely enhanced in lemongrass (37) due to the effects of the salt stress. Salinity stress damages the integrity of the cell membranes by creating ROS radicals, which, if this production continues, cause the plant's death [51,52]. Fe plays crucial roles in oxidation–reduction reactions, cytochromes and ferredoxin structure, respiration, and photosynthesis [8]. Proper nutrition with Fe and Zn nanoparticles maintains the health of the cell membranes and, therefore, reduces the adverse effects of salinity stress in plants [36].

3.12. Mineral Contents

Salinity stress causes nutrient disturbances that result in the retarded growth of the plant and its development by affecting the nutrients' availability, transport, and partitioning. Salinity may cause nutrient deficiencies or imbalances because of Na^+ and Cl^-, which compete with nutrients such as K^+, Ca^{2+}, and NO^{3-} [49,50]. Studies have shown that there had been an increase in Na and Cl under salinity conditions but a decrease in nitrogen, phosphorus, calcium, potassium, and magnesium levels in peppermint and *Lemon verbena* [53] and *Matricaria recutita* [53]. In the present study, the salinity level and foliar applications and their interactions affected the nutrient contents of *Aloe vera* leaves (Table 5).

3.12.1. Nitrogen Content

The foliar application of KNO_3 + 0 mM NaCl (28 g kg^{-1}), 0 mM NaCl + nano Fe + KNO_3 (28.3 g kg^{-1}), and 0 mM NaCl + nano Zn + KNO_3 (29.6 g kg^{-1}) increased the nitrogen content of the plants. The lowest N content of 9.3 g kg^{-1} was observed in the 100 mM NaCl + without foliar applications (Table 7). Salinity stress disrupts the absorption of nutrients in plants [54]. Long-term salinity exposure decreased the absorption of magnesium, iron, phosphorus, and nitrogen in plants [32]. In grapes, salinity raised the sodium content in the plant, but the foliar spraying with iron nanoparticles increased the nitrogen content of the plant [34]. In the study that was conducted on sunflowers, salt stress decreased the contents of calcium, magnesium, potassium, and nitrogen [27]. The possible reason for improving the growth of nano-Fe treated plants is related to Fe nanoparticles' electromagnetic nature, which enhances Fe transfer from plasma membranes and intensifies the dynamics of fatty acids and proteins of cell membranes, which affect the membrane's permeability [55,56]. The foliar application of Fe and Zn increased the nitrogen content in *Pimpinella anisum* L. [56]. Nitrogen plays an important role in the structure of proteins, nucleic acids, cytokinins, and chlorophyll biosynthesis [31].

3.12.2. Phosphorus Content

The phosphorus content of the plants was affected by the salinity conditions and the foliar application (Table 6). The foliar application of KNO_3 + no salinity increased the phosphorus content of the plant to 6.6 g kg^{-1} dry weight, indicating that there was a 42% increase when it was compared to that of the control treatment (Table 7). In a study that was conducted on *Aloe vera*, the salinity conditions reduced the P content of the plant [32]. Another study found that salinity reduced wheat's uptake of calcium, magnesium, potassium, phosphorus, and nitrogen [57]. Phosphorus is a prominent essential element in plants, which plays an inevitable role in plant growth, root growth and development, and protein and carbohydrate biosynthesis. Phosphorus is the integral component of the cell membrane, DNA, and RNA, which performs crucial roles in the cell membrane's stability and energy supply (ATP). The availability of sufficient phosphorus amounts plays an important role in the plant's performance and product quality [31].

Table 6. ANOVA for the effect of salinity and foliar application (without spraying, potassium nitrate, and Zn and Fe nanoparticles) on Na, Fe, and Zn content and K/Na ratio of *Aloe vera* plants.

S.o.V.	DF	K/Na	Na	Fe	Zn
Salinity	2	1763 **	894 **	69,198 **	677 **
Foliar treatments	6	205 **	33.3 **	20,884 **	269 **
Treatments × Salinity	12	98 *	4.27 *	4029 *	19.8 *
Error	42	1.1	0.62	246	2.4
CV		11.4	9.1	7.4	7.3

* and ** indicate significant differences at 5 and 1% probability levels, respectively. S.o.V: source of variation; DF: degrees of freedom.

3.12.3. Potassium Content

The foliar application of potassium nitrate under no saline conditions increased the potassium content of the plants. When the plants were exposed to the high-salinity level of 100 mM, the foliar treatments could not compensate for the salinity defects in regulating the potassium content of the plants (Table 7). It was previously reported that the salinity stress reduced the potassium content in *Aloe vera* [32]. A decrease in the potassium content was reported in Gossypium hirsutum plants that were exposed to salinity conditions [44]. The foliar spraying with potassium sulfate improved the K content in the plant, which played a pivotal action in reducing the destructive effects of salinity stress [34]. ATPase provides the energy that is necessary for potassium absorption and sodium excretion through sodium/hydrogen anti-porters. Accumulating moderate amounts of potassium under stress conditions in *Aloe vera* leaves indicates the plant's efficiency in reducing the

harmful effects of stress, which contributes to a reasonable rate of plant survival and productivity [46,58]. Similar results were reported regarding the increase of the potassium content in coriander plants due to their foliar application of potassium nitrate [28]. Those studies showed that potassium uptake at the root tip declined due to the decreased H^+-ATPase pump activity under salinity stress. Moreover, the polarity of the cells decreased, and this led to the high production of oxygen free radicals under stress conditions in the plant [46]. Potassium accumulation in the vacuoles plays a vital role in the cellular expansion, respiration process, and stimulated absorption of calcium and magnesium in plants [31].

Table 7. The effect of salinity and foliar applications (without spraying, potassium nitrate, and Zn and Fe nanoparticles) on minerals content of *Aloe vera* plants.

Salinity	Treatments	N (g kg^{-1} DW)	P (g kg^{-1} DW)	K (g kg^{-1} DW)	Na (g kg^{-1} DW)	K/Na Ratio	Zn (mg kg^{-1} DW)	Fe (mg kg^{-1} DW)
0	Control	15.6 ± 1.24 gh	3.8 ± 0.61 f–i	48 ± 1.05 cd	3.9 ± 0.94 jk	12.3 ± 3.91 c	22.0 ± 0.21 fg	113 ± 3.39 gi
	Fe-NPs	20.3 ± 2.05 de	5.0 ± 0.24 bd	42 ± 1.63 eg	3.4 ± 0.47 k	12.2 ± 2.85 c	16.6 ± 1.24 ij	**383 ± 2.05 a**
	Zn-NPs	19.0 ± 1.24 ef	4.9 ± 0.49 bd	43 ± 1.63 eg	3.6 ± 0.56 ik	11.8 ± 3.23 c	**37.6 ± 0.47 a**	186 ± 1.69 gi
	KNO_3	**28.0 ± 1.80 a**	**6.6 ± 0.49 a**	**69 ± 1.41 a**	1.9 ± 0.55 lm	**35.2 ± 7.76 a**	27.3 ± 2.05 d	217 ± 2.35 ef
	Fe-NPs + Zn-NPs	24.0 ± 1.41 b	4.6 ± 0.51 df	35 ± 1.68 ij	3.2 ± 0.69 kl	10.8 ± 2.71 cd	34.6 ± 2.16 b	346 ± 1.63 b
	Fe-NPs + KNO_3	**28.3 ± 0.47 a**	5.6 ± 0.4.b	55 ± 2.86 b	1.5 ± 0.52 m	**36.0 ± 7.29 a**	20.6 ± 2.16 gh	249 ± 0.94 d
	Zn-NPs + KNO_3	**29.6 ± 0.47 a**	5.4 ± 0.40 bc	53 ± 2.86 b	2.7 ± 0.57 km	19.6 ± 5.47 b	31.0 ± 1.41 c	239 ± 0.47 de
50	Control	12.0 ± 1.63 j	3.4 ± 0.56 gk	39 ± 0.47 gi	10.7 ± 2.14 f	3.6 ± 1.06 fg	18.6 ± 1.24 hi	167 ± 0.88 ik
	Fe-NPs	15.0 ± 2.05 hi	3.9 ± 0.60 eh	35 ± 1.41 ij	8.6 ± 1.34 g	4.0 ± 1.14 fg	13.6 ± 1.24 kl	247 ± 2.05 d
	Zn-NPs	14.6 ± 1.88 hi	3.4 ± 0.40 gk	33 ± 1.88 jk	8.5 ± 1.34 g	33.9 ± 0.94 fg	26.6 ± 2.05 d	180 ± 2.05 hj
	KNO_3	17.6 ± 4.18 fg	4.1 ± 0.61 eg	51 ± 2.16 bc	5.8 ± 0.73 hi	8.7 ± 1.83 e	20.6 ± 0.45 gh	207 ± 1.41 fg
	Fe-NPs + Zn-NPs	16.3 ± 2.16 gh	3.9 ± 0.49 eh	37 ± 2.35 hj	6.9 ± 0.82 h	5.3 ± 1.20 f	22.0 ± 0.47 eg	293 ± 1.42 c
	Fe-NPs + KNO_3	21.3 ± 3.67 cd	4.5 ± 0.66 df	44 ± 2.62 df	4.7 ± 0.54 ij	9.3 ± 1.65 de	18.0 ± 0.45 hi	301 ± 1.24 c
	Zn-NPs + KNO_3	22.6 ± 2.44 bc	4.7 ± 0.91 ce	46 ± 4.10 de	5.6 ± 0.78 hi	8.2 ± 2.12 e	25.0 ± 2.82 de	205 ± 1.31 fh
100	Control	9.3 ± 1.24 k	2.7 ± 0.23 kl	29 ± 1.69 kl	**21.3 ± 1.69 a**	1.3 ± 0.21 j	12.3 ± 0.41 l	109 ± 1.69 m
	Fe-NPs	13.3 ± 1.24 ij	2.8 ± 0.23 jl	27 ± 2.05 l	15.3 ± 1.88 ed	1.7 ± 0.29 hj	9.0 ± 0.40 m	178 ± 1.53 ij
	Zn-NPs	12.0 ± 1.69 j	2.6 ± 0.14 l	27 ± 2.62 l	17.2 ± 0.94 b	1.6 ± 0.20 ij	18.6 ± 0.1 hi	117 ± 1.69 lm
	KNO_3	15.6 ± 1.69 gh	3.2 ± 0.28 hl	42 ± 0.81 eg	13.3 ± 0.94 e	3.1 ± 0.26 gi	15.0 ± 2.16 jk	144 ± 2.86 k
	Fe-NPs + Zn-NPs	16.0 ± 2.86 gh	2.5 ± 0.33 l	30 ± 2.86 kl	16.0 c ± 0.81	1.8 ± 0.16 hj	19.0 ± 1.88 hi	155 ± 2.05 jk
	Fe-NPs + KNO_3	20.6 ± 2.49 ce	3.1 ± 0.49 il	42 ± 3.55 eg	12.2 ± 0.94 f	3.4 ± 0.12 gh	13.3 ± 3.74 kl	182 ± 2.49 gi
	Zn-NPs + KNO_3	20.0 ± 2.45 de	3.5 ± 0.50 gj	40 ± 3.39 fh	14.6 ± 0.47 d	2.7 ± 0.18 gj	23.3 ± 0.51 ef	143 ± 1.63 kl
LSD		2.9	0.78	4.6	1.03	0	2.5	25

Different letters within each column indicate significant differences based on LSD test ($p < 0.05$), and the **bold** data are the treatments that received the significance level of a.

3.12.4. Sodium Content

The highest sodium content (21.3 g kg^{-1} dry weight) was observed in the 100 mM NaCl salinity without foliar applications treatment. The foliar applications reduced sodium content in the plants versus that which was recorded in the non-foliar treated ones and those that were exposed to 50 mM NaCl (Table 7). An increase in the sodium content due to salt stress has been reported in many plants, including *Aloe vera* [40], coriander [28], rosemary [26], and sunflower [27]. Feeding by Zn nanoparticles maintains the cell membranes' integrity and increases the plants' photosynthesis rate by reducing the rate of sodium uptake and protecting against toxic ions under stressful environments [59]. Under stress conditions, the disruption of cell membrane carriers increases the rate of sodium uptake due to its similar ion radius to potassium [60]. Foliar application of potassium nitrate under salinity stress reduced the adverse effects of salinity on the plants and helped to increase the plant yield by improving the potassium uptake [61]. The foliar application of Zn increased the potassium content in soybeans [4]. In rice plants, OSMADS31 gene expres-

sion (increasing the expression of carriers involved in potassium uptake and translocation during salinity stress) improved the level of salinity tolerance [62].

3.12.5. Potassium to Sodium Ratio

With a salinity level of 100 mM, the K^+/Na^+ ratio decreased in the plants (Table 7). The highest K^+/Na^+ ratio was observed by the foliar applications of KNO_3 × no salinity and nano Fe + KNO_3 (Table 7). Increasing the sodium uptake by the roots triggers ion disruption and reduces the root cells' membrane integrity, thereby leading to retarded growth and productivity. The high potassium concentrations that are found in stress-tolerant plant tissues are mainly due to the potassium ions' selective uptake [63]. As a result of the loss of the cell membrane's integrity under the salinity stress, the sodium ion content increased in the plants, but the potassium content decreased due to the occurrence of potassium leakage out of cells [3]. Electrophysiological studies showed that GORK channel (potassium out-of-cell channel) was activated due to cell depolarization and oxygen free radicals, which caused potassium to exit the cell. It seems that in the short term, the cell uses this strategy to regulate its electrical change, but as a long-term strategy, increasing the activity of the ATPase H^+- pump during stress is a preference that prevents the active absorption of sodium and helps to regulate the cell's electrical change energy consumption [64]. The potassium/sodium ratio is a suitable indicator for evaluating a plant's tolerance to salinity stress [65].

3.12.6. Fe Content

Control plants that were foliar sprayed with Fe nanoparticles had the highest Fe content (383 mg kg^{-1} dry weight) (Table 7). With increasing salinity strength, the foliar treatments had no significant effect on the Fe content of the plants. Salinity stress decreased the iron content in grapes, but their foliar spraying with iron nanoparticles improved the iron content of the plants [11]. The foliar spraying of corn with zinc and iron nanoparticles added to the content of both of these elements under the salinity stress conditions [42]. A reduction in the Fe content in *Aloe vera* under salinity stress was reported previously [32]. Furthermore, the content of iron, zinc, and manganese increased in response to a K foliar application under stress conditions [32]. The effect of Fe on plant growth, chlorophyll content, thylakoid formation, and chloroplast development is undeniable. Salinity stress affects enzymatic, physiological, biochemical, and antioxidant activities and ion homeostasis by creating an ionic imbalance [28,38].

3.12.7. Zn Content

The foliar application of Zn nanoparticles led to the maximum Zn content in the unstressed plants, indicating a 41% increase when we were comparing this to the controls (Table 7). Under salinity conditions, the Zn content was decreased in *Aloe vera* [32]. Similar results were reported regarding an increased Zn content due to the foliar application of Zn nanoparticles in corn [42]. Zn deficiency declines photosynthesis, chlorophyll content, stomatal conductance, respiration rate, and cytokinins biosynthesis and increases the plants' ion leakage and MDA content [26,28]. Zinc improves the nutrient uptake, IAA production and consequently stimulates new root emergence and meliorates the salinity depression [66]. The foliar application of zinc increases the potassium uptake and contributes to high plant growth under salinity stress. Zn plays an essential role in the biosynthesis of phenolic compounds and maintains the integrity of the cell membranes as well [60].

4. Conclusions

Salinity harmed the growth and physiological traits of *Aloe vera*. The foliar application of potassium nitrate, Fe, and zinc nanoparticles under salinity conditions improved the plant's physiological function and nutrients content. In general, the results showed that *Aloe vera* is partially salt-tolerant. However, the high salinity levels greatly influence its

physiological responses and yield. There is an emergent need to try other compounds and/or strategies to combat the salinity and extend Aloe production in saline-prone lands.

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References

1. Sevengor, S.; Yasar, F.; Kusvuran, S.; Ellialtioglu, S. The effect of salt stress on growth, chlorophyll content, lipid peroxidation and antioxidative enzymes of pumpkin seedling. *Afr. J. Agric. Res.* **2011**, *21*, 4920–4924.
2. Hussein, M.M.; Abou-Baker, N.H. The contribution of nano-zinc to alleviate salinity stress on cotton plants. *R. Soc. Open Sci.* **2018**, *5*, 171809. [CrossRef]
3. Shabala, S. Salinity and programmed cell death: Unraveling mechanisms for ion-specific signaling. *J. Exp. Bot.* **2009**, *60*, 709–712. [CrossRef] [PubMed]
4. Weisany, W.; Sohrabi, Y.; Heidari, G.R.; Siosemardeh, A.; Badakhshan, H. Effects of zinc application on growth, absorption and distribution of mineral nutrients under salinity stress in soybean (*Glycine Max* L.). *J. Plant Nutr.* **2014**, *37*, 2255–2269. [CrossRef]
5. Bandehagh, A.; Taylor, N. Can alternative metabolic pathways and shunts overcome salinity-induced inhibition of central carbon metabolism in crops? *Front. Plant Sci.* **2020**, *11*, 1072. [CrossRef]
6. Pandy, K.; Lahiani, M.H.; Hicks, V.K.; Keith Hudson, M.; Green, M.J.; Khodakovskaya, M. Effects of carbon-based nanomaterials on seed germination and biomes accumulation and salt stress response of bioenergy crops. *PLoS ONE* **2018**, *13*, e0202274.
7. Chrysargyrisa, A.; Solomoua, M.; Petropoulosb, S.A.; Tzortzakis, N. Physiological and biochemical attributes of *Mentha spicata* when subjected to saline conditions and cation foliar application. *J. Plant Physiol.* **2019**, *232*, 27–38. [CrossRef]
8. Torabian, S.; Zahedi, M.; Khoshgoftarmanesh, A. Effects of foliar spray of Zinc oxide on some antioxidant enzymes activity of sunflower under salt stress. *J. Agric. Sci. Technol.* **2016**, *18*, 1013–1025.
9. Amuamuha, L.; Pirzad, A.; Hadi, H. Effect of varying concentrations and time of nanoiron foliar application on the yield and essential oil of Pot marigold. *Int. Res. J. Appl. Basic Sci.* **2012**, *3*, 2085–2090.
10. Tavallali, V.; Rahemi, M.; Eshghi, S.; Kholdebarian, B.; Ramezanian, A. Zinc alleviates salt stress and increases antioxidant enzyme activity in the leaves of pistachio (*Pistacia vera* L. 'Badami') seedlings. *Turk. J. Agric. For.* **2010**, *34*, 349–359. [CrossRef]
11. Aazami, M.A.; Vojodi Mehrabani, L.; Hashemi, T.; Hassanpouraghdam, M.B.; Rasouli, F. Soil based nano-graphene oxide and foliar selenium and nano-Fe influence physiological responses of sultana grape under salinity. *Sci. Rep.* **2022**, *12*, 4234. [CrossRef] [PubMed]
12. Langmead, L.; Makins, R.J.; Rampton, D.S. Anti-inflammatory effects of *Aloe vera* gel in human colorectal mucosa in vitro. *Aliment. Pharmacol. Ther.* **2004**, *19*, 521–527. [CrossRef] [PubMed]
13. Calvin, J. *Aloe vera* Plant History Uses and Benefits. Disabled World towards Tomorrow. 2008. Available online: http://www.disabledworld.com/artman/publish/aloevera (accessed on 10 September 2022).
14. Botes, L.; van der Westhuizen, F.H.; Loots, D.T. Phytochemical contents and antioxidant capacities of two *Aloe greatheadii* var: Davyana, extracts. *Molecules* **2008**, *13*, 2169–2180. [CrossRef] [PubMed]
15. Olfati, J.A.; Moqbeli, E.; Fathollahi, S.; Estaji, A. Salinity stress effects changed during *Aloe vera* L. vegetative growth. *J. Stress Physiol. Biochem.* **2012**, *8*, 152–158.
16. Camel, V. Solid phase extraction of trace elements. *Spectrochim. Acta Part B At. Spectrosc.* **2003**, *58*, 1177–1233. [CrossRef]
17. Arnon, D.I. The copper enzyme in isolated chloroplast polyphenol oxidase in *Beta vulgaris*. *Plant Physiol.* **1949**, *24*, 1–15. [CrossRef]
18. Kim, K.H.; Tsao, R.; Yang, R.; Cui, S.W. Phenolic acid profiles and antioxidant activities of wheat bran extracts and the effect of hydrolysis conditions. *Food Chem.* **2006**, *95*, 466–473. [CrossRef]
19. Giannopolitis, C.N.; Ries, S.K. Superoxide dismutase II. Purification and quantities relationship with water-soluble protein in the seedling. *Plant Physiol.* **1977**, *50*, 315–318. [CrossRef]

20. Aebi, H. Catalase in vitro. *Methods Enzymol.* **1984**, *105*, 121–126.
21. Bates, L.; Waldren, R.P.; Teare, I.D. Rapid determination of free proline for water stress studies. *Plant Soil* **1973**, *39*, 205–207. [CrossRef]
22. Honarjoo, N.; Hajrasuliha, S.H.; Amini, H. Three plants in absorption of ions from different natural saline and sodic soils. *Int. J. Agric. Crop Sci.* **2013**, *6*, 988–993.
23. Ullah, M.A.; Rasheed, M.; Mohmood, I.A. *Aloe vera* (*Aloe Barbadeenis* Mill) screen at suitable salinity and sodicity level. *Hortic. Int. J.* **2018**, *2*, 365–367.
24. Moghbeli, I.; Fathollahi, S.; Salari, H.; Ahmadi, G.; Saliqehdar, F.; Sfari, A.; Hosseini Grouh, M.S. Effects of salinity stress on growth and yield of *Aloe vera* L. *J. Med. Plants Res.* **2012**, *6*, 3272–3277.
25. Hassanpouraghdam, M.B.; Vojodi Mehrabani, L.; Tzortzakis, N. Foliar application of nano-zinc and iron affects physiological attributes of *Rosmarinus officinalis* and quietens NaCl salinity depression. *J. Soil Sci. Plant Nutr.* **2019**, *20*, 335–345. [CrossRef]
26. Vojodi Mehrabani, L.; Hassanpouraghdam, M.B.; Shamsi-Khotab, T. The effects of common and nano-zinc foliar application on the alleviation of salinity stress in *Rosmarinus officinalis* L. *Acta Sci. Pol. Hortorum Cultus* **2018**, *17*, 65–73. [CrossRef]
27. Akram, M.S.; Ashraf, M.; Akram, N.A. Effectiveness of potassium sulfate mitigating salt-induced adverse effects different physio-biochemical attributes in sunflower (*Helianthus annuus* L.). *Flora* **2009**, *204*, 471–483. [CrossRef]
28. Elhindi, K.M.; El-Hendawy, S.; Abdel-Salam, E.; Schmidhalter, U.; Rehman, S.; Adl Hassan, A. Foliar application of potassium nitrate affects the growth and photosynthesis in coriander (*Coriander sativum* L.) plants under salinity. *Prog. Plant Nutr.* **2016**, *18*, 63–73.
29. Tang, G.Y.; Shao, F.X.; Xu, P.L.; Shan, L.; Liu, Z.J. Overexpression of a peanut NAC gene, AhNAC4, confers enhanced drought tolerance in tobacco. *Russ. J. Plant Physiol.* **2017**, *64*, 525–535. [CrossRef]
30. Abou El-Naser, M.K.; El-Hennawy, H.M.; El-Kereamy, A.M.H.; Abou El-yazied, A.; salah Eldin, T.A. Effect of magnetite nanoparticles (Fe_3O_4) as nutritive supplement on pear sapling. *Middle East J. Appl. Sci.* **2015**, *5*, 777–785.
31. Marschner, H. *Mineral Nutrition of Higher Plants*, 3rd ed.; Academic Press: London, UK, 2012.
32. Amador, B.M.; Cordoba-Motson, M.V.; Villega-Espinoza, J.A.; Hernandez- Montiel, L.G.; Troyo-Dieguez, E.; Garcia-Hernandez, L.G. Mineral content and biochemical variables of *Aloe vera* L. under salt stress. *PLoS ONE* **2014**, *9*, e94870. [CrossRef]
33. Souguir, D.; Abd-Alla, H.I.; El-Ferjani, E.; Larbikhouja, M.; Hachicha, M. *Aloe vera* long-term saline irrigation increased the content of hydrogen peroxide, lipid peroxidation, and phenolic compound. *Acta Agric. Candinavica Sect. B—Soil Plant Sci.* **2015**, *65*, 688–696. [CrossRef]
34. Karimi, R.; Mohammadparast, B.; Minazadeh, R. Photochemical responses and antioxidant activity of potassium-treated vines under salinity stress conditions. *J. Plant Process Funct.* **2019**, *8*, 245–260. (In Persian)
35. Carocho, M.; Ferreira, I.C.F.R. A review on antioxidants, prooxidants and related controversy: Natural and synthetic compounds, screening and analysis methodologies and future perspectives. *Food Chem. Toxicol.* **2013**, *51*, 15–25. [CrossRef] [PubMed]
36. Askary, M.; Telebi, S.M.; Amini, F.; Dosti Balout Bangan, A. Effects of iron nanoparticles on *Mentha piperita* L. under salinity stress. *Biologia* **2017**, *63*, 65–75. [CrossRef]
37. Idrees, M.; Naeem, M.; Khan, M.N.; Tariq, A.; Khan, M.A.; Moinuddin, M. Alleviation of salt stress in lemongrass by salicylic acid. *Protoplasma* **2011**, *249*, 709–720. [CrossRef]
38. Munns, R.; Tester, M. Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol.* **2008**, *59*, 651–681. [CrossRef]
39. Misra, A.; Srivastava, A.; Srivastava, N.; Khan, A. Zn-acquisition and its role in growth, photosynthesis, photosynthetic pigments, and biochemical changes in essential monoterpene oil (s) of *Pelargonium graveolens*. *Photosynthetica* **2005**, *43*, 153–155. [CrossRef]
40. Jiang, C.Q.; Quan, L.I.; Shi, F.; Yang, N.; Wang, C.H.; Yin, X.M.; Zheng, Q. Distribution of mineral nutrients and active ingredients in *Aloe vera* irrigated with diluted sea water. *Pedosphere* **2014**, *24*, 722–730. [CrossRef]
41. Soliman, A.S.S.; El-Feky, S.A.; Darwish, E. Alleviation of salt stress on *Moringa peregrine* using the foliar application of nano fertilizers. *J. Hortic. For.* **2015**, *7*, 36–47.
42. Fathi, A.; Zahedi, M.; Torabian, S. Effect of interaction between salinity and nanoparticles (Fe_2O_3 and ZnO) on physiological parameters of *Zea mays* L. *J. Plant Nutr.* **2017**, *40*, 2745–2755. [CrossRef]
43. Munns, R. Comparative physiology of salt and water stress. *Plant Cell Environ.* **2002**, *25*, 239–250. [CrossRef] [PubMed]
44. Dong, Y.J.; Wang, Z.L.; Zhang, J.W.; Liu, S.; He, Z.K.; He, M.R. Interaction effects of nitric oxide and salicylic acid in alleviating salt stress of *Gossypium hirsutum* L. *J. Soil Sci. Plant Nutr.* **2015**, *15*, 561–573.
45. Miller, G.W.; Huang, J.; Welkie, G.W.; Pushmik, J.C. The function of iron in plants with special emphasis on chloroplast and photosynthetic activity. In *Iron Nutrition in Soil and Plants*; Abadia, J., Ed.; Kluwer Academic Publishers: Dordecht, The Netherlands, 1995; pp. 19–28.
46. Shabala, L.; Zhangm, J.Y.; Pottosin, I.; Bose, J.; Zhu, M.; Fugisang, A.T.; Velarde-Buendia, A.; Massart, A.; Hill, C.B.; Ressner, U.; et al. Cell-type-specific H^+ -ATPase activity in root tissues enables K^+ retention and mediates acclimation of barley (*Hordeum vulgare*) to salinity stress. *Plant Physiol.* **2016**, *172*, 2445–2458. [CrossRef]
47. Mozafari, A.A.; Ghadakchi, A.; Ghaderi, N. Grape response to salinity stress and role of iron nanoparticle and potassium silicate to mitigate salt-induced damage under in vitro conditions. *Physiol. Mol. Biol. Plants* **2018**, *24*, 25–35. [CrossRef] [PubMed]
48. Van Raamsdonk, J.M.; Hekimi, S. Superoxide dismutase is dispensable for normal animal lifespan. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 5785–5790. [CrossRef] [PubMed]

49. Che-Othman, M.; Harvey Millar, A.; Taylor, L. Connecting salt stress signaling pathways with salinity induced changes in mitochondrial metabolic processes in C_3 plants. *Plant Cell Environ.* **2017**, *40*, 2875–2905. [CrossRef] [PubMed]
50. Chrysargyris, A.; Michailidi, E.; Tzortzakis, N. Physiological and biochemical responses of *Lavandula angustifolia* to salinity under the mineral foliar application. *Front. Plant Sci.* **2018**, *9*, 489. [CrossRef]
51. Venu, A.; Delvadia, D.V.; Chitroda, R.L.; Bhalani, R. Effect of zinc, boron, and iron application on physicochemical parameters of acid lime (*Citrus aurantifolia*) cv. Kagzi lime. *Bioscan* **2016**, *11*, 1597–1599.
52. Hu, M.; Shi, Z.; Zhang, Z.; Zhang, Y.; Li, H. Effects of exogenous glucose on seed germination and antioxidant capacity in wheat seedling under salt stress. *Plant Growth Regul.* **2012**, *68*, 177–188. [CrossRef]
53. Tabatabaie, S.J.; Nazari, J. Influence of nutrient concentrations and NaCl salinity on the growth, photosynthesis, and essential oil content of peppermint and *Lemon verbena*. *Turk. J. Agric. For.* **2007**, *31*, 245–253.
54. Baghalian, K.; Haghiry, A.; Naghavi, M.R.; Mohammadi, A. Effect of saline irrigation water on agronomical and phytochemical characters of chamomile (*Matricaria recutita* L.). *Sci. Hortic.* **2008**, *116*, 437–441. [CrossRef]
55. Stange, B.C.; Rowland, R.E.; Rapley, B.I.; Podd, J.V. ELF magnetic fields increase amino acid uptake into *Vicia faba* L. roots and alter ion movement across the plasma membrane. *Bioelectromagnetics* **2002**, *23*, 347–354. [CrossRef] [PubMed]
56. Pirzad, A.; Barin, M. Iron and zinc interaction on leaf nutrients and essential oil of *Pimpinella anisum* L. *Iran. J. Plant Physiol.* **2018**, *8*, 2507–2515.
57. El-Fouly, M.M.; Mobarak, Z.M.; Salama, Z.A. Micronutrients (Fe, Mn, Zn) foliar spray for increasing salinity tolerance in wheat *Triticum aestivum* L. *Afr. J. Plant Sci.* **2011**, *5*, 314–322.
58. Liu, Y.L.; Wang, L.J. Response to salt stress in plants and their salt tolerance. In *Plant Physiology and Molecular Biology*; Yu, S.W., Tang, Z.C., Eds.; Science Press: Beijing, China, 1998; pp. 752–769.
59. Tufail, A.; Li, H.; Naeem, A.; Li, T.X. Leaf cell membrane stability-based mechanisms of zinc nutrient in mitigating salinity stress in rice. *Plant Biol.* **2017**, *20*, 338–345. [CrossRef]
60. Apse, M.P.; Blumwald, E. Engineering salt tolerance in plants. *Curr. Opin. Biotechnol.* **2002**, *13*, 146–150. [CrossRef]
61. Zheng, Y.; Xu, X.; Simmons, M.; Zhang, C.; Gao, F.; Li, Z. Responses of physiological parameters, grain yield, and grain quality to foliar application of potassium nitrate in two contrasting winter wheat cultivars under salinity stress. *J. Plant Nutr. Soil Sci.* **2010**, *173*, 444–452. [CrossRef]
62. Yu, J.; Zhao, W.; He, U.; Yoon, M.Y.; Li, F.P.; Choi, B.; Heo, E.B.; Kim, K.W.; Park, Y.J. A genome-wide association study reveals candidate gene related to salt tolerance in rice (*Oryza sativa*) at the germination stage. *Int. J. Mol. Sci.* **2018**, *19*, 3145. [CrossRef]
63. Carden, D.E.; Walker, D.J.; Flowers, T.J.; Miller, A.J. Single-cell measurements of the contributions of cytosolic Na^+ and K^+ to salt tolerance. *Plant Physiol.* **2003**, *131*, 676–683. [CrossRef]
64. Shabala, S. Signaling by potassium: Another second messenger to add to the list? *J. Exp. Bot.* **2017**, *68*, 4003–4007. [CrossRef]
65. Demiral, T.; Turkan, I. Comparative lipid peroxidation, antioxidant defense system, and proline content in roots of two rice cultivars differing in salt tolerance. *Environ. Exp. Bot.* **2005**, *53*, 247–257. [CrossRef]
66. Pessarakli, M. *Handbook of Photosynthesis*, 3rd ed.; CRC Press: Boca Raton, FL, USA, 2016; 846p.