Study of the role of nano zinc in the growth and yield of two broad bean cultivars under the influence of different levels of salt stress

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Abstract:
Two field experiments were conducted in two different locations to study the effect of cultivar and foliar spraying with nano zinc on broad bean (Vicia faba L.) under salt stress. The experiment included three factors. The first factor was choosing three levels of salt concentration (sodium chloride NaCl) at levels (0, 10 and 20 g/L) where the salt was dissolved well in water and the necessary solution was made. The second factor was cultivars (Spanish cultivar Fito and the Italian cultivar Franchi) and the third factor was the levels of spraying with nano zinc (0, 25, 50 and 75 mg/L). The experiment included 12 treatments, each of which was distributed in three replicates using a split-split plot design within a complete randomized block design. The results were statistically analyzed using the SAS9.4 program and the results were compared using the Duncuun multinomial test at a probability level of 0.05. The results are summarized as follows:The plants grown in control treatment of salt in location of Babylon province and in location of the holy Karbala Province were significantly excelled on the rest of the salt concentrations in traits of fresh weight (359.4 g and 338.4 g), and dry (119.8 g and 120.0 g) respectively and in the number of branches on the plant 2.4 and 2.8 as well as the plant height 148.7 and 132.7 cm and the leaf area index 3.8 and 3.9.Also, for foliar spraying with nano zinc, the 75 mg/L treatment recorded excelled in all studied traits, as it recorded the highest fresh weight (350.1, 315.1 g), dry weight (116, 117.8 g), number of plant branches (3.9, 3.7 branches), plant height (140.2, 140.2 cm), and leaf area index (3.9, 3.7).
The triple interaction between the effect of salt, Spanish cultivar and spraying with zinc at a level of 75 mg/L had the greatest significant effect among the treatments, as it gave excelled in all the studied traits, as it recorded the highest fresh weight (445.2, 400.6 g) and dry weight (148.4, 152.2 g) and number of branches on the plant (5.2, 4.8) and plant height (157.6, 143.6 cm) and leaf area index (4.44, 4.42.(

Key word: nano zinc, broad bean, salt stress, Spanish cultivar

Introduction

broad bean (Vicia faba L.) is an annual legume crop, belonging to the legume family Fabaceae, which has a large number of species cultivated all over the world. Current estimates range from 16,000 to 19,000 plant species in about 750 genera in this family [2] where the legume family comes in second place after the Poaceae family in terms of economic importance. Currently, different species of the legume family grow in temperate regions, humid tropical regions, arid regions, highlands, savannas, and lowlands, and there are also a few aquatic legumes [7]. Faba vicia L. is one of the winter crops belonging to the legume family, and its seeds contain a high percentage of protein, estimated at 25-40% [6] This increases the importance of the crop due to its high nutritional value, in addition to the carbohydrates contained in the seeds, which may reach 56% in most cultivars. The importance of the broad bean crop is also due to its ability to improve soil properties by

ISSN 2072-3857

fixing atmospheric nitrogen in the soil through root nodules in coexistence with Rhizobium bacteria, so it is included in crop rotation (crop rotation) with the aim of improving soil conditions [3]. The broad bean crop adapts to a wide range of soil acidity levels, PH 4.5 to 8.3, but when the soil pH decreases, the rate of root nodule formation decreases, and thus the efficiency of atmospheric nitrogen fixation decreases. Currently, more than eight million hectares of land worldwide are affected by salinity, representing 6% of the world's total arable land area. It is expected that 30% of arable land will be lost within the next 25 years, and 50% by the middle of the 21st century ([5] . Soil salinity has become one of the most alarming environmental issues of the 21st century. With the increasing population to feed and the insufficient arable land, it has become necessary to solve the problem of soil salinity. There are two main methods to mitigate soil salinity, namely, using chemical amendments to restore salt-damaged soils; and using biotechnology to grow salt-tolerant cultivars. When it comes to comparing one with the other, the former is expensive and may pose the risk of secondary salinization.

Nanotechnology can provide solutions to increase the value of agricultural products and reduce environmental problems. Using nanoparticles and powders, we can produce fertilizers that are controlled and rapidly absorbed into the soil. Nanoparticles have high reactivity due to the increased specific surface area of the particles, or the increased density of plant-interacting zones, or by increasing the interaction of these zones on the particle surfaces. These features simplify the absorption process of fertilizers and pesticides produced at the nanoscale [4]. Based on the above, this study aimed to: Study of the role of nano zinc in the growth and yield of two broad bean cultivars under the influence of different levels of salt stress.

Materials and methods

Two field experiments were conducted to evaluate the effect of spraying with nano nutrients on the growth and yield of broad bean plants under salt stress conditions. For this purpose, two experiments were conducted in two different locations. The first location is located in Babylon Province in Al-Mahawil District, 35 km southwest of Babylon Province, while the second location is located in Karbala Province in the fields of the Al-Hussainiya Holy Shrine, Karbala-Najaf Road, Column (1155.(

The experimental land was prepared for cultivation by removing the remains of the previous crop and the existing weeds. Then the land was plowed twice perpendicularly with Mold-board plow and smoothed with disc harrows and then leveled with a leveling machine. The drip irrigation network was installed and represented by extending the main pipe with a diameter of one and a half inches, from which the field pipes of the strip type (T-tape) branched out. The distance between one pipe and another was 50 cm, which represents the distance between the planting lines. A small hole was made below the pipes. Irrigation where soil fertilizer was added to it and then mixed well in the soil where compound fertilizer 20:20:20 NPK was added at a rate of 200 kg ha. -1

Show the physical and chemical properties of the experimental soil for the two locations in Table 1.

Samples were taken from the field soil before adding fertilizers and from many different locations and at depths ranging from 0 to 30 cm where they were mixed well and a homogeneous sample was taken from each location and the chemical and physical analyses shown in Table 1 were conducted on it.

Table-1: Some physical and chemical properties of the experimental soil before planting for the two locations

units	Karbala Province	Babylon Province	traits	
-	8.65	7.8	PH	
Dsm	4.20	3.4	ECe	
	25	24	Cation exchange capacity	
$mg.kg^{-1}$	75	45	Nitrogen	
$mg.kg^{-1}$	9.3	15.27	Phosphorus	
$mg.kg^{-1}$	12.4	16.4	Potassium	
%	0.80	0.85	Organic matter	
$g.kg^{-1}$	12	10	Sand %	**soil**
$g.kg^{-1}$	60	58	silt %	
$g.kg^{-1}$	28	32	Clay %	
	Silty clay loam		**soil texture**	

Experimental factors and design used:

The experimental factors were as follows:

.1The first factor is NACL levels:

During this study, three levels of salt concentration (sodium chloride NaCl) were selected at levels (0, 10 and 20 g/L), where the salt was dissolved well in water and the necessary solution was made and the plants were treated to evaluate the plants' response to salt stress and the effect of adding nutrients from nano zinc oxide.

.2The second factor is cultivars:

During this study, two cultivars of broad beans were selected, the Spanish Fito (Luz De Otonu) and the second cultivar was the Italian Franchi.

.3The third factor is spraying with nano zinc (zinc oxide(

The nano zinc oxide product was obtained from the Spanish company DisPer, where zinc oxide was used at rates of (0, 25, 50 and 75) mg/L.

The experimental design was used in a split plot design with three replicates, where salt concentrations were placed in the main plots and cultivars were distributed in the sub-main plots while nano zinc spray treatments were distributed randomly in the sub-plots. The number of experimental plots was (3*2*3*4). The averages were compared according to the Least Significant Difference (L.S.D) test at a probability level of 5% [1] The field was divided into experimental units and the area of the experimental unit was (2*3) in the form of panels and each panel contained six lines with a length of 2 meters for each line, and the distance between one line and another was 50 cm. The broad beans seeds were planted after soaking them in water for 12 hours at a rate of two seeds in each hole at a depth of (4-5 cm) and a distance of (35 cm) between one hole and another. After three weeks of germination, thinning was done to leave one plant in each hole. The planting took place in the first half of October 2022, and when the plants reached

ISSN 2072-3857

30 days of age, foliar spraying was carried out on the green group for the first time with the specified concentrations of nutrients and the plants were irrigated with the specified concentrations of salt. The treatment was carried out again 30 days after the first treatment, and 10 days after the second treatment, the required readings were taken. The required concentrations of salt were prepared, the full amount was calculated for each experimental piece, placed in large containers and added to the treated plants. The nano-fertilizer was also prepared according to the required proportions and was supplemented with water to the required concentration. The Zahi material was added as a spreading material and the spraying process was carried out in the early morning to avoid the damage of high temperatures, dry leaves and their burning, as the spraying was done using a backpack sprayer with a capacity of (18 liters). As for control treatment, it was sprayed with water and Zahi only. Traits of the study: Five plants were randomly taken from each experimental unit and for all replicates, then the following measurements were made:

-1Leaf Area Index (LAI(

After 105 days of planting, 5 plants were randomly selected from each experimental unit to determine the Leaf Area Index (LAI) using a (Digital planimeter) device, where the plant leaf was placed on a white paper and then placed under the device lens, and the leaf was scanned using a (Scanner.(

-2Plant Height (cm:(

The height of the plants was measured using a metric measuring tape from the soil surface to the terminal bud in the main stem for five plants randomly selected from each experimental unit.

-3Number of branches/plant

It is the average number of branches for five randomly selected plants from each experimental unit.

-4Fresh plant weight (g.(

To estimate the fresh weight of the plant, five plants were randomly selected from each experimental unit after 105 days of planting and weighed directly from the field to determine the average fresh weight of the plant.

-5Dry weight of the plant (g.(

The dry weight of the plant was calculated by taking the entire plant from the field and air drying it, then weighing it with a sensitive balance to estimate the average dry weight/plant.

Statistical analysis:

All collected data were evaluated statistically using the analysis of variance (ANOVA) method for a split-plot design twice, and the differences were tested using the least significant difference (LSD) method at a probability level of 5%. SAS 9.4 for Windows was used to perform all data analysis.

Results and Discussion

-1Fresh weight of the plant

The results of Table 2 indicate a significant effect of the cultivar on the fresh weight of the plant, as the Fito cultivar excelled with the highest plant weight reaching 344.8 and 319.2 g in the two locations, respectively, while it decreased to 301.2 and 280 g in the Franchi cultivar in the Babylon and Karbala locations, respectively. The salt concentration had a significant effect on the fresh weight trait, as the plants grown at a concentration of 0 g/L excelled with the highest increase in the green/fresh plant weight, reaching 394.2 and 354.7 g, while it decreased to 259.9 and 233.9 g in the two cultivation locations, respectively. Foliar fertilization with nano zinc in Table 2 showed a significant effect on the trait, as the

ISSN 2072-3857

plants treated with Z3 concentration excelled, recording a fresh weight of 350.1 and 315.1 g, while it decreased in the plants not treated with zinc to 292.4 and 263.1 g in the Babylon and Karbala locations, respectively. The results of Table 2 showed a significant effect of bi-interaction between the cultivar and salt, as the plants of the 0 salt treatment and the Fito cultivar were distinguished by the highest value, reaching 406.4 and 382.6 g, while this value decreased to 287 and 260.9 g in the 10 salt treatment and the Franchi cultivar. The interaction between the cultivar and zinc concentration had a significant effect on the trait, as treatment V1Z3 was excelled with the highest vegetative weight of the plant reaching 377.6 and 339.8 g, and decreased to 269.9 and 242.9 in treatment V2Z0. The interaction between salt and foliar spraying with zinc had a significant effect on the trait (Table 2), as treatment Z3 plants and the control treatment were excelled on salt with the highest weight reaching 394.2 and 354.7 g, and the weight decreased to 259.9 and 233.9 g in treatment plants. Z0 The triple interaction between the cultivar, salt and foliar fertilization with nano zinc had a significant effect on the trait, as the Fito cultivar treatment, the zero salt concentration treatment and the third zinc concentration treatment were distinguished by the highest plant vegetative weight, reaching 445.2 g and 400.6 g, while it decreased to 94.1 and 222.8 g.

Table 2: Effect of zinc spraying on fresh weight in some broad bean cultivars under salt stress

Cultivars and salt interaction	**Nano zinc foliar spraying**				**salt stress**	**cultivars**
	Z3	**Z2**	**Z1**	**Z0**		
	First location: Babylon province					
406.4a	445.2a	435.1a	395.2ab	350.1bc	**0**	**Fito**
316.1b	347.1bc	338.1bcd	306.8c-g	272.2fgh	**10**	
311.9b	340.7bcd	317.4c-g	267.5gh	322.2c-g	**20**	
312.6b	343.3bcd	335.3cde	302.2c-h	269.5fg	**0**	**Franchi**
287.1c	315.2c-g	307.1c-g	247.6h	94.1h	**10**	
304.1bc	309.5c-g	326.5c-f	292.6c-g	292.6c-h	**20**	
Average salt	**350.1a**	**336.8b**	**312.7c**	**292.4d**	**Average zinc**	
359.4a	394.2a	385.2ab	348.7bc	309.7de	**0**	**Salt and zinc interaction**
301.5c	331.1cd	322.6cde	292.9ef	259.9f	**10**	
308.1b	325.1cde	302.5de	296.9def	307.5de	**20**	
average cultivars **344.8a**	377.6a	363.5b	323.1c	314.8cd	**Fito**	**Cultivars and zinc interaction**
301.2b	322.2c	310.1d	302.3e	269.9g	**Franchi**	

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Cultivars and salt interaction	**Second location: Karbala province**					**cultivars**
382.65a	400.6a	391.5a	355.6ab	315.1bc	**0**	**Fito**
297.6b	312.3bc	304.2bcd	276.1ef	244.9fg	**10**	
277.68c	306.6cde	285.6ef	240.7gh	289.9ef	**20**	
294.24b	308.9cde	301.7cde	271.9de	242.5fg	**0**	**Franchi**
260.97d	283.6def	276.3ef	222.8fh	273.1cd	10	
278.58c	278.5e	293.8ef	263.3gh	263.3gh	**20**	
Average salt	**315.1a**	**303.1b**	**281.4c**	**263.1d**	**Average zinc**	
338.43a	354.7a	346.6ab	313.8bc	278.7de	**0**	**Salt and zinc interaction**
283.98b	297.9cd	290.3cde	263.6ef	233.9f	**10**	
277.35c	292.5cde	272.2	267.2def	276.7de	**20**	
average cultivars **319.26a**	339.8	327.1	290.7	283.3	**Fito**	**Cultivars and zinc interaction**
280.38b	289.9	279.1	272.1	242.9	**Franchi**	
	N.S				**Collect both location**	

-2Dry weight

The results of Table 3 indicate a significant effect of different levels of salt concentrations, as the higher the salt concentration, the lower the dry weight of the plant, as control treatment (control) gave the highest dry weight of the plant in the Babylon and Karbala locations, where the dry weight value reached 119.8 and 121 g, respectively. The results of the same table indicate a significant effect of the cultivar on the dry weight of the plant, as the Fito cultivar excelled with the highest dry weight of the plant, reaching 114.9 and 105.9 g, while it decreased to 4.100 and 90.7 g in the Franchi cultivar in both locations, respectively (Table 3.(

Foliar fertilization with nano zinc showed a significant effect on the trait, as plants treated with Z3 concentration excelled, recording a weight of 116.7 and 117.8 g in the Babylon and Karbala locations, respectively, while it decreased in plants not treated with zinc to 97.4 and 98.3 g (Table 3). The results of the same table showed a significant effect of the bi-interaction between the cultivar and salt concentration, as the plants of control treatment and the first cultivar Fito were distinguished by the highest value of 135.5 and 145.6 g, while this value decreased to 95.7 and 99.3 g in the treatment with a concentration of 20 and the cultivar Franchi. The interaction between the cultivar and zinc concentration had a significant effect on the trait, as the V1Z3 treatment excelled with the highest dry weight of the plant, reaching 125.8 and 127.1 g, and decreased to 89.9 and 90.7 g

ISSN 2072-3857

in the V2Z0 treatment (Table 3). The interaction between salt concentration and foliar spraying with zinc had a significant effect on the trait, where the plants of control and zinc Z3 treatment excelled with the highest weight reaching 131.4 and 132.7 g, and the weight decreased to 86.6 and 87.4 g when not sprayed with zinc and the salt concentration was 10 g/L (Table 3). The triple interaction between salt concentration, cultivar and foliar fertilization with nano zinc (Table 3) had a significant effect on the trait, as control treatment of salt and zinc spraying at a concentration of 75 mg/L and the Fito cultivar was characterized by the highest dry weight of the plant, reaching 148.4 and 152.2 g, while it decreased to 82.5 and 85.6 g in the interaction treatment between salt concentration of 10 g and the Franchi cultivar without spraying with zinc.

Table 3: Effect of zinc spraying on dry weight in some broad bean cultivars under the influence of salt stress

Cultivars and salt interaction	**Nano zinc foliar spraying**				**salt stress**	**cultivars**
	Z3	**Z2**	**Z1**	**Z0**		
	First location: Babylon province					
135.5a	148.4a	145.1a	131.7b	116.6c	**0**	**Fito**
105.3b	115.7c	112.7cd	102.3de	90.7gh	**10**	
103.9b	113.6cd	105.8cd	89.2h	107.4de	**20**	
104.2b	114.4cd	111.8cd	100.7de	89.8gh	**0**	**Franchi**
95.7c	105.1cd	102.4de	92.7fg	82.5h	**10**	
101.4bc	103.2de	108.8cd	108.8cd	97.6fg	**20**	
Average salt	116.7a	112.2b	104.2c	97.4d	**Average zinc**	
119.8a	131.4a	128.4ab	116.2bc	103.2de	**0**	**Salt and zinc interaction النانوي**
100.5c	110.3cd	107.5cde	97.5ef	86.6f	**10**	
102.6b	108.4cde	100.8de	99.1de	102.3de	**20**	
average cultivars						**Cultivars and zinc interaction النانوي**
114.9a	125.8a	121.2a	107.7b	104.9b	**Fito**	
100.4b	107.5b	103.4b	100.7b	89.9c	**Franchi**	
Cultivars and salt interaction	**Second location: Karbala province**					**cultivars**
145.6a	152.2a	122.4d	155.8a	152.2a	**0**	**Fito**
109.2e	94.1g	119.8de	117.1e	106.1f	**10**	
142.1b	122.4cd	155.8a	152.3a	138.1b	**20**	
118.3c	106.4f	128.2c	125.3cd	113.5f	**0**	**Franchi**
115.1d	117.1de	119.8de	117.1de	85.6h	**10**	
99.35f	106.1f	108.9f	106.4f	96.5g	**20**	
Average salt	117.8a	113.3b	105.2c	98.3d	**Average zinc**	
121.0a	132.7a	129.6ab	117.3bc	104.2de	**0**	**Salt and zinc**

ISSN 2072-3857

101.5b	111.4cd	108.5cde	98.4ef	87.4f	**10**	**interaction النانوي**
103.7b	109.4cd	101.8de	100.1de	103.3de	**20**	
average cultivars	127.1a	122.4a	108.7b	105.9b	**Fito**	**Cultivars and zinc interaction النانوي**
105.9a						
90.7b	108.5b	104.4b	101.7b	90.7c	**Franchi**	
	N.S				**Collect both location**	

-3Number of branches on the plant

The results of Table4 show that the rate of branch production on the plant has a negative effect as the salt concentration increases, as the number of branches on the plant decreased in the third salt concentration (20 g/L), and the highest number of branches on the plant was recorded at a value of 3.2 and 3.9 branches with a concentration of 10 g/L, and there is no significant difference between it and the concentration of 20 g/L.

It is noted from the results in Table4 that there is a significant effect of the cultivar on the number of branches on the plant, as the Fito cultivar gave the highest number of branches on the plant, reaching 3.1 branches, while it decreased to 2.8 branches in the Franchi cultivar.

Foliar spraying with zinc showed a significant effect on the index of the number of branches (Table4), as the plants treated with the concentration Z3 excelled with the highest value of 3.9 in Babylon and 3.7 in Karbala, while it decreased to 2 and 1.3 branches per plant in control treatment plants Z0 in both locations, respectively. The results of the same table showed that bi-interaction between the cultivar and nano zinc spraying had significant differences, as the Z3 zinc spraying treatments excelled the Fito cultivar with the highest value in the number of branches, reaching 3.9 in both locations, unlike the Franchi cultivar, which gave lower values without foliar zinc spraying Z0.

While the interaction between salt concentrations and foliar zinc spraying showed significant differences, as the concentration of 10 salt and the concentration of Z0 recorded the highest number of branches during the study (Table4.(

Table4 showed that the interaction between salt concentration and cultivar had significant differences, as the Fito cultivar showed a higher value during cultivation at a concentration of 0 grams/liter, with a value of 3.2 branches per plant, thus outperforming the Franchi cultivar. The data in Table4 showed a significant three-way interaction between all study factors, where the treatment 0 of salt, the Fito cultivar, and spraying with zinc at a concentration of 75 g/L gave the highest number of branches per plant with a value of 5.2, while the lowest treatment was the salt 10 g/L, the Fito cultivar, and spraying with zinc at a concentration of 0 g/L.

ISSN 2072-3857

Table 4. Effect of spraying with zinc on the number of branches in some broad bean cultivars under the influence of salt stress

Cultivars and salt interaction	Nano zinc foliar spraying				Salt stress	cultivars
	Z3	Z2	Z1	Z0		
	First location: Babylon province					
3.1a	5.2a	2.8bcde	3.3abc	1.9de	0	Fito
2.2b	3.8abcd	1.7de	2.0cde	1.4e	10	
2.9ab	2.9bcde	2.7cde	4.1abc	2.2cde	20	
2.6ab	3.7abcd	2.3cde	2.8cde	4.7a	0	Franchi
3.0ab	4.8ab	2.4bcde	3.6abcd	2.2cde	10	
3.0a	3.0bcde	3.1abcde	3.3abcde	2.6cde	20	
Average salt	3.9a	2.5c	3.1b	2.0d	Average nano zinc	
2.4b	1.9d	1.9de	2.4de	2.0de	0	Salt and nano zinc interaction
3.2a	1.5e	2.5cde	3.2abc	5.1a	10	
3.1a	2.4de	3bcd	3.9ab	3.7ab	20	
average cultivars						
3.1a	3.9a	2.2de	2.9bcd	1.8e	Fito	Cultivars and zinc interaction nano
2.8b	2.2de	2.8cde	3.3abc	3.8ab	Franchi	
Cultivars and salt interaction	Second location: Karbala provainc					cultivars
3.2a	4.80a	2.20cd	2.83 cd	3.60bc	0	Fito
3.1a	5.10a	1.90 de	2.30cd	2.73cd	10	
2.9ab	2.27 cd	1.17ef	1.17ef	1.77e	20	
2.6b	4.06 ab	1.76 e	2.10 cd	2.70 cd	0	Franchi
2.6b	3.67 bc	1.70e	2.20cd	2.77 cd	10	
2.2c	3.87 abc	1.47ef	1.77e	2.07cd	20	
Average salt	3.73 a	1.90b	1.90b	1.37c	Average nano zinc	
2.8a	4.5a	1.9e	2.4	2.0de	0	Salt and nano zinc interaction
3.9a	3.5b	2.5cde	3.2b	5.1a	10	
3.5a	2.4de	3bcd	3.9b	3.7b	20	
average cultivars						
3.1a	3.9a	2.2de	2.9bcd	1.8e	Fito	Cultivars and zinc interaction nano
2.8b	2.2de	2.8cde	3.3abc	3.8ab	Franchi	
	N.S.				Collect both location	

ISSN 2072-3857

-4Plant height (cm(

The results of Table 5 indicate that there is a significant effect of the cultivar on the plant height, as the Fito cultivar surpassed the highest height of 131.6 cm, while it decreased to 122.2 cm in the Franchi cultivar. The salt concentration had a significant effect on the trait, as the plants grown in the soil under a concentration of 0 (control) of salt exceeded the highest height of 132.7 cm, while it decreased to 114.3 cm in the concentration of 20 g. Foliar fertilization with nano zinc showed a significant effect on the trait, as plants treated with Z3 concentration were excelled in height, reaching 140.2 cm, while it decreased in plants not treated with zinc to 105.6 cm. The results of Table 5 showed a significant effect of the bi-interaction between the cultivar and the cultivation location, as the plants of the 0 (control) salt treatment and the Fito cultivar were distinguished by the highest value of 149 and 142.4 cm in the two cultivation locations, while this value decreased to 106.3 cm in the 20 g treatment with the second cultivar. The interaction between the cultivar and zinc concentration had a significant effect on the trait, as the V1Z3 treatment was excelled with the highest height of 146.5 cm in Babylon, while it was 135.5 cm in Karbala and decreased to 99 cm in the V2Z0 treatment in Babylon 102 cm in Karbala and the interaction between salt concentration and foliar spraying with zinc had a significant effect on the trait, as the plants treated with salt concentration 0 and spraying with zinc Z3 were excelled with the highest height reaching 152.6 and 140.2 cm in both locations, and the height decreased to 99 cm in the plants treated with Z0 and concentration 20 g/L. The triple interaction between the cultivar, salt concentration and foliar fertilization with nano zinc had a significant effect on the trait, as the zero treatment, the Fito cultivar and the Z2 concentration were characterized by the highest height of 158.2 and 148.2 cm, while it decreased to 94.1 cm in the interaction treatment between salt at a concentration of 10 and the second cultivar and no zinc treatment (Table 5 .(

Table 5 Effect of cultivar and nano zinc spraying on the height of broad bean plants under salt stress

Cultivars and salt interaction	**Nano zinc foliar spraying**				**salt stress**	**cultivars**
	Z3	**Z2**	**Z1**	**Z0**		
	First location: Babylon province					
149.4a	157.6a	158.2a	154.4ab	143gh	**0**	**Fito**
123.7b	135.1bc	131.6cd	121.1de	103.2gh	**10**	
121.8b	132.7cd	125.1de	103.1gh	126.3de	**20**	
148.1a	151.6a	149.1a	154.1ab	135.2h	**0**	**Franchi**
106.3c	115.3ef	112.7ef	103.2gh	94.1h	**10**	
106.7c	113efgh	103gh	103.2gh	107.8fgh	**20**	
Average salt	140.2a	134.9b	123.2c	105.6d	**Average nano zinc**	
148.7a	152.6a	148.7a	154.3 a	137.3c	**0**	**Salt and zinc interaction**
115.1b	125.2d	122.2d	112.1ef	100.5f	**10**	

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114.3b	122.8d	114.1e	103.1fg	117.1d	**20**	
average cultivars						
131.6a	146.5a	141.6ab	126.2cd	112.2e	**Fito**	**Cultivars and zinc interaction**
120.4b	133.9bc	128.3cd	120.2de	99.0f	**Franchi**	
Cultivars and salt interaction	**Second location: Karbala province**					**cultivars**
142.4a	143.6a	148.2a	144.4ab	135bc	**0**	**Fito**
123.7c	135.1bc	131.6c	121.1cd	103.2gh	**10**	
121.8c	132.7cd	125.1cd	113.1gh	116.3ef	**20**	
137.1b	141.6a	139.1a	134.1ab	129cd	**0**	**Franchi**
106.3d	115.3efg	112.7efg	103.2g	94.1h	**10**	
106.7d	113efgh	103gh	103.2gh	107.8fgh	**20**	
Average salt	140.2a	134.9b	123.2c	105.6d	**Average nano zinc**	
132.7a	138.95a	135.14b	130.07c	120.26 e	**0**	**Salt and zinc interaction**
115.1b	125.2d	122.2cd	112.1def	100.5gf	**10**	
114.3b	122.8cd	114.1cde	103.1efg	117.1cd	**20**	
average cultivars						
131.6a	135.5a	131.6ab	126.2cd	112.2e	**Fito**	**Cultivars and zinc interaction**
122.2b	133.9bc	128.3cd	120.2de	102f	**Franchi**	
	N.S.				**Collect both location**	

-Leaf area index of the plant

It is noted from the results in Table 6 that there is a significant effect of the cultivar on the leaf area, as the Fito cultivar gave the largest area of 3.9, while it decreased to 3.5 in the Franchi cultivar. The treatment with salt concentrations showed a significant effect, as the plants not treated with salt are the best in leaf area rate, and foliar spraying with zinc showed a significant effect on the leaf area index, as the plants treated with Z3 concentration excelled with the highest value of 3.9, while it decreased to 3.5 in control treatment plants. Z0

The results of Table 6 showed that there were significant differences in the bi-interaction between the cultivar and nano zinc spraying, as zinc spraying treatments excelled the Fito cultivar with the highest value in the leaf area index, unlike the Franchi cultivar, which gave lower values with foliar zinc spraying. As for the interaction between salt concentrations and the cultivar, it was found that there were significant differences, where the Fito cultivar showed a higher value during cultivation with control treatment of salt, as well as in cultivation at a concentration of 10 g/L sodium chloride, with a value of 4.1 and 3.9 in the Babylon and Karbala locations, respectively, outperforming the Franchi cultivar, which gave the lowest leaf area index. The data in the table showed a significant triple interaction between all study factors, where control treatment, the Fito cultivar, and spraying with

ISSN 2072-3857

zinc at a concentration of Z3 resulted in the highest leaf area index of 4.4 in the provinces of Babylon and Karbala.

Table 6 Effect of cultivar and spraying with nano zinc on the leaf area index of broad beans under salt stress conditions

Cultivars and salt interaction	Nano zinc foliar spraying				salt stress	cultivars
	Z3	Z2	Z1	Z0		
	First location: Babylon province					
4.1a	4.4ab	3.7abc	4.3ab	3.8ab	**0**	**Fito**
4.1a	4.3ab	4.1ab	4.4a	3.2bcd	**10**	
3.6ab	4.2ab	3.3abcd	3.4abcd	3.8abc	**20**	
2.9c	3.4abcd	3.4abcd	2.6cd	2.5d	**0**	**Franchi**
3.5b	3.7abc	4.1ab	3.5abcd	3.8abc	**10**	
3.6ab	4.1ab	3.9ab	4.1ab	3.2d	**20**	
Average salt	3.9a	3.7ab	3.6b	3.5b	**Average nano zinc**	
3.8a	4.2a	3.6ab	3.7ab	3.7ab	**0**	**Salt and nano zinc interaction**
3.5ab	3.8ab	3.7ab	3.9a	3.5ab	**10**	
3.5b	3.7ab	3.6qb	3.5ab	3.2b	**20**	
average cultivars	4.3a	3.7bc	4.1ab	3.6bc	**Fito**	**Cultivars and nano zinc interaction**
3.9a						
3.5b	3.6bc	3.5bc	3.4c	3.4c	**Franchi**	
Cultivars and salt interaction	**Second location: Karbala province**					**cultivars**
3.95a	4.42 a	3.95 d	3.27 g	4.18 c	**0**	**Fito**
3.5b	3.21 f	3.87 c	3.06 c	3.48 e	**10**	
3.1c	3.54 f	3.30 g	3.30 g	2.47 f	**20**	
3.9a	4.30 a	4.30 a	3.14 b	3.99 b	**0**	**Franchi**
3.2c	3.63 d	3.43 e	3.41 e	2.50 g	**10**	
3.2c	3.26 g	3.19 f	3.10 5	3.54 f	**20**	
3.46 b	3.74 a	3.67 b	3.46 c	3.4 c	**Average nano zinc**	
3.94a	4.3a	4.1a	3.2 bc	4.1a	**0**	**Salt and zinc interaction**
3.32b	3.4b	3.6b	3.2 bc	2.9d	**10**	
3.21c	3.4b	3.2bc	3.2 bc	3.1c	**20**	
average cultivars	3.7a	3.7a	3.2bc	3.4b	**Fito**	**Cultivars and zinc interaction**
3.5a						
3.4a	3.7a	3.6a	3.2bc	3.3b	**Franchi**	
	N.S.				**Collect both location**	

ISSN 2072-3857

Conclusions

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The plants grown in zero salt concentration in Babylon and Karbala location were significantly excelled on the rest of the salt concentrations in fresh and dry weight (359.4 g and 338.4 g), dry (119.8 g and 120.0 g) respectively, and in the number of branches per plant 2.4 and 2.8, as well as plant height 148.7 and 132.7 cm and leaf area index 3.8 and 3.9 Also for foliar spraying with nano zinc, the 75 mg/L treatment recorded excelled in all studied traits, as it recorded the highest fresh weight (350.1, 315.1 g) and dry weight (116, 117.8 g) and number of branches per plant (3.9, 3.7 branches) and plant height (140.2, 140.2 cm) and leaf area index (3.9, 3.7)The triple interaction between zero salt concentration, Spanish cultivar and zinc spraying at 75 mg/L had the most significant effect among the treatments, as it gave excelled in all studied traits, recording the highest fresh weight (445.2, 400.6 g) and dry weight (148.4, 152.2 g) and number of branches on the plant (5.2, 4.8) plant height (157.6, 143.6 cm) and leaf area index (4.44, 4.42.(

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ISSN 2072-3857