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Research Article

The Effect of Nano Potassium Foliar Application on Some Morphological Traits and Growth Yield of (Vicia faba L.) Plants under saline condition

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Abstract

A study was conducted to investigate the effect of nano-potassium foliar application on some morphological traits (plant height, stem diameter, number of branches, number of leaves, leaf area, number of flowers, number of seeds, weight of fresh seeds, and pod weight), as well as the growth and yield of faba bean (*Vicia faba* L.) plants exposed to salinity stress.

A factorial experiment was carried out in plastic pots using a Completely Randomized Design (CRD) with four replications in the city of Karbala during the 2023-2024 growing season. The first factor involved irrigation with four levels of saline water (2, 4, 6, and 8 dS m^{-1}), prepared by mixing well water with tap water. The second factor involved foliar spraying of nano-potassium at four concentrations (0, 50, 100, and 150 mg L^{-1}) applied in two equal doses for each level: the first at the three-leaf stage and the second at 100% flowering stage.

The experiment included 64 experimental units. The results were statistically analyzed, and the means of the studied traits were compared using the Least Significant Difference (LSD) test at a 0.05 probability level.

The results showed that irrigation with saline water significantly reduced all the studied morphological traits. In contrast, foliar application of nano-potassium had a significant positive effect on improving some of these traits .

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Introduction

Faba bean (*Vicia faba* L.) belongs to the Fabaceae family and represents an important food crop due to its high protein content in seeds[1]. Faba bean seeds are an essential protein source (35%) and contain significant amounts of potassium, calcium, iron, zinc, and magnesium [2]. Additionally, faba beans are rich in vitamin C, which is not present in other legumes like beans [3].

Salinity affects cell growth and water uptake, reducing turgor pressure and limiting vital biochemical processes, which negatively impacts the plant's morphological traits [4]. Salinity stress reduces plant growth due to osmotic stress caused by the presence of salts and ionic effects resulting from salt accumulation in leaves. This stress induces stomatal closure, impeding CO_2 fixation, which increases energy demand in chloroplasts [5]. [6] stated that stomatal closure due to saline irrigation decreases CO_2 intake, reducing the leaves' photosynthetic capacity and, consequently, seed productivity. Salinity also causes metabolic changes and reduces water transport to the leaves [7]

[8] reported that salinity affects water absorption by seeds in chickpea and inhibits cell division and elongation, thereby reducing plant growth and nutrient uptake [9]. [10]attributed reduced plant height to increased salinity levels in irrigation water, which limits the uptake of essential nutrients. [11] observed reductions in leaf count, branch number, and fresh seed production due to high salt concentrations, which increase the osmotic pressure in cells.

Potassium plays a critical role in activating enzymes, facilitating photosynthesis, transporting sugars and proteins, and starch formation. It interacts with nitrogen during plant growth to enhance productivity [12]. Adding potassium increases seed and pod numbers as it accelerates enzyme activity, promoting protein synthesis [13]. Potassium also improves plant height, leaf count, flowering, and leaf area by enhancing the uptake of essential nutrients. Nano-potassium fertilizer physiologically enhances plant development, offering higher absorption efficiency and greater stress tolerance [14].

Materials and Methods

A factorial experiment was conducted in plastic pots at a nursery in Karbala Province during the 2023-2024 agricultural season to study the effect of nano-potassium foliar application on some phenotypic traits, growth, and yield of faba bean (*Vicia faba L.*) irrigated with saline water.

The experiment utilized sandy loam soil with an electrical conductivity of 2 dS m^{-1}. The air-dried soil was sieved using a 2 mm mesh and packed into plastic pots (30 cm in diameter and 35 cm in height) at a rate of 25 kg per pot. A soil sample was collected prior to planting to determine its physical and chemical properties, as shown in Table 1, following the standard methods described by [15]

The experiment was designed as a factorial arrangement within a Completely Randomized Design (CRD) with four replicates. The first factor involved irrigation with saline water at four salinity levels (2, 4, 6, and 8 dS m^{-1}), prepared by diluting well water from the University of Karbala with tap water to achieve the desired salinity levels. Table 2 presents the chemical analysis of the irrigation water.

The second factor included the application of nano-potassium fertilizer through foliar spraying at four concentrations (0, 50, 100, and 150 mg L^{-1}), applied in two equal doses: the first at the three-leaf stage and the second at 100% flowering. This setup resulted in a total of 64 experimental units.

Nutrient fertilization was applied at 50 kg ha^{-1} of nitrogen from urea, in three doses: the first after germination, the second one month later, and the third two months after the second application, with all doses applied as a foliar spray. Phosphorus was added at 50 kg ha^{-1} from calcium superphosphate before planting.

Five faba bean seeds were sown per pot, spaced equally at a depth of 2 cm, and later thinned to three plants per pot. The experimental units were irrigated with saline water as per the salinity treatments, maintaining soil moisture near field capacity.

The experiment studied various phenotypic traits for each plant, including: Plant height [16]. Stem diameter(Measured using Vernier calipers) . Number of branches and leaves. Leaf area [17], Number of flowers , seeds and pods per plant. Seed weight and pod weight. Statistical analyses were conducted using the Statistical Analysis System (SAS), and the significance of differences between treatment means was tested using the Least Significant Difference (LSD) test at a significance level of 0.05.

Table (1) Some physical and chemical properties of the soil used in the experiment

Adjective		Value	unit
$pH_{1:1}$		7.70	——
Electrical conductivity (EC_e)		2.00	ds m^{-1}
Organic matter		8.62	gm kg^{-1}
carbonate minerals		430.00	gm kg^{-1}
organic carbon		5.00	
Gypsum		5.40	
CEC		12.80	Cmol (+) kg^{-1}
SAR		1.70	%
ESP		1.23	
Soluble cations	Ca^{2+}	11.40	meq L^{-1}
	Mg^{2+}	9.60	
	Na^{+}	7.80	
	K^{+}	0.62	
Soluble anions	SO_4^{2-}	8.10	
	CO_3^{2-}	Nill	
	HCO_3^{-}	8.00	
	Cl^{-}	13.20	
Available N		10.50	gm kg^{-1}
Available P		13.30	
Available K		88.90	
Texture Loamy sand	Sand	815.00	gm kg^{-1}
	Silt	92.00	
	Clay	93.00	

* Analyses was done at the laboratory of College of Agricultural Engineering Sciences - University of Baghdad

Table (2) Chemical analysis of irrigation water used in the irrigation process

Adjective	Irrigation water salinity levels (ds m-1)			
	(2) S1	(4) S2	(6) S3	(8) S4
pH	8. 15	8.22	8.32	8.38
Electrical conductivity EC dsm^{-1}	1.82	3.86	5.9	7.75
Calcium mg/L^{-1}	88.17	90.0	96.2	192.38
Magnesium mg/L^{-1}	14.1	16.81	25.86	28.08
Sodium mg/L^{-1}	206.5	625	2073	1691
Potassium mg/L^{-1}	9.5	21	49	57
Chloride mg/L^{-1}	1063.5	1354.5	1949.7	2304.25
Bicarbonate mg L^{-1}	100.04	112	117.12	146.4
Sulfate mg L^{-1}	813.1	502.81	1258.34	1464.91

Results

Plant Height Average (cm):

The results presented in Table (3) illustrate the effect of nano-potassium foliar application on the plant height of faba bean under salinity stress. Statistical analysis revealed a significant effect of irrigation water salinity on plant height. A decrease in plant height was observed with increasing irrigation water salinity levels. The height of faba bean plants decreased by 33.83%, 39.87%, and 45.63% at salinity levels of 4, 6, and 8 dS m^{-1}, respectively, compared to irrigation with water at 2 dS m^{-1} salinity.

Table (3) The effect of spraying with nano potassium on the rate of height of faba bean plants (cm) exposed to salt stress.

Levels of irrigation water salinity (dS m^{-1}) S	Spray levels of nano-potassium (mg L^{-1}) K				S rate
	0	**50**	**100**	**150**	
2	79.83	88.33	90.16	94.50	88.20
4	57.29	58.66	60.66	56.83	58.36
6	47.83	56.50	56.66	51.12	53.03
8	46.33	49.00	50.83	46.66	47.95
K rate	57.82	63.12	64.58	62.27	
L . S . D 0.05	K	S	K*S		
	2.8066	2.8066	5.6132		

The results also showed that nano-potassium foliar application significantly increased plant height. The height increased by 9.16%, 11.69%, and 7.69% at nano-potassium concentrations of 50, 100, and 150 mg L^{-1}, respectively, compared to the control (no foliar application). The highest plant height was recorded at the 100 mg L^{-1} level, reaching 64.58 cm, which was not significantly different from the values at 50 and 150 mg L^{-1}.

Regarding the interaction between the two factors (irrigation water salinity and nano-potassium fertilization), the treatment with 150 mg L^{-1} of nano-potassium combined with irrigation at 2 dS m^{-1} salinity achieved the highest plant height of 94.50 cm, representing an increase of 103.97% compared to the lowest value of 45.66 cm, observed in the control treatment (no foliar application) with irrigation at 8 dS m^{-1} salinity.

Stem Diameter Average (mm):

The results presented in Table (4) demonstrate the effect of nano-potassium foliar application on the stem diameter of faba bean under salinity stress. Statistical analysis revealed a significant effect of irrigation water salinity on stem diameter, with a decrease observed as salinity levels increased. The stem diameter decreased by 8.00%, 22.00%, and 36.00% at salinity levels of 4, 6, and 8 dS m^{-1}, respectively, compared to its value at 2 dS m^{-1} salinity.

The results also indicated that nano-potassium foliar application led to a significant increase in stem diameter, with an increase of 16.66% observed at the 50 mg L^{-1} and 150 mg L^{-1} levels compared to the control (no application). The highest stem diameter was recorded at the 100 mg L^{-1} level, reaching 0.48 mm, representing an increase of 33.33% compared to the control treatment.

Regarding the interaction between the two factors (irrigation water salinity and nano-potassium fertilization), the treatment with 100 mg L^{-1} of nano-potassium combined with irrigation at 2 dS m^{-1} salinity achieved the highest stem diameter of 0.62 mm, representing an increase of 129.62% compared to the lowest value of 0.27 mm observed in the control treatment (no foliar application) with irrigation at 8 dS m^{-1} salinity.

Table (4) The effect of spraying with nano potassium on the average stem diameter (mm) of faba beans exposed to salt stress.

Salinity levels of irrigation water (dS m⁻ ¹) S	Spray levels of nano-potassium (mg L⁻¹) K				S rate
	0	**50**	**100**	**150**	
2	0.40	0.46	0.62	0.52	0.50
4	0.40	0.45	0.52	0.50	0.46
6	0.36	0.43	0.40	0.37	0.39
8	0.27	0.33	0.39	0.30	0.32
K rate	0.36	0.42	0.48	0.42	
L .S.D 0.05	K		S	K*S	
	0.0381		0.0381	0.0762	

Average number of plant branches:

The results presented in Table (5) illustrate the effect of nano-potassium foliar application on the number of branches of faba bean plants under salinity stress. Statistical analysis showed a significant decrease in the number of branches due to the irrigation water salinity factor. A reduction in this trait was observed with increasing irrigation water salinity, with percentage decreases of: (18.65% and 24.46%) at salinity levels of 6 and 8 dS m⁻ ¹, respectively, with no significant difference between them compared to the salinity level of 2 dS m⁻ ¹.

The results indicated that nano-potassium foliar application led to a significant increase in the number of branches, with percentage increases of 37.12%, 67.82%, and 56.43% at the application levels of 50, 100, and 150 mg L⁻ ¹, respectively, compared to the control treatment (no foliar application). The number of branches in faba bean plants increased at the 100 mg L⁻ ¹ level, reaching 3.39 branches, which did not differ significantly from the values at the 150 mg L⁻ ¹ level.

Regarding the interaction between the two factors (irrigation water salinity and nano-potassium fertilization), the treatment with 100 mg L⁻ ¹ nano-potassium combined with irrigation at 2 dS m⁻ ¹ salinity achieved the highest number of branches, reaching 4.08 branches, representing an increase of 133.14% compared to the lowest value of 1.75 branches, observed in the control treatment (no foliar application) with irrigation at 8 dS m⁻ ¹ salinity.

Table (5) The effect of spraying with nano potassium on the average number of branches of fava beans exposed to salt stress.

Salinity levels of irrigation water (dS m^{-1}) S	Spray levels of nano-potassium (mg L^{-1}) K				S rate
	0	**50**	**100**	**150**	
2	2.33	3.00	3.27	3.66	3.27
4	2.16	2.91	2.93	3.33	2.93
6	1.83	2.66	2.66	3.00	2.66
8	1.75	2.50	2.47	2.66	2.47
K rate	2.02	2.77	3.39	3.16	
L . S .D 0.05	K: 0.4468		S: 0.4468	K*S: 0.8935	

Average Number of Leaves (Leaf per Plant^{-1}) :

The results presented in Table (6) indicate the effect of nano-potassium foliar application on the number of leaves in faba bean plants under salinity stress. Statistical analysis revealed a significant decrease in the number of leaves with increasing irrigation water salinity. The highest number of leaves was recorded at a salinity level of 2 dS m^{-1}, with a value of 24.10 leaves per plant, which did not differ significantly from the value at 4 dS m^{-1} salinity, which was 23.08 leaves. The number of leaves decreased by 15.72% and 32.61% when the irrigation water salinity increased to 6 and 8 dS m^{-1}, respectively.

The results also demonstrated the effect of nano-potassium foliar application on the number of leaves, with a significant increase in this trait. The percentage increases were 36.43%, 54.33%, and 28.00% at the application levels of 50, 100, and 150 mg L^{-1}, respectively, compared to the control (no foliar application). The highest increase in the number of leaves was achieved at the 100 mg L^{-1} level, with a value of 24.91 leaves per plant.

As for the interaction between the two experimental factors (irrigation water salinity and nano-potassium fertilization), the treatment with foliar application at 100 mg L^{-1} and irrigation with water at 2 dS m^{-1} salinity achieved the highest number of leaves, which amounted to 28.66 leaves per plant, representing an increase of 95.49% compared to the lowest value at the control (no foliar application) and irrigation with water at 8 dS m^{-1} salinity, which was 14.66 leaves per plant.

Table (6) The effect of spraying with nano potassium on the average number of leaves (leaf per plant^{-1}) of faba beans exposed to salt stress.

Salinity levels of irrigation water (dS m^{-1}) S	Spray levels of nano-potassium (mg L^{-1}) K				S rate
	0	**50**	**100**	**150**	
2	19.00	24.75	24.10	24.00	24.10
4	15.00	26.00	23.08	23.66	23.08
6	15.91	20.33	20.31	19.00	20.31
8	14.66	17.00	16.24	16.00	16.24
K rate	16.14	22.02	24.91	20.66	
L . S.D. 0.05	K		S	K*S	
	1.9847		1.9847	3.9694	

Average Leaf Area (cm²) :

The results presented in Table (7) indicate the effect of nano-potassium foliar application on the leaf area of the plant under salinity stress. Statistical analysis showed a significant decrease in the leaf area of faba bean plants with increasing irrigation water salinity. The highest leaf area was recorded at a salinity level of 2 dS m^{-1}, with a value of 15.96 cm². The leaf area decreased by 4.75%, 14.97%, and 29.63% when the irrigation water salinity increased to 4, 6, and 8 dS m^{-1}, respectively, compared to the 2 dS m^{-1} salinity.

The results also showed that nano-potassium foliar application significantly increased the leaf area, with increases of 14.35%, 21.33%, and 13.39% at the application levels of 50, 100, and 150 mg L^{-1}, respectively, compared to the control (no foliar application). The leaf area of faba bean plants was highest at the 100 mg L^{-1} application level, with a value of 15.13 cm².

Regarding the interaction between the two experimental factors (irrigation water salinity and nano-potassium fertilization), the treatment of foliar application at 100 mg L^{-1} and irrigation with water salinity of 2 dS m^{-1} resulted in the highest leaf area value, which was 16.92 cm², representing an increase of 65.39% compared to the lowest value at the control level (no foliar application) and irrigation with water salinity of 8 dS m^{-1}, which was 10.23 cm².

Table (7) The effect of spraying with nano potassium on the average leaf area (cm^2) of faba beans exposed to salt stress.

Salinity levels of irrigation water ($dS\ m^{-1}$) S	Spray levels of nano-potassium ($mg\ L^{-1}$) K				S rate
	0	50	100	150	
2	14.29	15.77	15.96	16.86	15.96
4	13.76	15.50	15.23	15.79	15.23
6	11.59	14.40	13.57	12.67	13.57
8	10.23	11.38	11.23	11.24	11.23
K rate	12.47	14.26	15.13	14.14	
L . S . D 0.05	K		S		K*S
	0.735		0.735		1.47

Average number of flowers per plant:

The results presented in Table (8) show the effect of foliar application of nano-potassium on the number of flowers in faba bean plants growing under salt stress. Statistical analysis revealed a significant decrease in the number of flowers with increasing irrigation water salinity to 8 $dS\ m^{-1}$, with a reduction of 27.34%.

No significant difference was observed in the number of flowers when irrigating with water at salinity levels of 4 and 6 $dS\ m^{-1}$, with values of 3.58 flowers and 3.41 flowers, respectively, compared to the 2 $dS\ m^{-1}$ irrigation water salinity level.

The results also showed that foliar application of nano-potassium led to a significant increase in the number of flowers, with an increase of 35.03% and 48.90% at the application levels of 50 $mg\ L^{-1}$ and 100 $mg\ L^{-1}$, respectively, with no significant difference between these two levels. However, the 150 $mg\ L^{-1}$ application level had no significant effect on this trait compared to the control treatment without foliar application.

Regarding the interaction between the two experimental factors (irrigation water salinity and nano-potassium fertilization), the foliar application at 50 $mg\ L^{-1}$ and 100 $mg\ L^{-1}$ with irrigation using water at 2 $dS\ m^{-1}$ salinity achieved the highest number of flowers, with a value of 4.50 flowers, representing an increase of 108.33% compared to the lowest value in the control treatment (no foliar application) with irrigation at 8 $dS\ m^{-1}$ salinity, which was 2.16 flowers.

Table (8) The effect of spraying with nano potassium on the average number of flowers of faba beans exposed to salt stress

Salinity levels of irrigation water (dS m^{-1}) S	Spray levels of nano-potassium (mg L^{-1}) K				S rate
	0	**50**	**100**	**150**	
2	3.16	4.50	3.95	3.66	3.95
4	3.00	3.66	3.58	3.33	3.58
6	2.66	3.66	3.41	3.16	3.41
8	2.16	3.00	2.87	3.00	2.87
K rate	2.74	3.70	3.45	3.29	
L . S .D. 0.05	K		S	K*S	
	0.9616		0.9616	1.9232	

Average number of seeds per pod:

The results presented in Table (9) show the effect of foliar application of nano-potassium on the average number of seeds per pod in faba bean plants exposed to salt stress. Statistical analysis indicates a decrease in this trait with increasing irrigation water salinity. The highest value for the number of seeds was recorded at a salinity level of 2 dS m^{-1}, with a value of 3.93 seeds. The number of seeds decreased by 9.41%, 17.30%, and 28.49% as the irrigation water salinity increased to 4, 6, and 8 dS m^{-1}, respectively, compared to the value at the 2 dS m^{-1} salinity level.

The results showed that foliar application of nano-potassium led to a significant increase in the number of seeds, with an increase of 43.75%, 58.59%, and 26.95% at the application levels of 50, 100, and 150 mg L^{-1}, respectively, compared to the control treatment (no foliar application). The highest value for the number of seeds was observed at the 100 mg L^{-1} application level, which was 4.06 seeds.

Regarding the interaction between the two experimental factors (irrigation water salinity and nano-potassium fertilization), the foliar application at the 100 mg L^{-1} level and irrigation with water at 2 dS m^{-1} salinity achieved the highest number of seeds, with a value of 4.75 seeds, representing an increase of 137.5% compared to the lowest value in the control treatment (no foliar application) with irrigation at 8 dS m^{-1} salinity, which was 2.00 seeds.

Table (9) The effect of spraying with nano potassium on the average number of seeds in the pod of faba beans exposed to salt stress.

Salinity levels of irrigation water (dS m⁻ ¹) S	Spray levels of nano-potassium (mg L⁻¹) K				S rate
	0	**50**	**100**	**150**	
2	3.00	4.25	3.93	3.75	3.93
4	3.00	3.75	3.56	3.25	3.56
6	2.25	3.75	3.25	3.00	3.25
8	2.00	3.00	2.81	3.00	2.81
K rate	2.56	3.68	4.06	3.25	
L . S . D 0.05	K	S	K*S		
	0.3035	0.3035	0.607		

Average Fresh Seed Weight (g):

The results presented in Table (10) indicate the effect of nano-potassium spraying on the average fresh seed weight of faba bean plants under salt stress. The statistical analysis results showed a significant effect of the irrigation water salinity factor on the reduction of the mentioned trait with increasing levels of irrigation water salinity. The reduction percentages were (23.80%, 46.93%, and 53.28%) as the salinity level of irrigation water increased to 4, 6, and 8 dS m⁻ ¹, respectively, compared to the salinity level of 2 dS m⁻ ¹.

The results showed that nano-potassium spraying led to a significant increase in the mentioned trait, with increase percentages of (65.25%, 306.77%, and 295.32%) at the nano-potassium spraying levels of (50, 100, and 150 mg L⁻ ¹), respectively, compared to the treatment without spraying. The highest fresh seed weight was recorded at the addition level of 100 mg L⁻ ¹, with a value of (4.80) g.

Regarding the interaction between the two experimental factors (irrigation water salinity and nano-potassium fertilization), the treatment with nano-potassium at 100 mg L⁻ ¹ and irrigation with water of salinity 2 dS m⁻ ¹ achieved the highest fresh seed weight, which amounted to 6.25 g, with an increase of (996.49%) compared to the lowest value at the no-spray treatment and irrigation with water of salinity 8 dS m⁻ ¹, which was (0.57) g.

Table (10) Effect of spraying with nano potassium on the average weight of fresh seeds (g) of faba beans exposed to salt stress

Salinity levels of irrigation water (dS m^{-1}) S	Spray levels of nano-potassium (mg L^{-1}) K				S rate
	0	**50**	**100**	**150**	
2	2.09	3.52	6.25	5.79	4.41
4	1.36	2.15	5.61	4.32	3.36
6	0.69	1.23	3.84	3.59	2.34
8	0.57	0.88	3.52	3.28	2.06
K rate	1.18	1.95	4.80	4.24	
L . S . D 0.05	K	S	K*S		
	0.1015	0.1015	0.2029		

Average weight of pod (g):

The results presented in Table (11) indicate the effect of nano-potassium spraying on the pod weight of broad bean plants growing under saline stress. The statistical analysis revealed a significant decrease in the mentioned trait with increasing irrigation water salinity. The highest pod weight was recorded at a salinity level of 2 dS m^{-1}, with a value of (8.39) g. The pod weight decreased by (15.25%, 37.54%, and 41.35%) as irrigation water salinity increased to (4, 6, and 8 dS m^{-1}), respectively, compared to its value at a salinity level of 2 dS m^{-1}.

The results showed that nano-potassium spraying led to a significant increase in the pod weight, with increase percentages of (57.34%, 142.93%, and 110.52%) at spraying levels of (50, 100, and 150 mg L^{-1}), respectively, compared to the treatment without spraying. The highest pod weight was recorded at the 100 mg L^{-1} level, with a value of (8.77) g, which was higher than all other levels.

Regarding the interaction between the two experimental factors (irrigation water salinity and nano-potassium fertilization), the treatment with nano-potassium at 100 mg L^{-1} and irrigation with water of salinity 2 dS m^{-1} achieved the highest pod weight, which amounted to 10.76 g, with an increase of (337.39%) compared to the lowest value at the no-spray treatment and irrigation with water of salinity 8 dS m^{-1}, which was (2.46) g.

Table (11) The effect of spraying with nano potassium on the average pod weight (g) of fava beans exposed to salt stress.

Salinity levels of irrigation water (dS m^{-1}) S	Spray levels of nano-potassium (mg L^{-1}) K				S rate
	0	**50**	**100**	**150**	
2	5.07	7.92	10.76	9.34	8.39
4	4.35	6.64	10.25	7.23	7.11
6	2.58	4.29	7.22	6.88	5.24
8	2.46	3.90	6.86	6.48	4.92
K rate	3.61	5.68	8.77	7.60	
L . S . D 0.05	K		S	K*S	
	0.2681		0.2681	0.5362	

Discussion

Effect of different levels of irrigation water salinity on the morphological characteristics of faba beans:

The results presented in Tables (3, 4, 5, 6, 7, 8, 9, 10, and 11) indicate a significant effect of irrigation water salinity levels on the morphological traits of faba bean plants under study. These tables sequentially show a decrease in plant height, stem diameter, number of branches, number of leaves, leaf area, number of flowers, number of seeds, seed weight, and pod weight for plants exposed to salt stress (8, 6, and 4 dS m^{-1}), particularly when irrigated with water with a salinity of 8 dS m^{-1}, compared to the treatment irrigated with water of 2 dS m^{-1}. Sodium chloride inhibits broad bean growth and productivity through suppressing cell division, preventing the cells from elongating because of growth and biomass disruption [18]. The plant can become imbalanced when salinity is too high and cannot absorb essential elements [19]. As a result, the soil's osmotic potential is reduced, and salt is taken up by the soil more readily [20]. In response to sodium accumulation and reduced potassium absorption, increased salinity levels result in decreased plant growth [21]. Salinity is considered an abiotic factor that limits the plant growth, especially its height as well as the numbers of the flowers [22].

In terms of stem diameter, the salt stress treatment does not affect it but at irrigation water salinity of 8 dS m^{-1} it significantly decreases compared to the control treatment. This reduction in stem diameter can be explained by the accumulation of salts, where the plant develops mechanisms for survival in the salinized medium surrounding the stem, which contains osmotic salts. Salts retain water which decreases absorption of water and nutrients resulting in less vegetative growth [23; 24].

The number of batterers, leaves, flowers, and seeds were decreased by the exposure of salt stress. The salt level is too high because of this, and cell elongation, division, and water absorption cannot continue, resulting in this decrease [25]. The decrease in branching under high salt concentrations (6 and 8 dS m⁻¹) is consistent with another research that found that [26]. This is due to the atrophy of the root system caused by the salts deposited in the cell walls and the cytoplasm and causing the sap to not absorb nutrients and subsequently die [27]. The reduction in the seeds number and productivity may be because of ionic imbalance, stress of osmotic, and decreased nutrient uptake [28].

The reduction in leaf area with the increasing irrigation water salinity levels is in accordance with the results of [29], who reported that leaf area decreases with increased levels of salinity. [30] has indicated that the leaf area decreases in response to stress, which affects cell division and expansion of leaves, resulting in reduced photosynthesis.

According to [31], irrigation with saline water at 8 dS m^{-1} reduced plant productivity, and salt stress decreased seed and pod weight. Salt stress reduced average pod weight, which in turn contributed to lower seed productivity, seed weight, and number due to decreased photosynthetic activity of the plant. This leads to a reduction of leave’s nutrient concentration, which was the same presented in the study by [32]on cowpea (*Vigna unguiculata* L.) and common bean (*Phaseolus filiformis* L.).

The effect of spraying with nano potassium on the morphological characteristics of faba beans:

The data in Table (3) demonstrated that nano potassium spray witnesses a significant increase in the height of broad bean plants, particularly at an addition rate of 100 mg L^{-1}. Potassium promotes cell division and elongation, especially in meristematic tissue in growing tips. It also regulates growth hormones and increases the plant's potential to produce food during photosynthesis resulting in plant height enhancement. These findings are in line with studies by [33], [34], [35], and [36].

The effect of nano potassium spraying on stem diameter can be seen in table (4) 100 mg L^{-1} addition treatment shows the most significant increase in stem diameter compared to the control treatment. The stem diameter significantly increased with the use of higher levels of nano potassium. These outcomes align with results by [37]. Potassium treatment increases the stem diameter by promoting protein, sugar, and starch formation, potassium induces enzyme activity, and potassium is one of the important nutrients [38]. Potassium spraying increases the diameter of the stem; this is due to the increase in the vascular bundle numbers and the stem's cell thickness under some conditions of stress [39].

The Table (5) data acknowledged that spraying potassium nano greatly increased the number of branches. The cell division takes place, and the vegetative growth of the cell occurs, the aggrandizement of which subsequently results in the increase of the two lateral tissues exposed to excessive sunlight. Then, the number of branches get higher with the influx of more potassium ion [40]. [41] in addition, observed directly how K fertilizer can bring about the increase in the number of branches because of cell division and elongation in axillary buds that are in so-called "round-the-buds"

The findings set forth in Table (6) indicate that application of nano potassium increased the leaf number. Such a dramatic surge is due to the plant’s generated capability to capture extra light for photosynthesis, so the plant can breathe, for example, and form carbohydrates. The addition of potassium fertilizer furthers plant activity which in turn results in a higher count of leaves as well as in the enlargement of their areas as commented on by [42] and [43].

The table (7) data showed that nano potassium had a great effect on the leaf area of the broad bean plants. The reasons behind this should be cell division, which is mainly in the leaf cells, transport of photosynthesis products to the needed sites where necessary, and also enhancement of the vegetative growth. Further, according to [44] leaf area is one of the traits that are most responsive to nanofertilizers are reported. Potassium works to elongate leaf cells and increase the leaf area of broad bean plants, in line with the results of [45] who proved it.

Table (8) showed the effect of nano potassium spraying on the number of flowers, where [46] indicated that potassium fertilizer increases the number of flowers, especially at the 100 mg L^{-1} addition level. They observed that the highest number of flowers was found in the treatments with increased potassium concentrations.

Spraying with nano potassium at various levels also increased the number of seeds, seed weight, and pod weight, particularly at the 100 mg L^{-1} level (Tables 9, 10, and 11). In a study by [47] on beans, they observed an increase in nutrient content in the leaves with higher potassium, which was then transferred to the pods and seeds. [48] also observed that potassium increased seed and pod weight. Additionally, potassium spraying increases pods and seeds due to the increased leaf area that allows for better light and air penetration, which boosts the plant's receptor activity [49].

The effect of the interaction between salinity and nano-potassium fertilizer on the studied traits:

From the results of Tables (3, 4, 5, 6, 7, 8, 9, 10, 11), it was unveiled that the interaction between the experimental factors, particular the spraying of 100 mg of L^{-1} of nanopotassium fertilizer and the irrigation with a 2 dS m^{-1} salinity level, gave the maximum values of plant height, stem diameter, number of branches, number of leaves, leaf area, the number of flowers, the number of seeds, the seed weight, and the pod weight, respectively.The lowest values of these traits were found at the non-spraying level with the irrigation salinity of 8 dS m^{-1}. Where between [50] That the plant height and the number of leaves decreased when the salinity level increased, and they explained the reason for the decrease by inhibiting cell division and the accumulation of sodium in the cytoplasm and cell walls of the leaves, which causes an imbalance in the elements as it reduces metabolic activities, affecting plant growth and reducing the number of leaves. These results are similar to what was reached by[51]. Spraying with nano potassium led to an increase in plant height because potassium helps the plant absorb nutrients from the soil [52].

Among other elements, potassium is an essential metal for the development of plants, and it speeds up cell division and photosynthesis under saline conditions [53]. Among the structures that were found in the studies of [54] and [55], these results are similar. [43] also reported that potassium supplementation of the term storage system not only boosts traits such as stem height, seeds, leaf number, branch formation, seed weight, pod number, and leaf area but also lengthens the leaf lifespan.

Conclusion

1-The current study showed that increasing the salinity levels of irrigation water led to a decrease in the phenotypic characteristics of the fava bean plant, including plant height, stem diameter, number of leaves, number of flowers, number of branches, number of seeds and their fresh weight, pod weight, and leaf area.

2-Spraying with nano potassium and some rare elements showed a significant effect in increasing the phenotypic characteristics, including plant height, number of leaves, number of flowers, fresh seed weight, pod weight, stem diameter, and leaf area.

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