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Mitigation The Deleterious Effect of Salinity on Faba Bean by Cobalt and Bio-stimulants

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THE COUNTRY has a tendency to secure food supply through vertical expansion by increasing productivity per unit area, especially under conditions of stress such as salinity, in addition to horizontal expansion in new lands that may be saline or irrigated with groundwater of high salinity which affects productivity especially for sensitive crops like beans. So, two field trials were conducted to study the effect of four cobalt foliar application rates (0 ppm (as control), 5 ppm, 7.5 ppm and 10 ppm) as the main plots and four bio-stimulant treatments (control, potassium humate, potassium fulvate and seaweed extract) as foliar treatment in the sub main plots on faba bean growth, yield and its components which cultivated under salt affected soil. During the winter seasons of 2021/2022 and 2022/2023, a split plot design was used. The obtained results could be summarized as follow: Foliar application of cobalt at 10 ppm concentration recorded the highest values of the vegetative growth, yield and its components compared to the other cobalt rates. Application of cobalt at 10 ppm concentration increased chl. a+b by 21.20%, proline content by 9.65% and seeds yield by 6.86% comparing with control treatment. At the same time foliar application of seaweed extract had a superior effect on all studied parameters with relative increments as example 41.84%, 45.41% and 13.63% for chl. a+b, proline content and seed yield, respectively compared to the other foliar treatments of bio-stimulants. The interaction among cobalt at 10 ppm concentration and seaweed extract achieved the highest values of vegetative growth criteria, yield and yield components of the tested plant. Economically founded that combination of cobalt at 10ppm and potassium fulvate application a viable alternative to existing treatments for increasing agricultural output and farmer revenue.

Keywords: Cobalt, Potassium humate, Potassium fulvate, Seaweed extract, Salinity and Faba bean.

1. Introduction

In Egypt, Faba bean is an important legume crop that not used only for human nutrition but also, used as animal feed, its seeds are a good source for certain minerals, protein, carbohydrates and vitamins (El-Husseiny et al. 2020 and Baddour et al. 2021). Although faba bean is a strategic food crop in Egypt, it has been shown that the cultivated area of faba bean crop has decreased from 350000 feddan in the 1980^s to 100000 feddan in the past few years, reaching approximately 92000 feddan in the 2022 season, with a total production of 140000 tons of dry seeds in the same season (Gomaa et al. 2023). The challenge of providing for the nutritional needs of an expanding population remains difficult since climate change has put the viability and productivity of agricultural production systems in risk. The amount and nature of agricultural production are directly and frequently inversely impacted by climate fluctuation (Abdel Latef et al. 2021).

Soil salinity is a global phenomenon that has expanded to over a hundred countries as a result of climate change, which has a severe impact on the agricultural sector and various agricultural practices, such as extensive irrigation in arid climates (Hammam and Mohamed 2020). In Egypt, saline lands account for 35% of total cultivated land area, with 60% located in the north of the Delta, 15% in the center and south of the Delta, and 15% in Upper Egypt (Aboelsoud et al. 2022).

Salinity is a common abiotic stress that had a negatively effect on bean plants, faba bean yield

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decreased gradually by increasing salinity more than 1.7 dsm^{-1} according to FAO (2000). Salinity affects plant production as it leads to changes in plant physiological processes and biochemistry through several ways i.e. reducing water uptake, increasing respiration rate, causing osmotic stress, causing toxicity by increasing Na^+ and Cl^- ions concentrations as well as increasing ROS production that cause oxidative stress (El-Mahdy et al. 2021).

Cobalt is one of important trace elements that required by leguminous plants in low levels for nitrogen fixation. Legumes grown without cobalt suffer from nitrogen deficiency where, it is necessary for combalamine co–enzyme synthesis that responsible for the relationship between nodulation and nitrogen fixation in legumes (Ahmed et al. 2023). On the other hand, cobalt is responsible for vitamin B12 production that required for human nutrition and searches concluded that the daily basis of human can be consumed up to 8 mg cobalt without any health hazard (Gad et al. 2022). Cobalt was utilized to mitigate the negative effects of salt on plants, where it boosts photosynthesis, raises proline concentration and is essential for a number of antioxidant enzymes (El-Shamly and Nassar 2023).

Recently, bio-stimulants have been used to improve plant growth, yield and increase plant resistant to abiotic stress salinity as example. Seaweed extracts were used as natural regulators to improve crop development and productivity in order to survive adverse environmental influences. They include high rates of nutrients and hormones which are responsible for increasing plant growth and yield consequently. Larger bioactive substances as oligosaccharides and phlorotannins found in Seaweed extracts, these substances have been found to behave as elicitors, encouraging plant development and activating stress responses (Medi and Manea 2020). Also, they are enriched in both inorganic elements necessary for plant development and phytohormones that promote growth.

Humic substances are organic plant bio-stimulants made up of heterogeneous molecules that are divided into humin, humic acid, and fulvic acid according to their molecular weight and solubility (Mohamed 2020). They are favorable to plants as they affect number of physiological and developmental processes in many plants, including germination, root development, cell enlargement, photosynthetic activity, mitochondrial respiration, nutrient intake, and resistance to abiotic stress. Additionally, they serve as an anti-stress agent that raises plants' tolerance to salinity by activating antioxidant enzymes. (Rashwan et al. 2020). However, foliar application of K-fulvate is more effective than K-humate where it has a comparatively little molecule size that make it easily more to enter plants (Omar et al. 2020).

Therefore, the purpose of our study was to maximize the bean plant's tolerance to saline conditions by foliar application of cobalt and some natural bio-stimulants as humic substances and seaweed extract.

2. Materials and Methods

Experiments were done to investigate the influence of cobalt rates and various bio-stimulants foliar applications on the growth, yield, and components, as well as the chemical composition, of faba bean plants cultivated in salt-affected soil.

2.1 Experimental Site

Two field trials were implemented in the Tag El-Ezz farm, Agricultural Research Station, Agricultural Research Centre, Dakahlia Governorate, Egypt (positioned at 30o59\ N latitude, 31o58\ E longitude´) for two consecutive winter seasons in 2021/2022 and 2022/2023.

2.2 Soil Sampling and Analyses

Before planting, random disturbed soil samples were taken from the earth's surface (at a depth of 0–30 cm). According to Klute (1986) and Page et al. (1982), some properties of the initial soil were pointed out in Table 1. Samples from bio-stimulants i.e. potassium humate, potassium fulvate and seaweed extract were analyzed according to methods described by (Tandon, 2005) in Table 2.

2.3 Experimental setup

Two field experiments were carried out using a split plot design with three replicates. Experiments consisted of sixteen treatments resulting from the combinations of four cobalt foliar application rates [Cobalt Nitrate ($Co(NO_3)_2.6H_2O$) 97%] (0 ppm (cont.), 5 ppm, 7.5 ppm, and 10 ppm) as the main plots and four bio-stimulants foliar treatments [control, potassium humate (6 g L^{-1}), potassium fulvate (6 g L^{-1}) and seaweed extract (15 g $L^{-1)}$] as the sub plots on faba bean (Vicia faba L.) var. Giza (716) plants growth, yield, yield components and chemical constituents. There were 48 plots in the experimental area. The sub plot area was 14.7 m^2 (4.2m ×3.5m). Seeds of tested plant were received from Egypt's Ministry of Agriculture's Legumes Crops Research

Department. Bio-stimulants were bought on the agricultural commercial market and cobalt nitrate was obtained from Al - Gomhoria Company for medicines and medical supplies.

Before sowing, faba bean seeds were pollinated with rhizobium bacteria which bought from the Agricultural Research Center (ARC) at the rate of 800 g fed^{-1}. Seeds of faba bean were sown at both sides of the ridge in hills spaced 25 cm apart at 10th of November during the two cultivated winter seasons. Thinning was done when the plant reached 15 cm in height, leaving two plants per hill. Regarding to the soil applied treatments, during soil preparation, 15 kg P_2O_5 fed^{-1} super phosphate [$Ca(H_2PO_4)_2$ 15.5% P_2O_5] fertilizer was added to the soil. Nitrogen was added as ammonium sulfate (20.5%N) at the rate of 15 kg N fed^{-1} and Potassium sulphate (48% K_2O) was added at a rate of 25 kg K_2O fed^{-1} as the Ministry of Agriculture and Land Reclamation (MALR) recommended. Cobalt and bio-stimulants sprayed twice on the plants at 45 and 65 days from planting with freshly prepared solutions. The harvest date was on 26th April.

Table 1. Average values of some properties of the initial soil (the combined data of two seasons).

Particle size distribution (%)				Texture class	EC, dS m^{-1}	pH	SSP	SAR	ESP
Coarse sand	Fine sand	Silt	Clay				(%)		
4.02	15.47	38.15	42.36	Clay	4.63	7.98	54.10	8.58	10.22
Soluble ions (mmol L^{-1})							Available elements, mg kg^{-1}		
Soluble cations				Soluble anions					
Mg^{++}	Ca^{++}	Na^{+}	K^{+}	SO_4^{--}	Cl^{-}	HCO_3^{-}	CO_3^{--}	N	P	K
8.30	8.78	25.15	4.07	23.88	20.38	2.04	0.00	49.64	8.72	241.38

Abbreviations: Soil Electrical Conductivity **(EC**) and soluble ions were determined in saturated soil paste extract.

Soil **pH** was determined in soil suspension (1: 2.5). **SSP**: Soluble Sodium Percentage. **SAR**: Sodium Adsorption Ratio. **ESP**: Exchangeable Sodium Percentage.

Table 2. Average values of Physical and chemical analyses of used bio-stimulants.

Bio-stimulants	Humic Acid	Fulvic Acid	Solubility	Moisture	pH	Total macro element N	P	K
	%					%		
Potassium humate	61.0	2.78	100	5.82	8.30	0.32	1.30	10.92
Potassium fulvate	4.0	64.5	100	5.75	5.10	0.47	2.33	7.39
	Fe	Mn	Ca	Si	B	N	P	K
Seaweed extract				%				
	0.03	0.2	0.33	24.23	3.2	1.0	0.2	16

2.4 Data recorded

1- Growth parameters during growing season

Plant samples from each replicate were taken after 70 days from sowing to estimate some growth parameters such as plant fresh & dry weights (g) and plant height (cm). Chlorophyll a, b, and total chlorophyll (mg g^{-1} FWT) were measured according to Nayek et al. (2014).

N, P and K content in leaves were evaluated according to Walinga et al. (2013). Nutrient uptake was calculated according to the following formula:

$$\text{Nutrient uptake (mg plant}^{-1}) = \frac{\text{Nutrient concentration x dry weight (mg plant}^{-1})}{100}$$

Determination of Endogenous Hormones and Proline: Auxins, Gibberelines and cytokinins in faba bean fresh leaves were determined according to Shindy and Smith (1975). Proline was measured calorimetrically according to Bates et al. (1973).

2- Harvest stage

- At harvest, the following characteristics were recorded at a random sample of guarded plants from each plot: pods number plant^{-1}, seeds number plant^{-1}, pods weight (g plant^{-1}), 100 seeds weight (g), seeds yield (ton fed^{-1}).

- As previously stated with leaves, the seeds yield was cleaned and crushed to calculate total N, P, and K components. The uptake of nutrients was calculated according to the following formula:

$$\text{Nutrients uptake in mature seeds (kg fed}^{-1}) = \frac{\text{Nutrient concentration x seeds yield kg fed}^{-1}}{100}$$

- Protein (%) was calculated according to A.O.A.C. (1990) as below: Protein% = (N) × 6.25. Total carbohydrates content in seeds were determined as described by A.O.A.C (1995).

2.5 Economic analyses

Total cultivation costs and gross returns were estimated using current market rates for various practices and products. For each treatment, the total cost of cultivation per feddan was reduced from the gross income to compute net returns.

Net return (LE. fed^{-1}) = Gross return ((LE. fed^{-1}) - Cost of cultivation LE. fed^{-1})

Benefit cost ratio (BCR) was calculated treatment wise as below:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

2.6 Statistical Analyses

For analysis, the results of two years of identical tests were merged. The LSD test and Duncan's Multiple Comparisons Test were used to find significant differences in treatment means at P 0.05 (Snedecor and Cochran 1980). Data of the current study were statistically analyzed using Co-STATE Computer Software, according to Gomez and Gomez (1984).

3. Results

1- Vegetative growth stage

Data tabulated in Tables 3, 4 and 5 show influence of different cobalt foliar rates and different bio-stimulants foliar applications on some vegetative growth parameters, chlorophyll content, foliage nutrients (N, P and K) content, endogenous hormones and proline content of faba bean plants grown under salt affected soil.

Data revealed that all studied parameters were significantly increased by increasing cobalt rates comparing with the control. Cobalt at 10 ppm concentration was the superior where it had the greatest levels of vegetative growth parameters with relative increments 23.68% for plant height and 21.20% for chl. a+b comparing with the control. Moreover, the highest values of nutrients concentration and their uptake increased gradually by increasing cobalt rates and the highest values of nutrients concentration were achieved by cobalt foliar application at 10 ppm with increments 9.46, 16.80 and 16.39% for N, P and K, respectively comparing with the control.

Regarding to endogenous hormones and proline content, plants treated with foliage cobalt at 10 ppm recorded the highest values of endogenous hormones and proline content where the values were increased by 10.74, 9.12, 16.24 and 9.65% for auxin, gibberelline, cytokinines and proline, respectively comparing with the control.

Concerning the effect of used bio-stimulants foliar application it’s clear that all bio-stimulants treatments induced vegetative growth parameters and significantly affected faba bean growth under salinity conditions comparing with the control. Seaweed extract foliar application was the superior treatment comparing with the control, where it increased plant height by 7.78%, chl. a+b by 41.84% and nutrients concentrations (N, P and K) by 16.20, 30.93 and 34.45%, respectively.

The bio-stimulants used in this research i.e., potassium humate, potassium fulvate and seaweed extract increased plant hormones and proline content in faba bean leaves under salinity stress comparing with the un treated treatment. Seaweed extract gave the highest values of endogenous hormones and proline content with relative increments 20.51, 16.76, 28.87 and 45.41% for auxin, gibberelline, cytokinines and proline, respectively comparing with untreated.

The interaction of cobalt at 10 ppm concentration and seaweed extracts foliar application produced the highest values of previously examined parameters at vegetative growth stage of faba bean plant cultivated under salinity stress.

2- Harvest stage

Data elucidated in Tables 6 and 7 show the impact of different cobalt foliar rates and some bio-stimulants foliar applications on yield, nutrients concentrations, protein and carbohydrates content of faba bean plant at harvest stage under salinity conditions. While, the individual impact of cobalt and some bio-stimulants foliar application on N, P and K uptake by mature seeds of faba bean under salinity condition showed in Figs 1, 2 and 3, respectively.

Table 3. Average impact of cobalt rates and some bio-stimulants foliar application on vegetative growth parameters and chlorophyll contents of faba bean plants under salt affected soil.

Treatments	**Weight (g plant^{-1})**		**Plant height**	**Chlorophyll content (mg g FWT)**		
	Fresh	**Dry**	**(cm)**	**Chl. a**	**Chl. B**	**Chl. a+b**
			Main: cobalt rates			
0 ppm	111.66^d	13.08^d	49.99^d	1.060^d	0.486^d	1.547^d
5 ppm	132.24^c	15.83^c	56.66^c	1.206^c	0.577^c	1.783^c
7.5 ppm	147.16^b	17.83^b	59.91^b	1.235^b	0.591^b	1.826^b
10 ppm	173.08^a	20.74^a	61.83^a	1.267^a	0.608^a	1.875^a
F. test	***	***	***	***	***	***
			Sub main: bio-stimulants			
Cont.	130.91^d	15.66^d	54.58^d	0.966^d	0.424^d	1.391^d
K. Humate	138.24^c	16.24^c	57.16^c	1.200^c	0.570^c	1.770^c
K. Fulvate	146.41^b	17.24^b	57.83^b	1.279^b	0.617^b	1.897^b
Seaweed extract	148.58^a	18.33^a	58.83^a	1.321^a	0.651^a	1.973^a
F. test	***	***	***	***	***	***
			Interactions			
F. test	***	***	*	***	***	***

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 4. Average impact of cobalt rates and some bio-stimulants foliar application on N, P and K concentrations and their uptakes on leaves of faba bean plants under salt affected soil.

Treatments	Concentration (%)			Uptake (mg plant $^{-1}$)		
	N	P	K	N	P	K
Main: cobalt rates						
0 ppm	3.38^d	0.351^d	2.165^d	444.22^d	46.22^d	285.85^d
5 ppm	3.58^c	0.389^c	2.405^c	566.76^c	61.81^c	381.73^c
7.5 ppm	3.64^b	0.401^b	2.458^b	649.93^b	71.70^b	439.36^b
10ppm	3.70^a	0.410^a	2.520^a	770.84^a	85.78^a	527.37^a
F. test	***	***	***	***	***	***
Sub main: bio-stimulants						
Cont.	3.27^d	0.333^d	1.985^d	514.72^d	52.53^d	312.94^d
K. Humate	3.55^c	0.379^c	2.393^c	579.55^c	62.08^c	392.36^c
K. Fulvate	3.67^b	0.402^b	2.500^b	635.81^b	70.00^b	434.32^b
Seaweed extract	3.80^a	0.436^a	2.669^a	701.67^a	81.90^a	494.68^a
F. test	***	***	***	***	***	***
Interactions						
F. test	***	***	**	***	***	***

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 5. Average impact of cobalt rates and some bio-stimulants foliar application on endogenous hormones and proline content on leaves of faba bean plants under salt affected soil.

Treatments	Phytohormones (Pmol.g^{-1} FWT)			(mg g^{-1} FWT)
	Auxin	Gibberelline	Cytokinin	Proline
		Main: cobalt rates		
0 ppm	109.59^d	1897.50^d	9.42^d	5.49^d
5 ppm	117.59^c	2012.66^c	10.42^c	5.83^c
7.5 ppm	119.57^b	2041.91^b	10.67^b	5.84^b
10ppm	121.37^a	2070.66^a	10.95^a	6.02^a
F. test	***	***	***	***
		Sub main: bio-stimulants		
Cont.	104.50^d	1828.50^d	8.90^d	4.69^d
K. Humate	116.62^c	1992.08^c	10.25^c	5.38^c
K. Fulvate	121.05^b	2067.08^b	10.85^b	6.29^b
Seaweed extract	125.94^a	2135.08^a	11.47^a	6.82^a
F. test	***	***	***	***
		Interactions		
F. test	***	***	***	**

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 6. Average impact of cobalt rates and some bio-stimulants foliar application on yield and yield parameters of faba bean plants under salt affected soil.

Treatments	No. of		Weight (g)		Seeds yield Yield (ton fed^{-1})
	Pods $plant^{-1}$	Seeds $plant^{-1}$	Pods $plant^{-1}$	100 seeds	
Main: cobalt rates					
0 ppm	17.25^{d}	69.87^{d}	159.47^{d}	90.88^{d}	1.412^{d}
5 ppm	20.75^{c}	74.21^{c}	169.31^{c}	93.79^{c}	1.447^{c}
7.5 ppm	23.37^{b}	77.81^{b}	174.58^{b}	96.94^{b}	1.483^{b}
10ppm	27.37^{a}	80.50^{a}	181.55^{a}	102.89^{a}	1.509^{a}
F. test	***	***	***	***	***
Sub main: bio-stimulants					
Cont.	19.93^{d}	71.62^{d}	156.66^{d}	86.84^{d}	1.371^{d}
K. Humate	21.81^{c}	74.68^{c}	168.46^{c}	96.35^{c}	1.426^{c}
K. Fulvate	22.87^{b}	76.81^{b}	176.29^{b}	99.26^{b}	1.496^{b}
Seaweed extract	24.12^{a}	79.28^{a}	183.49^{a}	102.03^{a}	1.558^{a}
F. test	***	***	***	***	***
Interactions					
F. test	Ns	**	***	***	***

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 7. Average impact of cobalt rates and some bio-stimulants foliar application on N, P, K, protein and carbohydrates content on mature seeds of faba bean plants under salt affected soil.

Treatments	N	P	K	Protein	Carbohydrates
	%				
Main: cobalt rates					
0 ppm	3.18^{d}	0.313^{d}	1.92^{d}	19.87^{d}	52.41^{d}
5 ppm	3.38^{c}	0.349^{c}	2.22^{c}	21.16^{c}	53.32^{c}
7.5 ppm	3.44^{b}	0.358^{b}	2.29^{b}	21.55^{b}	53.48^{b}
10 ppm	3.50^{a}	0.365^{a}	2.35^{a}	21.89^{a}	53.72^{a}
F. test	***	***	***	***	***
Sub main: bio-stimulants					
Cont.	3.04^{d}	0.296^{d}	1.77^{d}	19.02^{d}	51.99^{d}
K. Humate	3.39^{c}	0.342^{c}	2.20^{c}	21.21^{c}	53.27^{c}
K. Fulvate	3.47^{b}	0.363^{b}	2.33^{b}	21.71^{b}	53.62^{b}
Seaweed extract	3.60^{a}	0.384^{a}	2.46^{a}	22.53^{a}	54.05^{a}
F. test	***	***	***	***	***
Interactions					
F. test	**	***	**	**	***

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Results in Table 6 recorded that all cobalt foliar rates had a significant effect on yield and yield parameters of faba bean grown under salinity stress, it's obvious that foliar application of cobalt at 10 ppm concentration produced the highest values of studied parameters where values increased by 58.66, 15.21, 13.84, 13.21 and 6.86% for pods No. plant $^{-1}$, No. of seeds $plant^{-1}$, pods weight, 100 seeds weight and seeds yield, respectively. On the other hand, different rates of cobalt foliar applications significantly increased N, P, K, protein and carbohydrates content in mature seeds of fab bean plants under salinity as shown in Table 7 and Figs 1, 2 & 3, the superior was with the application of cobalt at 10 ppm concentration where values of N, p and K concentration increased by10.06, 16.61and 22.39%, respectively, while protein and carbohydrates content in mature seeds increased by 10.16 and 2.49 %, respectively comparing with the control.

Regarding to bio-stimulants foliar application, they alleviated the negative effect of salinity on faba bean yield and yield parameters as shown in Table 6, and the most favourable one was seaweed extract foliar application where the values increased by 21.02, 10.69, 17.12, 17.49 and 13.63% for No. of pods plant-

^{1}, No. of seeds plant^{-1}, pods weight, 100 seeds weight and seeds yield, respectively comparing with untreated. Also, Seaweed extract foliar application achieved the highest values of N, P and K concentrations as well as protein and carbohydrates content in mature seeds of faba bean with relative increments 18.42% for N, 29.72% for P, 38.98% for K, 18.45% for protein content and 3.96% for carbohydrates content.

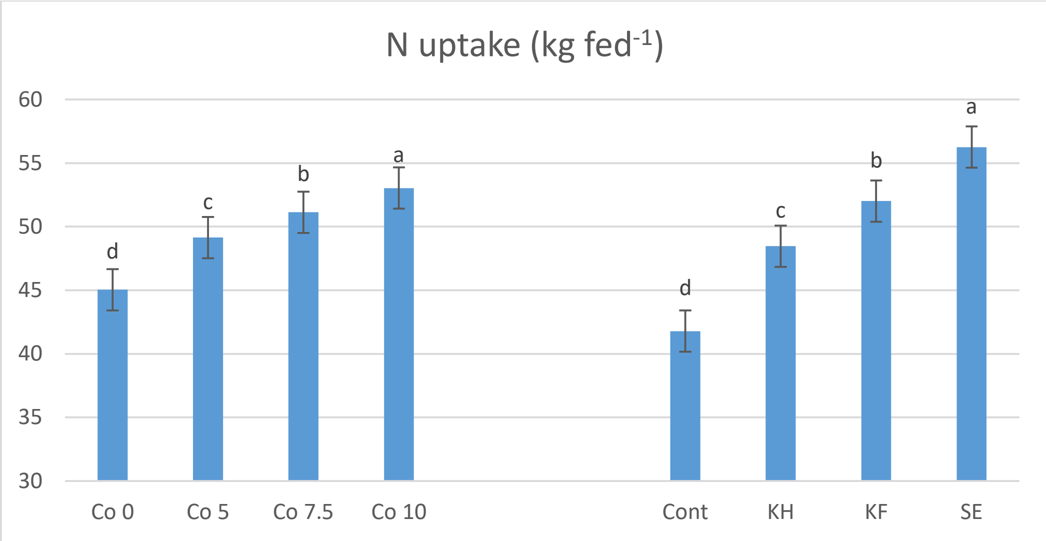

Fig. 1. Individual impact of cobalt rates and some bio-stimulants foliar application on N uptake by seed yield (kg. fed^{-1}) of faba bean grown under salt affected soil.

Co 0: Cobalt at rate 0 ppm; **Co 5**: Cobalt at rate 5 ppm; **Co 7.5**: Cobalt at rate 7.5 ppm; **Co 10**: Cobalt at rate 10 ppm; **Cont**.: Without bio- stimulants foliar application; **KH**: Potassium humate; **KF**: Potassium fulvate; **SE**: Seaweed extract.

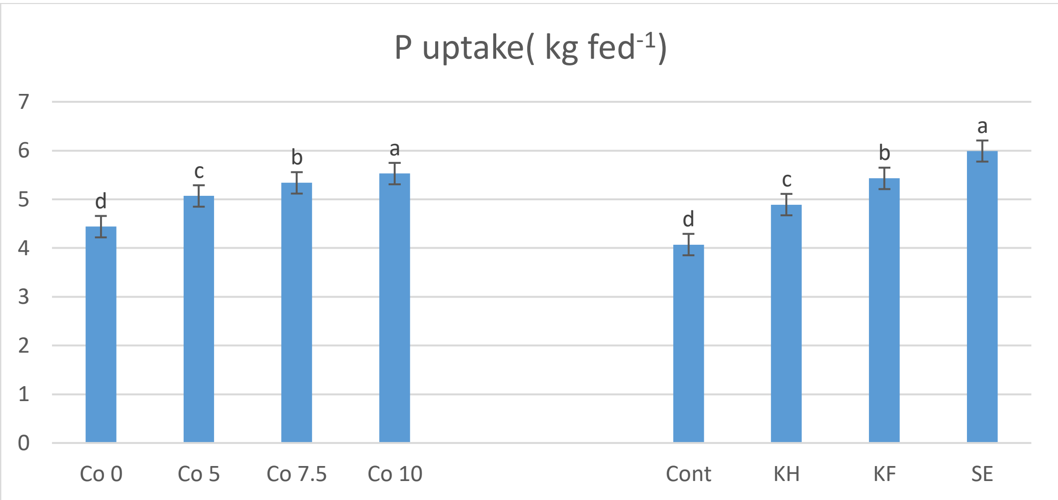

Fig. 2. Individual impact of cobalt rates and some bio-stimulants foliar application on P uptake by seed yield (kg. fed^{-1}) of faba bean grown under salt affected soil.

Co 0: Cobalt at rate 0 ppm; **Co 5**: Cobalt at rate 5 ppm; **Co 7.5**: Cobalt at rate 7.5 ppm; **Co 10**: Cobalt at rate 10 ppm; **Cont**.: Without bio- stimulants foliar application; **KH**: Potassium humate; **KF**: Potassium fulvate; **SE**: Seaweed extract.

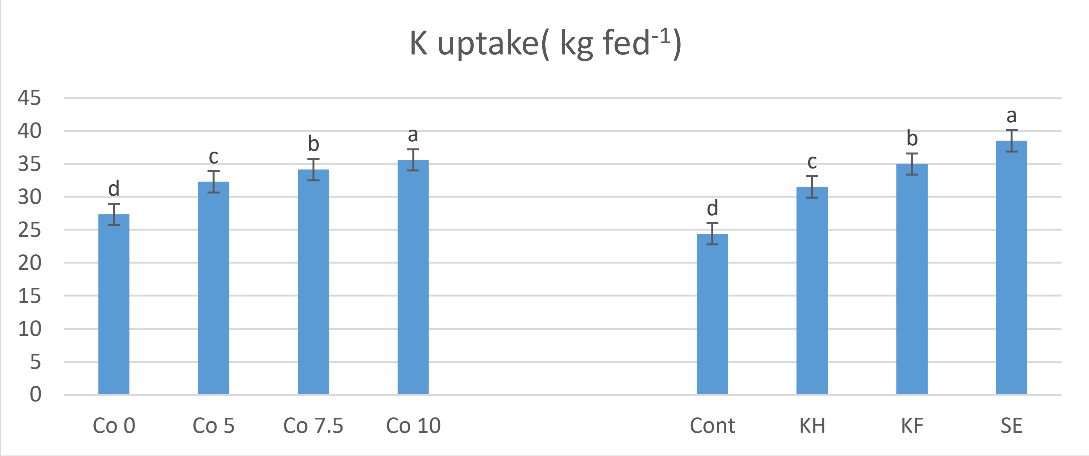

Fig. 3. Individual impact of cobalt rates and some bio-stimulants foliar application on K uptake by seed yield (kg fed^{-1}) of faba bean grown under salt affected soil.

Co 0: Cobalt at rate 0 ppm; **Co 5**: Cobalt at rate 5 ppm; **Co 7.5**: Cobalt at rate 7.5 ppm; **Co 10**: Cobalt at rate 10 ppm; **Cont.**: Without bio- stimulants foliar application; **KH**: Potassium humate; **KF**: Potassium fulvate; **SE**: Seaweed extract.

Interaction of cobalt at 10 ppm concentration and seaweed extract foliar application enhanced plant tolerance to salinity and recorded the highest values of yield productivity and quality (nutrients, protein and carbohydrates content in mature seeds) of faba bean comparing with other treatments.

3- Benefit: Cost Ratio

Table 8 shows the economics of faba bean as influenced by cobalt and certain bio-stimulants foliar treatments. The highest overall cost of culture (LE. fed^{-1}) was observed with all seaweed extract treatments, followed by potassium fulvate treatments, and the lowest with potassium humate treatments when compared to the control. The cost of cultivation for control (no foliar application) was 14000 LE. fed^{-1}. The highest gross income that 33747 LE. fed^{-1} of faba bean was listed with the combination of cobalt foliar application at 10ppm and seaweed extract applied treatment followed by interaction of cobalt at 7.5 ppm and seaweed extract applied treatment with gross income of 33306 LE. fed^{-1}. The highest net return of 18186.09 LE. fed^{-1} was gained from cobalt at 10ppm concentration and seaweed extract applied treatment followed by cobalt at 10 ppm concentration and potassium fulvate applied treatment with net return 17865.09 LE. fed^{-1}.

The highest B: C ratio 2.24 was listed from cobalt at 10 ppm concentration and potassium fulvate foliar treatment which was followed by cobalt at 7.5 ppm and potassium fulvate foliar treatment with 2.21 B: C ratio.

Table 8. Cost of cultivation, gross and net return and benefit: cost ratio of different treatments.

Treatments		Basic cost	Treatments cost	Total cost	Gross return	Net return	B.C ratio
Cobalt rates	Bio- stimulants			(LE. fed^{-1})			
0 ppm	Cont.	14000	0.00	14000	27510	13510	1.97
	K. Humate	14000	312.00	14312	29064	14752	2.03
	K. Fulvate	14000	390.00	14390	30345	15955	2.11
	Seaweed extract	14000	1560.00	15560	31689	16129	2.04
5 ppm	Cont.	14000	0.46	14000.46	28581	14580.55	2.04
	K. Humate	14000	312.46	14312.46	29652	15339.55	2.07
	K. Fulvate	14000	390.46	14390.46	31206	16815.55	2.17
	Seaweed extract	14000	1560.46	15560.46	32172	16611.54	2.07
7.5 ppm	Cont.	14000	0.68	14000.68	29274	15273.32	2.09
	K. Humate	14000	312.68	14312.68	30177	15864.32	2.11
	K. Fulvate	14000	390.68	14390.68	31857	17466.32	2.21
	Seaweed extract	14000	1560.68	15560.68	33306	17745.32	2.14
10 ppm	Cont.	14000	0.91	14000.91	29820	15819.09	2.13
	K. Humate	14000	312.91	14312.91	30954	16641.09	2.16
	K. Fulvate	14000	390.91	14390.91	32256	17865.09	2.24
	Seaweed extract	14000`	1560.91	15560.91	33747	18186.09	2.17

4. Discussion

Faba bean has been labeled as a salt-sensitive crop, and yields significantly decreased when soil salinity levels exceeded 1.7 dSm^{-1}. This study aimed to maximize faba bean plants' tolerance to salinity by treating with cobalt and bio-stimulants foliar application.

1- Impact of different cobalt foliar rates

Cobalt is considered a limiting element for plant nutrition that required by leguminous plants in low levels for nitrogen fixation (Baddour et al. 2021). Previous data indicates that faba bean plants treated by cobalt foliar application at 10 ppm recorded the maximum vegetative growth parameters, yield and yield components under salt affected soil. The significant effect of cobalt on faba bean growth under salt affected soil could be related to a beneficial role of cobalt in increasing loghaemoglobin formation that required for N fixation, improving activity of nodules as well as its role in inducing activity of nitrogenase enzyme in root nodulation that increase nodules efficiency to generate healthful plants (Vaseer et al. 2020). Cobalt significantly affected on chlorophyll content where it has anabolic effect on chlorophyll content through acting as a co-enzyme for enzymes responsible for chlorophyll production. In addition to, cobalt induces production of endogenous hormones especially auxin and gibbereline that have a vital role in regulation the response of plant to salinity stress through promoting plant growth as stem elongation and leaf expansion and induce the plant resistance to salinity thus reflected on maximize vegetative growth parameters and increased chlorophyll biosynthesis (Gad et al. 2022).

On the other hand, cobalt alleviates adverse impact of salinity on faba bean by inducing proline accumulation in plant, increasing the cytoplasmic osmotic pressure and regulating ions homeostasis (Akeel and Jahan 2020). Cobalt in all its concentrations increased the content of N, P and K in mature seeds, due to its effective role in increasing the efficiency of nitrogen fixation in legumes and its ability to increase plant retention of K, which acts as a major factor for plant tolerance to salinity (Onte et al. 2021).

All these effective roles of cobalt increase anabolic processes of faba bean plant and induce its tolerance against salinity thus reflected maximum yield productivity with highest quality of protein and carbohydrates. These outcomes are in harmony with that recorded by Baddour et al. (2021) and El-Shamly and Nassar (2023).

2- Impact of different bio-stimulants

Salinity had an adverse effect on all studied parameters of faba bean plant via several ways as ionic toxicity, reduction of water absorption and nutrients translocation from root to shoot (Abdeen and Hefni 2023), in addition to inhibition of cytokinine that inhibit growth parameters (Nasrallah et al. 2022). Also, it increased chlorophyllase enzyme activity which damage chlorophyll structure and had a negatively effect on balance of plant hormones as well as proline content (Ghanaym et al. 2022). This harmful effect of salinity on growth, chlorophyll content, photosynthetic pigment, nutrients uptake especially N that consequently reduces efficiency of developing seeds filling, decreases yield productivity and quality. These findings are in accordance with that found by (El-Mahdy et al. 2021).

Agriculture researchers now frequently employ more environmentally friendly techniques as plant bio-stimulants to alleviate stress, increase yield productivity and reserve environment. Bio-stimulants are compounds that can be applied to soil, seeds and plants to cause changes in plant's physiological processes that might be promote growth, development, or stress responses (Rouphael and colla 2020).

Results recorded that potassium humate, potassium fulvate and seaweed extract had a positively effect on faba bean growth, yield, and productivity under salinity stress and the superior was seaweed extract foliar application.

Under salinity stress, potassium humate application significantly effects on growth, yield productivity and quality of faba bean plant where it has cytokinin-auxin like properties in stimulating plant developmental processes such as cell division, enlargement, and differentiation. Additionally, it has a bio stimulant role in promoting germination, development, and yield, as well as increasing plant tolerance to biotic stress such as salt through the stimulation of antioxidant enzyme activities, resulting in the best yield productivity with improved quality (El-Beltagi et al. 2023). On the other hand, potassium fulvate acts as a bio stimulant where it promotes seed germination, root growth, and elongation, increases growth parameters and total photosynthetic pigments content in leaves, in addition to its ability to deliver bioactive molecules and free radical scavenging, reducing the negative effects of salinity on plants and improving yield productivity and quality (Taha et al. 2023).

Regarding to the superior application, seaweed extract as a bio-stimulant ameliorate the harmful effect of salinity where it contains high amounts of minerals and organic components that increase macronutrients i.e. N, P and K absorption and consequently increase their concentrations in plant overall growth stages till maturity, in addition to, a high content from plant hormones such as auxins and cytokinine that enhances different developmental processes that led to high vegetative growth parameters (Ghanaym et al. 2022). These findings agree with those of Sulieman et al. (2023).

On the other hand, seaweed extract able to reduce chlorophyll degradation and consequently increase chlorophyll content comparing to control by stimulating ascorbic acid biosynthesis that protect photosynthetic apparatus from damage (Aboualhamed and Loutfy 2020). Moreover, it promotes salt tolerance by increasing proline production which responsible for promoting ROS scavenging (El-Nwehy et al. 2021).

Increments in yield and yield parameters in plants treated by seaweed extract foliar application may be related to beneficial role of seaweed extract on enhancing growth, fruit production as it contains boron that is responsible for flowering and pods filling in addition to activation of antioxidant enzymes and scavenging of ROS radicals thus consequently increase plant tolerance against salinity, increasing yield productivity and its chemical component from protein and carbohydrates. These results are in agreement with that recorded by Elshalakany et al. (2023).

3- Impact of the interaction

The interaction of cobalt at 10 ppm and seaweed extract foliar applications recorded the highest yield productivity and highest mature seeds quality as a result of their effective role in mitigation the negative impact of salinity on faba bean plants.

Cobalt and seaweed extract positively affected on anabolic physiological process through increasing nutrients uptake, inducing chlorophyll content, enhancing endogenous hormones production and increasing plant resistant against salinity through accumulating of proline, decreasing chlorophyll degradation and promoting nutrients uptake thus consequently produced healthy plants with high yield productivity and quality under saline conditions.

Economically, the cost of using seaweed extract ~~treatments~~ was higher than that of potassium fulvate and potassium humate treatments because of the price of seaweed extract. For seaweed extract feddan required about 10 kg and 1kg costs about 160 LE. While feddan needed about 4 kg of potassium fulvate with cost 100 LE. for 1 kg. Furthermore, seaweed extract and potassium fulvate improved seed yield and estimated higher net return than potassium humate treatments. Among seaweed extract and potassium fulvate treatments there was much difference in B: C ratio. Cobalt at 10 ppm and potassium fulvate applied treatment estimated a high net return and B: C ratio, so it may be a feasible alternative to existing therapies for increasing agricultural output and farmer income.

5. Conclusion

The results indicated that cobalt at 10 ppm concentration is the optimal rate in all investigated faba bean development characteristics in these soil conditions; in respect to bio-stimulants seaweed extract foliar treatment is the best bio-stimulant applications used. In the end, the interaction of cobalt at 10 ppm concentration and seaweed extract foliar application ameliorate the harmful effect of salinity on faba bean plants and record the highest growth, yield, nutrients uptake and productivity. Economically the combination of cobalt at 10 ppm and potassium fulvate applied treatment could be a realistic solution for increasing crop productivity and farmer income.

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