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EFFECT OF FOLIAR FEEDING WITH SELENIUM NANOPARTICLES ON PHYSIOLOGICAL AND BIOLOGICAL FACTORS AND BEAN YIELD UNDER SALINE STRESS CONDITIONS

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ABSTRACT

Pot experiments were conducted in the 2022 and 2023 seasons in a plastic greenhouse at the Experimental Station, Faculty of Agriculture, Zagazig University, Sharkia Governorate, Egypt. This study used common bean seeds (*Phaseolus vulgaris* L., cv. Bronco), the most prevalent cultivar in Egypt and susceptible to salt stress. In both seasons, seeds were planted on October 15 in plastic pots filled with 8 kg of air-dried clay soil. To keep four plants per pot, seedlings were thinned before the first irrigation. Three replicates were used in a split-plot, complete randomized block system, as the experimental design. No stress (control), 100 mM NaCl, and 150 mM NaCl treatments were used in the main plots. After full plant emergence, deionized water and selenium nanoparticles (Se-NPs) foliar spraying were applied to sub-main plot plants. During both seasons, salinity stress notably decreased the number of pods and green pod yield in each pot, as well as MSI; the membrane stability index, and RWC; relative water content compared to the control. However, Se-NPs overcame the negative impacts of salinity stress and produced more pods and total green pods per pot than the control. In addition, RWC, MSI, proline, and total soluble sugars were increased. It can be concluded that the use of Se-NPs in the **c**ommon bean crop is an effective treatment in overcoming salt stress, leading to the possibility of producing this crop under high salinity conditions.

INTRODUCTION

In the natural world, plants are constantly subjected to a variety of stress, both biological and abiotic. One of these stresses, salinity stress is among the most detrimental to growth and productivity of plants. It is also regarded as a serious threat to sustainable crop production in the context of climate change. **Munns (2002)** reported that salinity reduces the ability of common bean plants to take up water, and this quickly causes reductions in growth rate, along with a suite of metabolic changes identical to those caused by water stress. Salt stress causes cellular defects through impairment of water potential of cells, ion homeostasis, ROS control, membrane integrity and function, and uptake of essential mineral nutrients (**Arzani and Ashraf, 2016). Keshavarz and Moghadam (2017)** subjected common bean to salinity stress by NaCl solution (75 mM) daily, carotenoids content, catalase activity in roots and superoxide dismutase activity in leaves increased due to salinity stress. **Sofy *et al.*(2020)** reported that irrigation of common bean plants with either 50 or 100mM NaCl fresh and dry weights of

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shoot decrease as NaCl concentration increases. Also, it reduced the growth dynamics, photosynthetic pigments (Chl. a, Chl. b, and carotenoids), membrane stability index (MSI), relative water content (RWC), and pod yield. **Nobre *et al.* (2022)** reported that salinity is a major abiotic stress that adversely affects several physiological and biochemical aspects of plants.

Rady *et al.* (2021) reported that *Phaseolus vulgaris* (L.) plants growing on soil impacted by salt (EC = 7.55–7.61 dS m^{-1}), foliar nourishment with Se-NPs of plant compared to plants in the comparison treatment, had an improvement in plant performance which led to a greatly rise in the indices of photosynthesis efficiency. Since SOD, POX, GR, APX, and CAT activities were greatly enhanced and EL and MDA were at lower levels, the comparison treatment generated noticeably higher levels of MSI, RWC, soluble sugar, free proline, and Se. Additionally, the content of Na+ was significantly reduced, and there was a notable increase in the K+/Na+ ratio

Se, nano-Se, or Na2SO4 sprayed at up to 10 µM concentrations significantly increased the levels of carotenoids, total photosynthetic pigments (TPP), and chlorophyll a and b inside the leaves of red kidney bean plants. Compared with no treatment, treatment with 1–50 µM nano-Se significantly elevated levels of photosynthetic pigments. GA-Se-NPs (1–50 µM) were more effective than Na_2SeO_4 and Na_2SO_4 at increasing the content of Mg, N, P, and K; increasing the content of S and Se in leaves; increasing the N and P contents in seeds; and decreasing the K and Mg contents in seeds at higher concentrations (**Abouelhamd *et al.*, 2023**). Seventy days following seeding, the actions of polyphenol oxidase, peroxidase, and catalase were measured in common bean leaves. Using nano-Se in application yielded the highest results. The treatments with fungicide and nano-Se produced the greatest levels of chlorophyll a and chlorophyll b. The antioxidant activity was greatly enhanced using nano-Selenium and nano-Silicon. Applying nano-Se resulted in low leakage percentages (**Taha *et al.*, 2023**). The utilization of GA-Se-NPs, Na2SO4, or Na2SeO4 up to 10 µM raised the yield of red kidney beans, was considerably higher than the control owing to sulfur's interaction with Se or nano-Se up to 5 µM (**Abouelhamd *et al.*, 2023**). Additionally, when nano selenium was applied to common beans, the dry seed yield increased in both growing seasons; plants treated with 100 ppm nanos produced the highest yield (**Taha *et al.*, 2023**). So, this work aimed to overcome salt stress, leading to the possibility of producing **c**ommon bean crops under high salinity conditions.

MATERIALS AND METHODS

Analysis and Preparation of Soil, Plant Material, and Experimental Technique

During two consecutive seasons (2022 and 2023), two greenhouse-based pot experiments were conducted at the Experimental Station, Faculty of Agriculture, Zagazig University, Sharkia Governorate, Egypt. During the Experimental duration, the average daily temperature was 21.2± 2.5°C and the average relative humidity was 56.0 ± 3.6%. The nutritious *Phaseolus vulgaris* L. cv. Bronco seeds were supplied by the Horticulture Research Institute's Vegetative Research Section at the Agriculture Research Center in Giza. Bronco cultivar was selected for this study because of its sensitivity to salt stress and it is the most widely grown bean cultivar in Egypt. The seeds were cleaned with deionized water following surface sterilization using 0.1% $HgCl_2$. On October 15^{th}, 2022, and October 17^{th}, 2023, seeds were planted in plastic pots with a depth of 25 cm and an inner diameter of 33 cm, each pot containing 8 kg of air-dried clay soil.

Seeds of a certain color and size were chosen to ensure uniformity. After being cleaned with distilled water. The chosen seeds underwent sterilization for two minutes in one percent (*V/V*) sodium hypochlorite, rinsed with deionized water, and allowed to dry process at room temperature (21°C). After that, the air-dried seeds were planted. To maintain four plants per pot, eight seeds were planted in every pot, and thinning was carried out before the initial irrigation. Analysis of the soil at the experimental site for each season was carried out in accordance with **Jackson (1967) and Black *et al.* (1965)**. Table 1 shows the results of soil physical and chemical evaluations. The recommended agricultural methods for cultivating common beans were used.

Using a complete randomized block system, three replicates of the experiments were conducted in a split-plot design. In the primary plots, the pots were divided into three parts: control (nonstress), the salinity is 100 mM and 150 mM NaCl. A foliar spray with selenium nanoparticles (Se-NPs) was allotted to the sub-plots (without foliar Se-NPs and with foliar Se-NPs) after the plants fully emerged (25 days after sowing).

Nano selenium (Se-NPs) preparation

Table 2 displays the properties of the Se-NPs, which were acquired through Sigma Aldrich Co. (Sigma-Aldrich, nano-SiO2 with 99.5% purity).

Applications of selenium nanoparticles (Se-NPs)

Three early-morning foliar sprays of distilled water (control) and Se-NPs (1.5 mM) were applied at 20, 35, and 50 days after sowing. Run-off was handled with a twenty-liter dorsal sprayer. As a surfactant, tween-20 drops (0.1 percent, *V/V*) were added to the spray solutions to maximize their infiltration of the plant leaf tissues.

Sampling

From every experimental pot, samples of 55-day-old plants of common beans were gathered.

Sample preparation for analysis

To minimize the loss of the root system, the common bean plants that were selected for the sampling dates were carefully removed from the pots' soil using a stream of water. Each bean plant was then divided into stems and leaves. The following information was noted:

Green yield estimation

Samples were taken from each pot to determine how many pods were in each pot at the marketable green pod stage, and each pot produced 1g of green pods.

Biochemical and physiological evaluation

The following chemical analyses were performed on the samples:

The activity of photochemistry

Common bean plant leaves that are fresh were tested for photochemical activity using **Jagendorf's (1956)** methodology, which **Avron (1960)** modified.

Finding the relative water content (RWC)

The relative water content was computed using the process outlined by **Barrs and Weatherley (1962).**

The membrane stability index (MSI) estimation

In accordance with **Rady (2011)**, the membrane stability index was computed.

Proline content determination

Using the **Bates *et al.* (1973)** method, it was established what proline concentration was.

Measurement of the total amount of soluble sugars

In accordance with **Irigoyen *et al.* (1992),** the total soluble sugar content was calculated.

Determination of malondialdehyde (MDA)

The methods suggested by **Heath and Packer (1968)** were used to determine the amount of malondialdehyde.

Table 1. Mechanical and chemical analysis of the soil used

Mechanical analysis			Chemical analysis										
Coarse Sand %	**Silt %**	**Clay %**	**Cations mg/100g soil**				**Anion mg/100g soil**				**E.Ca+ 25°C ds/m**	**pH**	**W. H. C.**
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO3^{-}$	$HCO3^{-}$	Cl^{-}	$SO4^{--}$			
52.95	27.95	19.3	3.0	1.8	2.5	0.1	0.00	0.5	1.18	5.72	2.96	7.71	34.64

Table 2. Principal attributes of the Se-NPs used in this investigation

The Property	The Unit	The Value
Diameter	Nm	10-45
Surface area	m2 g-1	30-50
Density	g cm-3	3.89
Purity	%	99.98
Morphology	Spherical	

Assessment of electrolyte leakage (EL)

To determine the overall content of inorganic ions that leak out of the leaves, the **Sullivan and Ross (1979)** method was applied.

Measurement of Hydrogen Peroxide and Superoxide Concentrations

0.05 percent NBT, a NaN3 concentration of 10 mM, and 10 mM of K-phosphate buffer (pH 7.8) were added to the leaf fragments for one hour in order to measure the superoxide (O^{2-}) content. The absorbance at 580 nm was measured following the immersion solution's heating (at 85°C for 15 minutes) and quick cooling **(Kubiś, 2008).**

The acetone extract's hydrogen peroxide content was measured. 1 M H2SO4 was used to dissolve the extract following the addition of titanium reagent and ammonium, and the absorbance was measured at 415 nm **(Mukherjee and Choudhuri, 1983).** The **AOAC (1984)** states that atomic absorption spectrophotometry was used to determine the heavy metal contents of the spinach leaves, dried and powdered, which were then weighed.

Statistical Analysis

The impact that the treatments have on all the criteria were evaluated using a one-way ANOVA. Fisher test results were used when significant variations ($p < 0.05$) were found **(Sokal and Rohlf, 1980).** For analysis, the SAS software was utilized.

RESULTS AND DISCUSSION

Notably, the results obtained during the two successive growing seasons concerning the responses of common bean to three selenium nanoparticles applied topically (Se-NPs) were related to biochemical and physiological properties, and yield components under different levels of stress caused by salinity. Therefore, the responses of the values obtained in both seasons are discussed.

Physiological and Biochemical Properties

The information in Table 3 illustrates how foliar feeding with selenium nanoparticles (Se-NP) effects on total soluble sugars, relative water content, proline content, and membrane stability index of the common bean plant *cv* Bronco grown under varying salinity stress levels in the 2022 and 2023 seasons. Because of salinity stress, MSI and RWC dramatically decreased during both seasons. The biggest decrease observed was under extreme salt stress. Salinity at 150 mM NaCl reduced the RWC by 19.1 and 19.2% and the MSI by 25.1 and 23.4% in season one and season two, respectively.

These findings are explained by the fact that *Phaseolus vulgaris* (L.) experiences salinity stress, which lowers RWC and MSI because antioxidant defenses are unable to withstand the salt stress as stated by **Rady *et al*. (2021).** Also, salinity stress increases free radicals, which may induce membrane lipid peroxidation **(Nagesh and Devaraj, 2008)**. In addition, Salinity stress causes membrane peroxidation mediated by H_2O_2 to decrease membrane stability **(Ahanger *et al*., 2018).** Additionally, because of the buildup of harmful ions (Na and Cl), saline water the reduces relative water content, which exhibits stomatal closure and leaf expansion **(El-Afry *et al*., 2018)**.

There are three primary ways that plants grow in saline conditions, which could explain our findings: 1) water deficit may result from lowering the potential for water in the root zone; 2) increasing ions such as sodium+ and chloride's phytotoxicity; and 3) decreased transport of nutrients can lead to an increase in nutrient imbalance as reported by **Yildirim and Taylor (2005).** However, stress from salinity rose dramatically both proline and total soluble sugars during the two seasons. The greatest increase recorded under the high level (150 mM NaCl) of salt stress increased proline by 56.1 and 59.5% and total soluble sugars by 51.4 and 57.4% in seasons one and two, respectively. In stressed plants, proline serves two purposes as an efficient defensive antioxidant. It functions as an efficient osmotic agent to support cellular osmotic regulation, membrane stabilization, and toxic ion detoxification **(Rady *et al*., 2016).** In stressed *Phaseolus vulgaris* plants, soluble sugars and proline levels rose (**Sitohy *et al*., 2020).**

Soluble sugars and proline are accumulated by numerous plant species react to salinity stress; this accumulation may compete with salinity stress and may be connected to a nodule osmotic adjustment response under salinized conditions (**Mansour *et al*., 2005; Tejera *et al*., 2005)**. Also, Selenium nanoparticles increased RWC by 4.6 and 4.5%, MSI by 7.1 and 6.8%, proline by 4.2 and 3.8% and total soluble sugars by 6.3 and 6.1%, correspondingly in the one and two season. By enhancing RWC and Rubisco protection and maintaining amounts of soluble sugar and proline to aid in the removal of ROS, Se-NPs control the buildup of proline, boost enzymatic activity, and safeguard photosynthesis (**Ahanger *et al*., 2017**).

Stressed by salinity, selenium can control the accumulation of soluble sugars and proline within the leaves of plants by maintaining the osmotic and ionic balance inside the plant cells. (**Ahanger *et al*., 2017; Elkelish *et al*, 2019).** Because EL, and MDA were reduced and POX, CAT, SOD, APX, and GR reactions were significantly elevated, foliar nourishment with Se-NPs for Plants of the *Phaseolus vulgaris* (L.) species that are stressed by salt increased the free proline, RWC, soluble sugar, MSI, and the content of Se in comparison to the comparison treatment, along with a significant rise in the ratio of K+/Na+ and a significant diminished in the Na+ content (**Rady *et al*., 2021).**

Comparing the proline content, RWC, total soluble sugars, and MSI of common plants with the control, data regarding the

Table 3. Influence of salinity stress, foliar feeding with Se-NPs, and their interaction on the RWC, proline, MSI, and total soluble sugars of common bean plants *cv.* Bronco during the 2022 and 2023 growing seasons

Treatments	Parameter	RWC (%)		MSI (%)		Proline (μg g^{-1})		Total soluble sugars (mg g^{-1} dry weight)	
Effect of salinity		**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Control		83.3±[a]	85.3±[a]	77.3±[a]	79.1±[a]	24.4±[c]	24.7±[c]	18.1±[c]	18.3±[c]
100 Mm NaCl		76.3±[b]	77.8±[b]	66.8±[b]	68.7±[b]	31.9±[b]	33.4±[b]	23.1±[b]	24.5±[b]
150 Mm NaCl		67.4±[c]	68.9±[c]	57.9±[c]	60.6±[c]	38.1±[a]	39.4±[a]	27.4±[a]	28.8±[a]
Effect of foliar spray									
DW		74.0±[b]	75.1±[d]	65.0±[b]	66.2±[d]	30.8±[b]	31.6±[d]	22.1±[b]	22.9±[d]
Se-NPs		77.4±[a]	78.5±[b]	69.6±[a]	70.7±[b]	32.1±[a]	32.8±[b]	23.5±[a]	24.3±[b]
Effect of interaction									
Salinity	**Foliar feeding**								
Control	**DW**	81.7±[b]	83±[c]	76.2±[b]	77.3±[c]	23.8±[f]	23.9±[j]	17.4±[f]	17.5±[j]
	Se-NPs	84.8±[a]	86.1±[ab]	78.3±[a]	79.4±[b]	24.9±[e]	25.0±[i]	18.7±[e]	18.7±[i]
100 Mm NaCl	**DW**	74.7±[d]	75.8±[f]	63.9±[d]	65.0±[f]	31.2±[d]	32.3±[g]	22.2±[d]	23.2±[h]
	Se-NPs	78.0±[c]	79.1±[d]	69.6±[c]	70.8±[d]	32.5±[c]	33.6±[e]	24.0±[c]	25.0±[f]
150 Mm NaCl	**DW**	65.5±[f]	66.5±[i]	55.0±[f]	56.1±[j]	37.4±[b]	38.5±[c]	26.8±[b]	27.8±[d]
	Se-NPs	69.3±[e]	70.3±[h]	60.8±[e]	62.0±[h]	38.7±[a]	39.8±[b]	28.0±[a]	29.1±[b]
ANOVA	**Df**	*P-value*							
S	**2**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
F	**1**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000
SxF	**2**	0.5519	0.5519	0.0146	0.0146	0.7566	0.7566	0.1418	0.1418

At $p \leq 0.05$, the means in each column that contain distinct letters are regarded as a substantially different.

MSI for membrane stability index, DW for deionized water, and RWC stands for relative water content.

combined effects of applying selenium nanoparticles (Se-NPs) topically and varying levels of salinity stress are provided, Se-NPs improved most plant photosynthesis parameters, including proline content, MSI, total soluble sugars, and RWC, and they were able to conquer the adverse consequences of salinity stress. All the abovementioned outcomes concur with those of **Desoky *et al*. (2020 & 2021).**

According to our findings in Table 4, electrolyte leakage, hydrogen peroxide, malondialdehyde, and superoxide all significantly increased during the two seasons because of the stress caused by salinity. 150 mM NaCl as the highest salt stress recorded the greatest increase, which raised EL by 97.3 and 84.7%, MDA by 177.5 and 176.7%, $O_2^{\bullet-}$ by 91.5 and 84.4% and H_2O_2 by 70.5 and 70.2%. Accordingly,

Table 4. Influence of salinity stress, foliar feeding with Se-NPs and their interaction on EL, MDA, O_2•− as well as H_2O_2 of common bean plants *cv.* Bronco in 2022 and 2023 seasons

Treatments	Parameter	EL (%)		MDA (µmol g1)		$O_2^{\bullet-}$ (µmol g^{-1} FW)		H_2O_2 (µmol g^{-1} FW)	
Effect of salinity		**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Control		6.74±[c]	6.66±[c]	0.89±[c]	0.86±[c]	0.47±[c]	0.45±[c]	1.46±[c]	1.41±[c]
100 Mm NaCl		10.6±[b]	9.62±[b]	1.83±[b]	1.76±[b]	0.68±[b]	0.63±[b]	2.00±[b]	1.93±[b]
150 Mm NaCl		13.3±[a]	12.3±[a]	2.47±[a]	2.38±[a]	0.90±[a]	0.83±[a]	2.49±[a]	2.40±[a]
Effect of foliar spray									
DW		11.2±[a]	10.5±[a]	1.90±[a]	1.84±[a]	0.73±[a]	0.69±[a]	2.09±[a]	2.02±[a]
Se-NPs		9.30±[b]	8.58±[b]	1.56±[b]	1.49±[b]	0.64±[b]	0.59±[b]	1.87±[b]	1.80±[b]
Effect of interaction									
Salinity	**Foliar feeding**								
Control	**DW**□	7.18±[e]	7.10±[d]	0.94±[e]	0.91±[e]	0.49±[e]	0.47±[e]	1.55±[e]	1.50±[e]
	Se-NPs	6.29±[f]	6.21±[e]	0.84±[f]	0.81±[f]	0.45±[f]	0.43±[f]	1.36±[f]	1.31±[f]
100 Mm NaCl	**DW**	11.6±[c]	10.6±[b]	2.01±[c]	1.94±[c]	0.75±[c]	0.70±[c]	2.15±[c]	2.08±[c]
	Se-NPs	9.69±[d]	8.66±[c]	1.65±[d]	1.58±[d]	0.61±[d]	0.56±[d]	1.85±[d]	1.78±[d]
150 Mm NaCl	**DW**	14.7±[a]	13.7±[a]	2.76±[a]	2.67±[a]	0.95±[a]	0.88±[a]	2.58±[a]	2.49±[a]
	Se-NPs	11.9±[b]	10.87±[b]	2.18±[b]	2.09±[b]	0.85±[b]	0.78±[b]	2.39±[b]	2.30±[b]
ANOVA	**Df**				*P-value*				
S	**2**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
F	**1**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SxF	**2**	0.0000	0.0000	0.0002	0.0002	0.0012	0.0012	0.0023	0.0023

Means with different letters in each column are regarded as drastically different when $p \leq 0.05$.
[#] EL= electrolyte leakage O_2− = superoxide radical MDA= malondialdehyde
H_2O_2 = hydrogen peroxide
□ DW = Deionized water

in first and second seasons. These findings concur with those of **Sitohy *et al.* (2020), Sofy *et al.* (2020), Desoky *et al.* (2021), and Rady *et al.* (2021),** who found elevated levels of oxidative stress markers, electrolyte leakage, and membrane lipid peroxidation in plants cultivated in soil impacted by salt.

Table 4 data illustrate the impacts of foliar feeding (Se-NPs) on electrolyte leakage, malondialdehyde, superoxide, and hydrogen peroxide in common bean plants *cv*. Bronco are cultivated under different levels of salinity stress in the 2022 and 2023 seasons. It was reported that, mutilation to proteins, membrane lipids, and nucleic acids can result from the buildup of harmful active oxygen species brought on by salt stress. Aerobic metabolism produces harmful byproducts called reactive oxygen intermediates (ROS), which include O2− and H_2O_2. The nucleic acids, lipids in membranes of plant cell, and metabolic enzymes can all be directly attacked by these ROS **(Mittler, 2002; Jaleel *et al.*, 2007).** Moreover, **Yadavi**

***et al*. (2014**) revealed that, the electron acceptance of NADP is limited; As a result, O_2 may function as an electron acceptor, increasing the generation of free radicals, which damages cell membranes and raises EL under stress. In addition, **Van Breusegem and Dat (2006)** reported that lipid peroxidation, quantified as the content of malondialdehyde, an outcome of lipid peroxidation, it is regarded as an indication of the damage caused by oxidation, decreasing the fixation of carbon dioxide, but light reactions and electron transfer occur normally. Additionally, since NADP has limited electron acceptance, O_2 can act as an electron acceptor to boost the generation of reactive oxygen species (OH^-, H_2O_2, and $O_2^{\bullet-}$), which causes lipid peroxidation in cell membranes and raises EL under stress of drought **(Yadavi *et al.*, 2014).**

Released ROS can build up to phytotoxic levels under a variety of abiotic stress conditions, which causes them to indiscriminately attack and harm DNA, lipids, and proteins. Situations that promote electron transport chain leakage and reduced antioxidant capacity are often associated with this type of ROS-dependent cell death, which has a necrotic appearance. The process of cell death involves excessive accumulation of this ROS **(Van Breusegem and Dat, 2006).** Under salinity stress, seedlings are unable to adjust osmotically, and the toxic ions of Cl^- and Na^+ are transported to and accumulate in cells (**Kaymakanova**, **2009**). During respiration and photosynthesis, drought increases electron leakage to O_2, which stresses plant cells. H_2O_2, $O_2^{\bullet-}$, and OH^- are among the reactive oxygen species that are overproduced as a result (**Sitohy *et al.*, 2020**). Pigments involved in photosynthetic reactions, properties of gas exchange, water balance, and cell integrity are all disrupted under drought stress, and markers of oxidative stress rise as a result of the negative osmotic influence of drought-related stress **(Desoky *et al.*, 2021)**.

Selenium nanoparticles decreased EL by 17 and 18.3%, MDA by 17.9 and 19%, $O_2^{\bullet-}$ by 12.3 and 14.5% and H_2O_2 by 10.5 and 10.9% in the initial and subsequent seasons, respectively. Se application decreases ROS production by regulating antioxidant systems to decrease ROS generation **(Hawrylak-Nowak, 2013)**. By enhancing photosynthesis, selenium application reduces nutrient accumulation and ROS **(Alyemeni *et al.*, 2018).** By stimulating the synthesis of enzymatic and nonenzymatic antioxidants and regulating osmolyte levels, Se application reduced ROS levels and promoted growth (**Desoky *et al*., 2021).** Se contents minimize levels of indicators of oxidative stress, EL, and MDA in *Phaseolus vulgaris* (L.) Plants growing in soil that has been impacted by salt (**Rady *et al.*, 2021).** When Se-NPs are applied, oxidative damage from salt stress is prevented by low-molecular-mass (nonenzymatic) and ingredients with a high molecular mass (enzymatic) like the initial defense line (SOD), which changes it to H_2O_2 in order to defend against $O_2^{\bullet-}$ **(Rady *et al.*, 2021)**, and APX, the most crucial enzyme in lowering ROS, is present when peroxidases convert it to O_2 and H_2O (**Feierabend, 2005).** By controlling how these enzyme-related genes express themselves, Bio-Se-NPs activate Enzymes of antioxidants that aid in the detoxification of ROS, reducing the ROS level and MDA content (**El-Badri *et al*., 2022)**.

Table 4 lists data concerning the interaction implications of topically applying selenium nanoparticles (Se-NPs) and different levels of salinity stress on the EL, MDA, $O_2^{\bullet-}$ and H_2O_2 contents of common bean plants. These findings are consistent with those of **Desoky *et al*. (2020 & 2021)** who said that compared with the control, all the bio stimulants overcame the adverse consequences of exposure to salt and significantly reduced EL, MDA, $O_2^{\bullet-}$ and H_2O_2.

Yield Component

The data presented in Table 5 demonstrate the impact of foliar selenium nanoparticles on the quantity of pods in each pot and the quantity of green pods per pot of common bean cv Bronco's cultivation under different levels of salty stress in the 2022 and 2023 seasons. Stress due to salinity caused a greatly decline in the quantity of green pods/pots and pods/pots during both seasons. The greatest reduction in yield parameters was observed during a period of elevated salt stress (150 mM NaCl), which reduced the quantity of pods per pot by 48.4 and 46.1% and the green pod yield per pot by 53.8 and 52.2% in the first and second batches, respectively.

Our results may be related to the fact that Common beans lose yield at soil salinity levels below 2 dSm^{-1} because they are highly salinity-sensitive as reported by **Läuchli (1984).** Also, the yield's decline due to salt stress may lead to ion and mineral element imbalances as reported by **Aziz and Khan (2001),** as well as alters gas exchange variables, osmotic stress and reduces water, and lowers chlorophyll content among other detrimental effects on plant physiological processes (**Kyoro, 2006**). In the same direction, (**Vaidyanathan *et al*., 2003)** reported that in arid and semiarid regions in particular, salinity is one of the primary elements that impacts plant growth and metabolism, causing serious harm and a decline in productivity. Also, the biomass yield of common bean was negatively impacted by salinity (**Gama *et al.*, 2007**). Furthermore, **Sofy *et al.* (2020)** found that when common bean plants were irrigated with 50 or 100 mM of NaCl, $NaCl^-$ induced osmotic stress is aggravated by a notable decrease in the quantity of pods per plant.

Our results are clear that selenium nanoparticles increased the quantity of pods per pot by 16.9% and 14.5% and the green pod yield per pot by 16.1% and 15.1% during the two seasons, in turn. These outcomes are in line with **Zafar *et al*. (2024),** who found that applying Se-NPs to wheat plants under circumstances of salty stress can increase their yield per plant. **Rady *et al.* (2021)** applied foliar nourishment with Se-NPs of *Phaseolus vulgaris* (L.) plants growing in soil impacted by salt. They found that, compared with the comparison treatment, this treatment caused a substantial increase in soluble sugar, RWC, free proline, MSI, and the content of Se due to the decreased levels of electrolyte leakage, and malondialdehyde and greatly elevated levels of GR, POX, SOD, APX, and CAT, Additionally, there was a noteworthy decline in the amount of sodium and an appreciable rise in the ratio of K+/Na+.

The outcomes we obtained concur with the conclusions of **El-Badri *et al*. (2022)** who reported that **t**he bio-Se-NPs improved the photosynthetic efficiency and osmolyte content both in typical and salt-stressed circumstances. Furthermore, along with adjusting K+ and Na+ uptake, by activating the antioxidant enzymes involved in ROS detoxification through the regulation of these enzyme-related gene expression patterns, bio-Se-NPs reduce the ROS level and MDA content. Significantly, alterations in the degree of expression of genes related to Se seemed to be connected with the primary impact of bio-Se-NPs on plant growth. Also, **Taha *et al*. (2023)** showed that the actions of peroxidase, catalase, and polyphenol oxidase increased when nano-Se was applied to common bean. With the nano-Se treatments, the greatest amounts of Chl. a and Chl. b were recorded. When nano-Se and nano-Si were applied, the antioxidant activity was significantly increased. The application of nano-Se led to low percentages of leakage. Therefore, as a result of all these effects of the selenium nanoparticles, yield parameters such as the quantity and yield of green pods in each pot improved.

Table 5. Influence of salinity stress, foliar feeding with Se-NPs and their interaction on the quantity and yield of green pods pot^{-1} of common bean plants in 2022 and 2023 seasons

Treatments	Parameter	No. of pods pot^{-1}		Green pod yield pot^{-1} (g)	
Effect of salinity		**1st season**	**2nd season**	**1st season**	**2nd season**
Control		27.3±[a]	29.3±[a]	36.8±[a]	38.7±[a]
100 Mm NaCl		22.1±[b]	23.7±[b]	28.5±[b]	30.2±[b]
150 Mm NaCl		14.1±[c]	15.8±[c]	17.0±[c]	18.5±[c]
Effect of foliar spray					
DW		19.5±[b]	21.4±[b]	25.4±[b]	27.1±[b]
Se-NPs		22.8±[a]	24.5±[a]	29.5±[a]	31.2±[a]
Effect of interaction					
Salinity	**Foliar feeding**				
Control	**DW**	26.2±[b]	28.2±[b]	35.2±[b]	37.1±[b]
	Se-NPs	28.3±[a]	30.3±[a]	38.3±[a]	40.2±[a]
100 Mm NaCl	**DW**	20.5±[d]	22.4±[d]	25.9±[d]	27.6±[d]
	Se-NPs	23.7±[c]	25.0±[c]	31.1±[c]	32.8±[c]
150 Mm NaCl	**DW**	11.8±[f]	13.5±[f]	15.0±[f]	16.5±[f]
	Se-NPs	16.4±[e]	18.1±[e]	19.0±[e]	20.5±[e]
ANOVA	**Df**				
S	**2**	0.0000	0.0000	0.0000	0.0000
F	**1**	0.0000	0.0001	0.0000	0.0000
SxF	**2**	0.0023	0.0319	0.0259	0.0259

A significant difference is defined as a mean with a distinct letter in each column at $p \leq 0.05$.

#DW stands for deionized water.

Data concerning the interaction effects of foliar feeding of selenium nanoparticles (Se-NPs) and salinity stress with different levels of salt stress on the yield characteristics of Common plants are shown in Table 5. Compared with the control, all the bio-stimulants overcame the negative consequences of salty stress and caused greater features of plant yield, including the quantity and yield of green pods per pot, than did the control. These findings concur with those published by **Zahedi *et al*. (2019), Desoky *et al*. (2020, 2021), Abouelhamd *et al.* (2023) and Zafar *et al.* (2024).**

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الملخص العربي

تأثير التغذية الورقية بجزيئات السيلينيوم النانوية على العوامل الفسيولوجية والحيوية ومحصول الفاصوليا تحت ظروف الإجهاد الملحي

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أجريت تجارب أصص في موسمي 2022، و2023 تحت الصوب البلاستيكية في المحطة التجريبية بكلية الزراعة جامعة الزقازيق بمحافظة الشرقية بمصر . بذور الفاصوليا (صنف برونكو)، وهي أكثر أصناف الفاصوليا شيوعا في مصر، وهي حساسة للإجهاد الملحي، تم تعقيم البذور وغسلها بالماء منزوع الأيون. زرعت البذور في 15 أكتوبر في كلا الموسمين في اصص بلاستيكية، واحتوى كل اصيص على 8 كجم من التربة الطينية المجففة هوائياً . تم إجراء خف للبادرات قبل الرية الأولى للاحتفاظ بأربعة نباتات/اصيص. واستخدم تصميم القطع المنشقة بنظام القطاعات كاملة العشوائية في ثلاث مكررات لتنفيذ التجارب؛ حيث اشتملت القطع الرئيسية على المعاملات التالية: كنترول (بدون إجهاد ملحي)، و100 ملي كلوريد الصوديوم، و150 ملي كلوريد الصوديوم؛ أما القطع المنشقة فاحتوت على معاملتين (بدون رش الأوراق بجزيئات السيلينيوم النانوية، ومع رش الأوراق بجزيئات السيلينيوم النانوية بعد اكتمال ظهور النباتات). أدى إجهاد الملوحة إلى انخفاض معنوي في المحتوى المائي النسبي (RWC)، ومؤشر ثبات الغشاء (MSI)، بالإضافة إلى انخفاض معنوي في عدد القرون /الأصيص، وعدد القرون الخضراء/ الأصيص خلال الموسمين .زادت جزيئات السيلينيوم النانوية من RWC، وMSI، والبرولين، والسكريات الكلية القابلة للذوبان، وبالمقارنة مع العنصر الكنترول، تغلبت جزيئات السيلينيوم النانوية على الآثار الضارة لإجهاد الملوحة وأسفرت عن عدد أكبر من القرون لكل اصيص، وعدد القرون الخضراء لكل اصيص، مقارنة بمعاملة الكنترول في الموسمين . يمكن استنتاج أن استخدام جزيئات السيلينيوم النانوية في محصول الفاصوليا هو علاج فعال في التغلب على الإجهاد الملحي، مما يؤدي إلى إمكانية إنتاج محصول الفاصوليا وهو تحت ظروف الملوحة العالية.

الكلمات الإسترشادية: الفاصوليا، إجهاد الملوحة، جزيئات السيلينيوم النانوية، التغذية الورقية، النمو الخضري، محصول القرون.

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