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Optimizing snap bean production under salt affected soil via compost, selenium and cobalt

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SNAP beans are a valuable vegetable crop due to their high nutritional value, but their production can be challenging under salt-affected soil conditions, which can adversely affect their growth and productivity. To optimize snap bean production under this issue, a field experiment was conducted to evaluate the effect of various interventions on the growth performance and yield quality of two snap bean cultivars (Savana and Newten) grown on saline soil. The main factor was the selected cultivars, while compost soil addition at a rate of 8.0 ton ha^{-1} (applied or not) was evaluated as a sub main factor. Also, foliar applications of selenium (as sodium selenite, Na_2SeO_3, 45.56 %Se) and cobalt (cobalt sulphate, $CoSO_4$, 36%Co), at rates of 0.0 and 5.0 mg L^{-1} for each one, were assessed as a sub-sub-plot factor. The Savana cultivar outperformed the Newten cultivar in achieving maximum values for all performance traits expressing growth and productivity. Additionally, the addition of compost to soil led to an increase in some parameters *e.g.*, dry foliage weight, chlorophyll, No. of pods $plant^{-1}$, pods yield, protein and carbohydrates compared to plants grown without compost. On the other hand, the exogenous application of selenium was superior to the cobalt treatment, followed by the control treatment. Conversely, the plant's need for antioxidants such as peroxidase and catalase decreased with Savana cultivar plants treated with compost and selenium. The findings of this study can also be extended to other vegetable crops grown in saline conditions to enhance their productivity and nutritional quality.

Keywords: Saline soil, compost, cobalt, selenium.

1. Introduction

Snap bean (*Phaseolus vulgaris* L.) is an important crop in Egypt and contributes significantly to the country's economy. Egypt is one of the major producers and exporters of snap bean in the world **(Taha *et al.* 2023).** The crop is mainly grown in the Nile Delta and along the Mediterranean coast, where the favorable climate and soil conditions support its growth and productivity **(El-Mougy *et al.* 2020).** However, the cultivation of snap bean in saline soils is often hampered by the adverse effects of salinity stress. Saline soils have high concentrations of salt, which can cause osmotic stress, ion toxicity, nutrient deficiency, and oxidative stress in the plants, leading to reduced growth, yield, and quality of the crop **(Kumar *et al.* 2020).**

It is possible to overcome the problems of saline soils when cultivating bean crops through the use of cultivars that are more tolerant to salinity stress. The cultivation of salt-tolerant cultivars is an effective strategy to mitigate the negative effects of salinity on bean crops. The use of salt-tolerant cultivars can help to minimize these effects by maintaining normal physiological processes even under high salt concentrations. In other words, these cultivars can help to maintain plant growth and productivity even under high salt concentrations, thus ensuring stable

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and sustainable bean crop production **(Nemeskéri *et al.* 2010).**

Also, to overcome the negative effects of salinity stress on snap bean, various strategies have been proposed, including the use of compost, selenium, and cobalt. Compost is a rich source of organic matter, which can improve soil structure **(Elsherpiny *et al.* 2023a& b),** water-holding capacity, and nutrient availability, thus helping to alleviate the adverse effects of salinity on snap bean **(El Hasini *et al.* 2020).** Additionally, selenium and cobalt are essential micronutrients that can improve plant tolerance to salinity stress. Selenium acts as an antioxidant, protecting the plant from oxidative stress caused by salinity **(Jiang *et al.* 2017; Elsherpiny and Kany 2023; Abdalla *et al.* 2023),** while cobalt is involved in nitrogen fixation and enhances plant growth and productivity **(Baddour *et al.* 2021).** Although its direct impact on plant growth under salinity stress may be limited, by improving nutrient uptake and enhancing metabolic processes, cobalt supplementation can indirectly support plant growth and mitigate the negative effects of salinity **(Akeel and Jahan 2020).**

Therefore, the objective of this study was to assess the effectiveness of compost, selenium, and cobalt in enhancing the tolerance of two snap bean cultivars to salinity stress, and to investigate their impact on the growth, yield, and quality of the plants grown in saline soil conditions.

2. Material and Methods

- Experimental location and soil sampling

The study was conducted at the Experimental Farm of Mansoura University in Egypt, which is located at coordinates 31°22′32.32″ E and 31° 3′ 17.05″ N, and has an elevation of 6 meters above sea level. According to the Agriculture Extension services affiliated with the Ministry of Agriculture and Soil Resources in Egypt (MASR), the average temperature at the experimental site was 29°C during the summer and 13°C during the winter.

Table 1. Properties of the initial soil.

Traits and units		Values
pH (1:5 soil suspension)		8. 10
EC, dSm^{-1}(soil extract 1:5)		6.25
Organic matter%		1.75
Total $CaCO_{3,}$ %		2.21
Nitrogen, mg kg^{-1}		50.59
Phosphorus, mg kg^{-1}		7.550
Potassium, mg kg^{-1}		230.9
Particles size distribution, g kg^{-1}	Sand	204.0
	Silt	299.6
	Clay	496.4
Texture		Clayey

Notes: The soil is saline because the EC exceeds 4.0 dSm^{-1}.

Table 2. Properties of compost.

Traits and units	Values
Total C, g kg^{-1}	217
Total N, g kg^{-1}	17.6
C:N ratio	12.3
pH	6.15
EC, dSm^{-1}	3.70
Available nutrients, mg kg^{-1}	
Iron	59.0
Manganese	29.0
Phosphorus	0.59
Potassium	0.83
Zinc	19.0

Prior to sowing the snap bean, a composite soil sample was collected from the experimental site (at a depth of 0-30 cm). The sample was analyzed using methods described by **Dane and Topp (2020) and Sparks *et al.* (2020).** The initial soil characteristics are shown in Table 1.

- Studied cultivars and substances

Two snap bean cultivars, Savana and Newten, were procured from a private agricultural company in the Egyptian commercial market. The compost with properties listed in Table 2 was obtained from the agricultural commercial market. Sodium selenite (Na_2SeO_3, 45.56% Se) and cobalt sulfate ($CoSO_4$, 36% Co) were purchased from Sigma Company, Egypt. To create standard solutions, selenium and cobalt were dissolved in a solvent at a specific concentration. The resulting standard solutions were then utilized to prepare the Se and Co concentrations used in the study.

- **Experimental setup**

A field experiment was conducted during two successive seasons (2022-2023) under a split-split-plot design with three replicates to evaluate the effect of various interventions on the growth performance and yield quality of two snap bean cultivars (Savana and Newten) grown on salt-affected soil (with an EC value of 6.25 dsm^{-1}). The main factor was the selected cultivars, while compost soil addition at a rate of 8.0 ton ha^{-1} (applied or not) was evaluated as a sub main factor. Also, foliar applications of selenium (as sodium selenite, Na_2SeO_3, 45.56 %Se) and cobalt (cobalt sulphate, $CoSO_4$, 36%Co), at rates of 0.0 and 5.0 mg L^{-1} for each one, were assessed as a sub-sub-plot factor.

The experimental sub-sub-plot had an area of 10.23 m² (3.1 m × 3.3 m) and contained six ridges of 0.75 m width and 3.0 m length, with a planting distance of 7 cm between each plant. Prior to sowing, compost was mixed thoroughly with the surface layer of soil (0-50 cm) according to the treatment under investigation. On February 16th, seeds were sown at a rate of 45 kg fed^{-1}, and pods were harvested at the appropriate maturity stage during both seasons. One hour prior to sowing, Okadin biofertilizer obtained from the bio-fertilizer production unit affiliated with MASR was used to inoculate the seeds at a rate of 200g of rhizobium inoculant carried on peat moss fed^{-1}, with sugar solution used as a sticker. Other fertilization processes (P and K) and all traditional agricultural practices for snap bean production were executed according to the recommendations of MASR. The foliar application of selenium and cobalt was repeated twice at two-week intervals, starting from the first watering, which was 21 days after sowing, with a volume of 400 L fed^{-1} for each element. Surface irrigation was used for watering, with the Nile River serving as the source of irrigation.

- **Measurement traits**

After 50 days of sowing, the growth traits and leaf chemical constituents of snap bean plants were measured, including plant height, foliage fresh and dry weights, chlorophyll content (SPAD value) **(Castelli *et al.* 1996),** and antioxidant enzymes such as peroxidase enzyme (POD) and catalase enzyme (CAT) (**Tunley, 1971)**. POD activity was assessed by observing the guaiacol oxidation at 470 nm through a spectrophotometer. The reaction mixture comprised guaiacol, hydrogen peroxide, and crude plant extract. The absorbance was continuously monitored over time to measure the rate of change, and the POD activity was reported as units per minute per gram of fresh weight (FW). CAT activity was determined by tracking the hydrogen peroxide decomposition at 240 nm using a spectrophotometer. The reaction mixture contained hydrogen peroxide and crude plant extract. The absorbance changes were measured over time, and the CAT activity was expressed as units per minute per gram of FW. Also, nitrogen, phosphorus, and potassium were determined in leaves using the Kjeldahl method, spectrophotometer, and flame photometer, respectively **(Tandon, 2005),** as the leaves were oven-dried, ground, and wet digested with a mixture of perchloric and sulfuric acids (1:1) **(Peterburgski (1968).**

When the pods reached maturity, yield and its components such as the No. of pods per plant, pod length, pod weight, pod diameter, and pod yield were measured. The chemical constituents of the pods (outer shell + grains inside the pods), including N, P, K were determined as formerly mentioned in leaves. Also, the quality traits of the pods, including crude protein, carbohydrates, fiber, and total dissolved solid TDS, were determined (**AOAC, 2000).**

- **Statistical analysis.**

The statistical analysis was carried out using **CoStat (Version 6.303, CoHort, USA, 1998–2004)** following the methodology described by **Gomez and Gomez (1984).**

2. 3. Results

- **Plant performance at 50 days from sowing**

Table 3 presents the outcomes of the application of compost to soil and cobalt/selenium foliar treatment on various growth traits of snap beans (two cultivars) grown under saline conditions after 50 days from sowing, during two seasons. The growth traits analyzed were plant height (cm), fresh and dry foliage weight (g $plant^{-1}$), and chlorophyll SPAD readings. Also, Table 4 demonstrates the impact of the same treatments on chemical components, such as N, P, and K (%), and enzymatic antioxidants production, such as peroxidase and catalase (A564 min^{-1} g^{-1} protein), in the leaves of snap beans at the same period.

With the exception of enzymatic antioxidants, the Savana cultivar outperformed the Newten cultivar in achieving maximum values for all performance traits mentioned. Additionally, the addition of compost to soil led to an increase in plant height (cm), fresh and dry foliage weight (g $plant^{-1}$), chlorophyll (SPAD readings), N, P, and K (%) values compared to plants grown without compost. On the other hand, the exogenous application of selenium was superior to the cobalt treatment, followed by the control treatment which came in the last order (without foliar application). Conversely, peroxidase and catalase (A564 min^{-1} g^{-1} protein) values took a reverse trend, with the Newten cultivar recording the highest values compared to the other cultivar. Furthermore, plants treated with compost had lower values of peroxidase and catalase compared to those untreated with compost. Also, the foliar application of both beneficial elements (Se and Co) led to a decreased need for antioxidants, as the control treatment realized the highest values of peroxidase and catalase. Overall, Tables 3 and 4 demonstrate that the best performance in terms of growth and decreased need for antioxidants was achieved with Savana cultivar plants treated with compost and selenium.

Table 3. Effect of compost soil addition and cobalt/selenium foliar application on growth traits and chlorophyll SPAD reading of snap bean grown under salinity conditions at the period of 50 days from sowing.

Treatments			Plant height, cm		Fresh weight, g $plant^{-1}$		Dry weight, g $plant^{-1}$		Chlorophyll, SPAD reading	
			1st season	2nd Season	1st season	2nd Season	1st season	2nd Season	1st season	2nd Season
Cultivars										
Savana			46.35a	47.81a	109.51a	110.83a	18.26a	18.47a	39.92a	40.59a
Newten			43.55b	44.92b	105.82b	107.10b	17.23b	17.51b	38.07b	38.76b
LSD at 5%			**0.04**	**0.02**	**0.20**	**0.40**	**0.15**	**0.12**	**0.11**	**0.50**
Organic fertilization										
Without compost			42.19b	43.49b	104.06b	105.22b	16.71b	16.92b	37.14b	37.80b
With compost			47.71a	49.24a	111.27a	112.72a	18.78a	19.06a	40.86a	41.56a
LSD at 5%			**0.02**	**0.16**	**0.36**	**1.32**	**0.14**	**0.01**	**0.09**	**0.26**
Folair application										
Control (Cont.)			44.02c	45.40c	106.51c	107.74b	17.38c	17.58c	38.39c	39.12c
Cobalt (Co)			44.94b	46.31b	107.70b	108.91b	17.77b	18.05b	39.00b	39.64b
Selenium (Se)			45.89a	47.39a	108.79a	110.26a	18.10a	18.34a	39.60a	40.27a
LSD at 5%			**0.60**	**0.15**	**0.47**	**1.22**	**0.25**	**0.07**	**0.16**	**0.47**
Interaction										
Savana	**Without compost**	**Cont.**	42.65hi	44.03i	104.61h	105.81gh	16.89hi	17.06i	37.48i	38.19hi
		Co	43.56gh	44.91h	105.92g	106.96fg	17.21gh	17.46h	38.05h	38.67gh
		Se	44.57fg	45.90g	107.14f	108.36ef	17.56fg	17.74g	38.61g	39.19fg
	With compost	**Cont.**	48.15bc	49.63c	111.89c	113.08bc	18.92bc	19.09c	41.21c	41.93bc
		Co	49.15ab	50.49b	112.99b	114.69ab	19.32ab	19.58b	41.80b	42.43ab
		Se	50.01a	51.90a	114.50a	116.10a	19.68a	19.90a	42.40a	43.13a
Newten	**Without compost**	**Cont.**	39.86k	41.19l	101.05j	102.24i	15.80k	16.00l	35.55l	36.24k
		Co	40.79jk	42.00k	102.48i	103.41hi	16.25jk	16.46k	36.24k	36.89jk
		Se	41.69ij	42.88j	103.16i	104.52ghi	16.57ij	16.80j	36.91j	37.60ij
	With compost	**Cont.**	45.40ef	46.74f	108.49e	109.82de	17.89ef	18.19f	39.33f	40.11ef
		Co	46.25de	47.83e	109.40de	110.56de	18.29de	18.70e	39.91e	40.57de
		Se	47.29cd	48.87d	110.34d	112.06cd	18.60cd	18.91d	40.48d	41.16cd
LSD at 5%			**1.20**	**0.30**	**0.96**	**2.45**	**0.50**	**0.14**	**0.32**	**0.95**

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

Table 4. Effect of compost soil addition and cobalt/selenium foliar application on chemical constituents and enzymatic antioxidants production in leaves of snap bean grown under salinity conditions at the period of 50 days from sowing.

Treatments			Leaves chemical constituents						Enzymatic antioxidants			
			N,%		P,%		K,%		Peroxidase, A564 $min^{-1} \cdot g^{-1}$		Catalase, A564 $min^{-1} \cdot g^{-1}$	
			1st season	2nd Season	1st season	2nd Season	1st season	2nd Season	1st season	2nd Season	1st season	2nd Season
Cultivars												
Savana			3.68a	3.75a	0.406a	0.413a	2.13a	2.20a	0.718b	0.667b	54.52b	50.53b
Newten			3.42b	3.47b	0.385b	0.392b	2.02b	2.08b	0.867a	0.800a	62.57a	57.75a
LSD at 5%			**0.02**	**0.02**	**0.007**	**0.005**	**0.05**	**0.04**	**0.034**	**0.007**	**0.12**	**0.02**
Organic fertilization												
Without compost			3.26b	3.33b	0.375b	0.381b	1.95b	2.01b	0.946a	0.874a	65.71a	60.75a
With compost			3.83a	3.90a	0.416a	0.424a	2.20a	2.27a	0.639b	0.593b	51.38b	47.53b
LSD at 5%			**0.01**	**0.01**	**0.001**	**0.002**	**0.03**	**0.06**	**0.016**	**0.003**	**0.18**	**0.11**
Folair application												
Control (without)			3.46c	3.53c	0.388c	0.396c	2.03b	2.10b	0.841a	0.777a	60.82a	56.40a
Cobalt			3.55b	3.61b	0.395b	0.402b	2.08a	2.15c	0.792b	0.734b	58.63b	54.12b
Selenium			3.63a	3.70a	0.403a	0.410a	2.11a	2.18a	0.745c	0.689c	56.20c	51.89c
LSD at 5%			**0.01**	**0.01**	**0.005**	**0.004**	**0.05**	**0.04**	**0.011**	**0.009**	**0.25**	**0.73**
Interaction												
Savana	**Without compost**	**Cont.**	3.28i	3.36i	0.380gh	0.388i	1.96ghi	2.02fg	0.935d	0.865d	63.11d	58.49d
		Co	3.40h	3.46h	0.384gh	0.391h	2.02fgh	2.08ef	0.863e	0.801e	61.31e	56.55e
		Se	3.51g	3.59g	0.388fg	0.396g	2.05efg	2.11e	0.815f	0.752f	59.53f	55.25e
	With compost	**Cont.**	3.89c	3.96c	0.420bc	0.428c	2.22abc	2.29bc	0.607j	0.567j	50.53j	47.60h
		Co	3.96b	4.03b	0.427ab	0.434b	2.26ab	2.32ab	0.565k	0.533k	48.06k	44.25i
		Se	4.03a	4.09a	0.435a	0.444a	2.30a	2.38a	0.525l	0.484l	44.59l	41.02j
Newten	**Without compost**	**Cont.**	3.07l	3.13l	0.357j	0.364l	1.86i	1.93h	1.059a	0.973a	72.32a	66.61a
		Co	3.13k	3.18k	0.366ij	0.370k	1.91i	1.97gh	1.028b	0.946b	69.98b	64.80b
		Se	3.20j	3.24j	0.374hi	0.378j	1.93hi	1.98gh	0.976c	0.904c	68.04c	62.78c
	With compost	**Cont.**	3.61f	3.67f	0.397ef	0.405f	2.09def	2.15de	0.763g	0.704g	57.30g	52.89f
		Co	3.71e	3.77e	0.404de	0.413e	2.15cde	2.22cd	0.711h	0.655h	55.17h	50.90g
		Se	3.79d	3.87d	0.414cd	0.422d	2.18bcd	2.26bc	0.666i	0.615i	52.64i	48.52h
LSD at 5%			**0.01**	**0.01**	**0.010**	**0.009**	**0.10**	**0.08**	**0.001**	**0.018**	**0.49**	**1.45**

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

Table 5. Effect of compost soil addition and cobalt/selenium foliar application on pods yield and its components of snap bean grown under salinity conditions at harvest stage "A 2-year study on two cultivars".

Treatments			No. of pods		Pod length, cm		Pod weight, g		Pod diameter, cm		Pod yield ton fed^{-1}	
			1st season	2nd Season	1st season	2nd Season	1st season	2nd Season	1st season	2nd Season	1st season	2nd Season
Cultivars												
Savana			26.89a	30.00a	10.87a	10.99a	5.05a	5.15a	0.46a	0.47a	2.86a	2.91a
Newten			25.00a	27.61b	10.22b	10.39b	4.55b	4.62b	0.39b	0.41b	2.48b	2.54b
LSD at 5%			**NS**	**0.24**	**0.08**	**0.01**	**0.16**	**0.05**	**0.06**	**0.01**	**0.02**	**0.04**
Organic fertilization												
Without compost			23.83b	26.67b	9.95b	10.08b	4.29b	4.38b	0.36b	0.37b	2.10b	2.15b
With compost			28.06a	30.94a	11.14a	11.30a	5.31a	5.40a	0.49a	0.51a	3.24a	3.29a
LSD at 5%			**0.94**	**0.93**	**0.08**	**0.11**	**0.04**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**
Folair application												
Control (without)			25.17c	28.00c	10.34c	10.46c	4.61c	4.71c	0.41c	0.42a	2.61c	2.65c
Cobalt			26.00b	28.75b	10.54b	10.71b	4.81b	4.89b	0.42b	0.44ab	2.68b	2.73b
Selenium			26.67a	29.67a	10.77a	10.91a	4.98a	5.07a	0.45a	0.46a	2.72a	2.79a
LSD at 5%			**0.55**	**0.63**	**0.15**	**0.14**	**0.06**	**0.01**	**0.03**	**0.03**	**0.01**	**0.04**
Interaction												
Savana	**Without compost**	**Cont.**	24.00fg	27.00gh	10.10hi	10.19gh	4.39i	4.50i	0.37efg	0.38fgh	2.17h	2.20f
		Co	24.67ef	27.67fg	10.25gh	10.40fg	4.52h	4.61h	0.40def	0.41efg	2.25g	2.29e
		Se	25.33de	28.33ef	10.43fg	10.53ef	4.66g	4.76g	0.41de	0.42def	2.35g	2.39d
	With compost	**Cont.**	28.00b	31.00c	11.26bc	11.35b	5.38c	5.49c	0.51ab	0.53ab	3.44c	3.49a
		Co	29.33a	32.33b	11.49ab	11.65a	5.59b	5.69b	0.53ab	0.54a	3.46b	3.53a
		Se	30.00a	33.67a	11.70a	11.82a	5.78a	5.88a	0.54a	0.56a	3.49a	3.55a
Newten	**Without compost**	**Cont.**	22.33h	25.00j	9.39k	9.52j	3.85l	3.93l	0.31h	0.32h	1.90l	1.93h
		Co	23.00gh	25.67ij	9.66jk	9.78ij	4.08k	4.15k	0.33gh	0.35gh	1.96k	1.99h
		Se	23.67fg	26.33gh	9.89ij	10.03hi	4.25j	4.31j	0.34fgh	0.35gh	2.01j	2.10g
	With compost	**Cont.**	26.33cd	29.00e	10.60ef	10.77de	4.82f	4.91f	0.44cd	0.45cde	2.95f	3.00c
		Co	27.00bc	29.33de	10.76de	10.99cd	5.04e	5.13e	0.45cd	0.47bcd	3.03e	3.09b
		Se	27.67b	30.33cd	11.04cd	11.25bc	5.23d	5.33d	0.49bc	0.51abc	3.05d	3.11b
LSD at 5%			**1.09**	**1.26**	**0.29**	**0.29**	**0.12**	**0.01**	**0.06**	**0.06**	**0.01**	**0.09**

Means within a row followed by a different letter (s) are statistically different at a 0.05 level
***NS:Non-significant**

- Yield, quality and qualitative traits at harvest stage

It is clear that physical and qualitative traits of the snap bean (two cultivars) plants grown under salinity conditions at the harvest stage *i.e.*, No. of pods $plant^{-1}$, pods, length (cm), weight (g), diameter (cm), yield (ton fed^{-1}) **(Table 5),** N, P, K, **(Table 6),** crude protein, carbohydrates, fiber and TDS (%) **(Table 7)** were significantly affected as a result of compost soil addition and cobalt/selenium foliar application treatments.

Table 6. Effect of compost soil addition and cobalt/selenium foliar application on seeds quality traits (seeds chemical constituents) of snap bean grown under salinity conditions at harvest stage "A 2-year study on two cultivars".

Treatments			N,%		P,%		K,%	
			1st season	2nd	1st	2nd	1st	2nd
Cultivars								
Savana			3.00a	3.05a	0.336a	0.343a	1.75a	1.78a
Newten			2.89b	2.94b	0.319b	0.324b	1.55b	1.58b
LSD at 5%			**0.04**	**0.01**	**0.012**	**0.004**	**0.07**	**0.04**
Organic fertilization								
Without compost			2.83b	2.88b	0.310b	0.316b	1.45b	1.47b
With compost			3.07a	3.12a	0.344a	0.351a	1.86a	1.89a
LSD at 5%			**0.02**	**0.01**	**0.008**	**0.004**	**0.04**	**0.02**
Folair application								
Control (without)			2.90c	2.96a	0.320c	0.328c	1.57c	1.60c
Cobalt			2.95b	3.00a	0.328a	0.333b	1.66b	1.69b
Selenium			2.99a	3.03a	0.334b	0.339a	1.72a	1.75a
LSD at 5%			**0.02**	**NS**	**0.002**	**0.004**	**0.03**	**0.04**
Interaction								
Savana	**Without compost**	**Control**	2.85e	2.91cd	0.311h	0.321f	1.48f	1.51fg
		Cobalt	2.90d	2.95cd	0.319g	0.325ef	1.55e	1.58f
		Selenium	2.92d	2.96cd	0.325f	0.332de	1.64d	1.67e
	With compost	**Control**	3.08b	3.13ab	0.348c	0.355b	1.90b	1.94bc
		Cobalt	3.13a	3.18ab	0.353b	0.359b	1.95ab	1.98ab
		Selenium	3.15a	3.20a	0.360a	0.367a	1.99a	2.03a
Newten	**Without compost**	**Control**	2.71g	2.76e	0.291j	0.297h	1.23h	1.25i
		Cobalt	2.78f	2.83de	0.305i	0.308g	1.36g	1.38h
		Selenium	2.81ef	2.86de	0.310h	0.313g	1.42fg	1.44gh
	With compost	**Control**	2.98c	3.04bc	0.332e	0.339cd	1.69d	1.72e
		Cobalt	3.00c	3.04bc	0.335e	0.342c	1.78c	1.81d
		Selenium	3.07b	3.12ab	0.340d	0.346c	1.83c	1.87cd
LSD at 5%			**0.04**	**0.15**	**0.005**	**0.008**	**0.07**	**0.08**

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

***NS:Non-significant**

Table 7. Effect of compost soil addition and cobalt/selenium foliar application on seeds quality traits (seeds quality and biochemical traits) of snap bean grown under salinity conditions at harvest stage "A 2-year study on two cultivars".

Treatments			Protein, %		Carbohydrates, %		Fiber, %		TDS, %	
			1st season	2nd Season	1st season	2nd Season	1st season	2nd Season	1st season	2nd Season
Cultivars										
Savana			18.77a	19.09a	37.59a	38.77a	13.09a	13.26a	6.17a	6.24a
Newten			18.06b	18.38b	34.62b	35.71b	12.48b	12.64b	5.82b	5.91b
LSD at 5%			**0.30**	**0.04**	**0.03**	**0.02**	**0.04**	**0.01**	**0.04**	**0.01**
Organic fertilization										
Without compost			17.67b	17.97b	33.10b	34.12b	12.22b	12.37b	5.67b	5.74b
With compost			19.16a	19.49a	39.10a	40.36a	13.36a	13.53a	6.32a	6.41a
LSD at 5%			**0.11**	**0.02**	**0.01**	**0.13**	**0.03**	**0.03**	**0.04**	**0.06**
Folair application										
Control (without)			18.15c	18.49a	35.12c	36.23c	12.59c	12.74c	5.87c	5.94b
Cobalt			18.44b	18.74a	36.12b	37.22b	12.79b	12.93b	6.02b	6.11a
Selenium			18.66a	18.95a	37.06a	38.27a	12.99a	13.18a	6.11a	6.18a
LSD at 5%			**0.14**	**NS***	**0.48**	**0.12**	**0.05**	**0.05**	**0.07**	**0.08**
Interaction										
Savana	**Without compost**	**Control**	17.79e	18.19cd	33.63g	34.72i	12.30i	12.44h	5.77e	5.84ef
		Cobalt	18.10d	18.42cd	34.71f	35.79h	12.52h	12.64g	5.89d	5.98de
		Selenium	18.25d	18.48cd	35.76e	36.82g	12.77g	12.93f	5.97cd	6.02d
	With compost	**Control**	19.25b	19.58ab	39.48b	40.70c	13.44c	13.59c	6.35b	6.41bc
		Cobalt	19.54a	19.88ab	40.51a	41.61b	13.64b	13.82b	6.49a	6.57ab
		Selenium	19.67a	19.98a	41.43a	42.99a	13.89a	14.11a	6.55a	6.61a
Newten	**Without compost**	**Control**	16.94g	17.23e	30.54i	31.57l	11.68l	11.83k	5.29g	5.35h
		Cobalt	17.35f	17.67de	31.53h	32.46k	11.92k	12.06j	5.49f	5.57g
		Selenium	17.56ef	17.85de	32.46h	33.38j	12.12j	12.30i	5.62f	5.69fg
	With compost	**Control**	18.60c	18.98bc	36.85d	37.93f	12.94f	13.09e	6.05c	6.14d
		Cobalt	18.75c	19.02bc	37.74cd	39.02e	13.06e	13.19e	6.20b	6.32c
		Selenium	19.17b	19.50ab	38.59bc	39.88d	13.19d	13.39d	6.29b	6.40c
LSD at 5%			**0.28**	**0.92**	**0.96**	**0.24**	**0.10**	**0.10**	**0.14**	**0.17**

Means within a row followed by a different letter (s) are statistically different at a 0.05 level
*NS:Non-significant

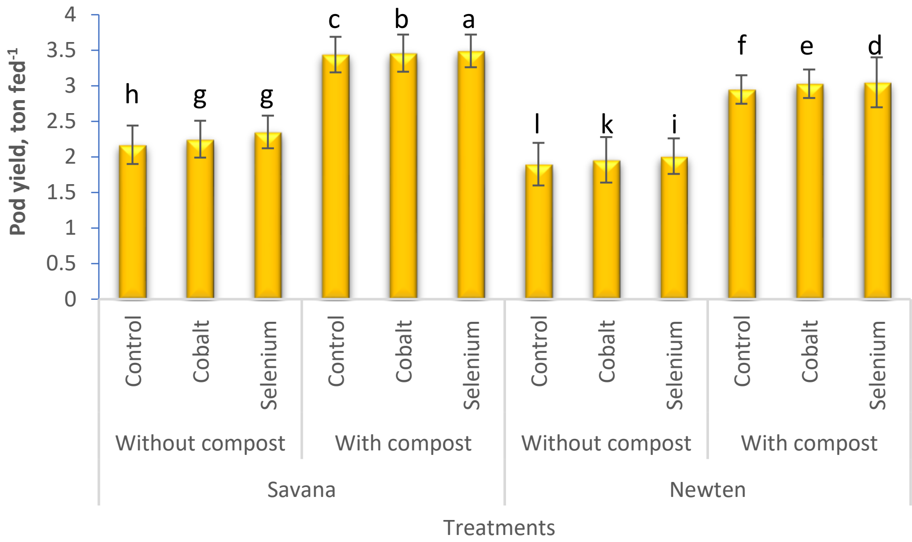

Fig. 1. Interaction effect of compost soil addition and cobalt/selenium foliar application on pods yield of snap bean grown under salinity conditions at harvest stage during the first season.

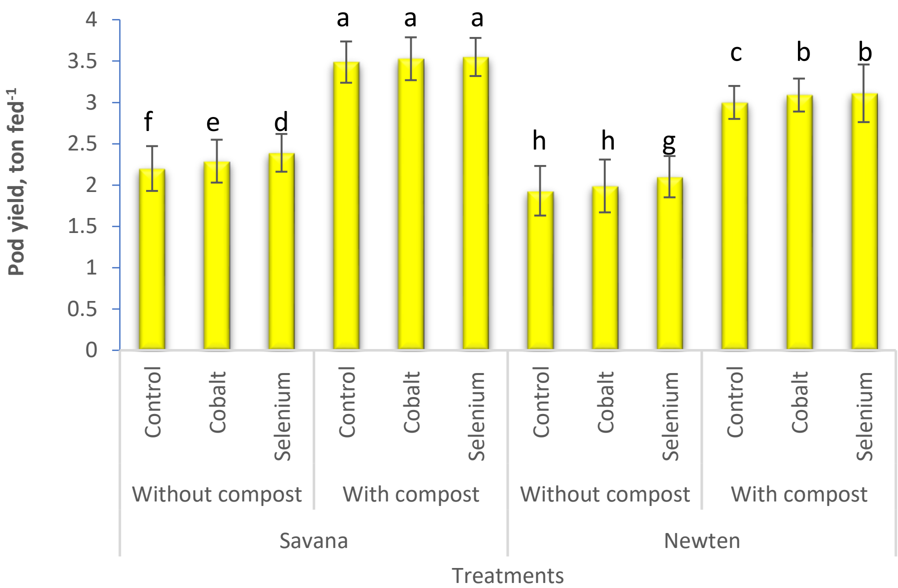

Fig. 2. Interaction effect of compost soil addition and cobalt/selenium foliar application on pods yield of snap bean grown under salinity conditions at harvest stage during the second season.

Also, Figs 1 and 2 illustrate the interaction effect of compost soil addition and cobalt/selenium foliar application on pods yield (ton fed^{-1}) of snap bean grown under salinity conditions at harvest stage during the first and second seasons. The Savana cultivar achieved the highest values for yield, quality, and qualitative traits at the harvest stage, outperforming the newten cultivar. Furthermore, the addition of compost to soil led to an increase in the values of these traits compared to plants grown without compost. On the other hand, the exogenous application of selenium was superior followed by the cobalt treatment then the control treatment (without foliar application). The trend remained consistent in both seasons studied. Generally, Tables 5, 6, and 7 as well as figs 1 and 2 demonstrate that savana cultivar plants treated with compost and selenium achieved the highest values of yield, quality, and qualitative traits.

4. Discussion

Excessive salt concentration in the soil can hinder the growth of snap bean plants. Salinity interferes with water absorption by the roots, creating an imbalance in osmotic pressure and causing water stress **(Garcia *et al.* 2019).** This can result in stunted growth, reduced plant height, and smaller overall plant size. The salinity of soil could lead to an increase in free radicals in the tissues snap bean plants. This is because the excessive accumulation of salt in the soil can cause osmotic stress, which in turn leads to the production of reactive oxygen species (ROS) such as superoxide anion (O^{2-}), hydrogen peroxide (H_2O_2), and hydroxyl radical (OH) in the snap bean plant cells (**Motaleb *et al.* 2020).** These ROS can cause oxidative damage to cell components such as lipids, proteins, and DNA, leading to cell death and impaired plant growth and productivity. The production of free radicals can also trigger a chain reaction that further increases the levels of ROS in the plant cells, leading to a state of oxidative stress **(Saxena *et al.* 2019).**To mitigate the harmful effects of salinity-induced free radicals, plants have developed antioxidant defense systems such as peroxidase and catalase enzymes that scavenge ROS and prevent oxidative damage. However, under severe salt stress, the antioxidant defense mechanisms may become overwhelmed, leading to a buildup of free radicals and oxidative stress in the snap bean plant cells.

The results of the study suggest that the addition of compost to soil and the exogenous application of cobalt/selenium had a significant positive effect on the growth, yield, and quality traits of snap bean plants grown under saline conditions. The Savana cultivar outperformed the Newten cultivar in achieving maximum values for most of the studied traits.

The superior performance of the Savana cultivar may be attributed to genetic variations that confer tolerance to salt stress. Different plant varieties have varying genetic backgrounds, which influence their ability to tolerate salt stress. Savana cultivar may have possessed genes that were more efficient in managing the adverse effects of salinity, resulting in better plant growth and yield compared to the Newten cultivar **(Kumar *et al.* 2020).**

The addition of compost to soil improved the physical and chemical properties of soil, which positively impacted plant growth and yield. The compost provides a source of nutrients, increases soil organic matter, improves soil structure, and enhances the availability of water and nutrients to plants. This helps plants to establish healthy root systems, uptake essential nutrients, and maintain optimum physiological processes, resulting in improved growth and yield **(El Hasini *et al.* 2020).**

The exogenous application of cobalt/selenium to the leaves of plants acted as a beneficial element that facilitated various metabolic processes in plants. Cobalt is an essential component of vitamin B12 and plays a critical role in nitrogen fixation and chlorophyll synthesis. Selenium is an essential component of selenoproteins, which play important roles in stress responses and antioxidant defense mechanisms. The foliar application of selenium was superior to cobalt, indicating its higher efficiency in improving plant performance under saline conditions. Selenium and cobalt are both micronutrients that are essential for plant growth and development. However, selenium is known to have a higher toxicity threshold in plants than cobalt. This means that plants can tolerate higher levels of selenium without experiencing negative effects, whereas cobalt toxicity can occur at lower concentrations. Additionally, selenium has been shown to have a more significant impact on plant growth and development than cobalt. Selenium plays a crucial role in photosynthesis and can enhance the activity of antioxidant enzymes, which protect plants from oxidative stress. It has also been linked to increased seed germination, root and shoot growth, and improved plant resistance to biotic and abiotic stress. On the other hand, cobalt is essential for nitrogen fixation in leguminous plants, which can contribute to plant growth and development. However, it has not been shown to have significant effects on other growth traits or antioxidant enzyme activity, as compared to selenium (**Jiang *et al.* 2017; Baddour *et al.* 2021).**

Therefore, based on the results obtained from this study, it is likely that the superior performance of the snap bean plants treated with selenium is due to its ability to enhance photosynthesis, antioxidant activity, and plant resistance to stress, which ultimately leads to improved growth and yield.

5. Conclusion

The results of this study demonstrate that the application of compost soil and selenium foliar treatment can significantly improve the growth, yield, and quality of snap bean plants grown in saline conditions. The Savana cultivar outperformed the Newten cultivar in achieving maximum values for most of the traits analyzed. Additionally, the application of compost soil led to an increase in the values of most traits, while selenium foliar treatment was superior to cobalt treatment in enhancing the plant's performance.

Generally, the results of this study can recommend the following;

- Farmers growing snap beans in saline conditions should consider the application of compost soil and selenium foliar treatment to improve plant growth, yield, and quality.
- The selection of the appropriate cultivar, such as the Savana cultivar in this study, can also significantly enhance plant performance in saline conditions.
- Further research should be conducted to determine the optimal application rates and methods for compost soil and selenium foliar treatment, as well as the long-term effects of these treatments on soil health and plant growth.
- The findings of this study can also be extended to other vegetable crops grown in saline conditions to enhance their productivity and nutritional quality.

The findings of this study could contribute to ensuring a stable and sustainable production of snap bean in Egypt, which could in turn have positive implications for the country's economy and food security.

Conflicts of interest

Authors have declared that no competing interests exist.

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