Egyptian Journal of Soil Science
http://ejss.journals.ekb.eg/

Selenium Nano-Biofortification under Soil Nutrient Deficiency: A Comparative Study between Green Bean and Pepper

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SANDY soils are often associated with low fertility due to their physical and chemical properties. Sandy soils have a coarse texture and large pore spaces, which allow water and nutrients to drain quickly, leaving little time for plants to absorb them. Additionally, sandy soils have a low capacity to hold nutrients, which can easily leach out of the soil with excessive watering or rainfall. This makes it difficult for plants to access the nutrients they need to grow and develop properly, leading to nutrient deficiency stress. So, the current study was designated to investigate the responses of pepper and green bean plants to various selenium (Se) forms (Nano and bulk forms) and doses (0.0, 10, 20, 30, and 40 ppm for each form) during the biofortification program under sandy soil conditions.In general, the response of studied vegetable crops had a similar behavior under such studied stress regarding all selected attributes. This response represents in increasing the studied trials of growth, and nutritional status of both crops by increasing the applied nano-Se up to 20 or 30 ppm, while bulk forms of Se at 20 ppm for both crops. The production of biofortified fruits of both green bean and pepper were not only contain high content of Se to prevent the biofortification program, but also increased the all studied attributes of crops. This study seeks to remedy the problems of cultivation of sandy soils under biofortification program by applying both mineral and nano-Se sources with propriety to the biological nano-Se. This study also opened many questions concerning the biofortification program using other vegetable crops under different stresses.

Keywords: Soil fertility, Bio-nanofertilizer, Potassium deficiency, Nitrogen deficiency, Sandy soil

1. Introduction

Vegetable crops are important sources and essential components of the dietary diet for maintaining the human health (Abobatta 2021). These crops are considered a rich source of numerous phytochemicals compounds for human health including antioxidants, carbohydrates, carotenoids, dietary fibers, flavonoids, polyphenols, minerals, and vitamins (Ramya and Patel 2019; Yahia et al. 2019; Kumar et al. 2020). Producing vegetables in a safe and healthy manner for human diet is of a great challenge facing the globe particularly under environmental stress (El-Ramady et al. 2023). The production of vegetables under stressful conditions mainly depends on the vegetable species, and the kind of stress including biotic, and abiotic stresses (Hossain et al. 2022; Sharma et al. 2022a). Recently, many studies have been published on the production of vegetables biofortified with Se under alkaline sandy soil conditions including broccoli (Fawzy et al. 2023a), onion (Fawzy et al. 2023b), eggplant (Mahmoud et al. 2023), and the current study for both pepper and green bean. More

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Received: 05/03/2023; Accepted: 28/03/2023
DOI: 10.21608/EJSS.2023.198184.1577

studies on different stresses were also reported on vegetables such as biotic stress on melon (Kang et al. 2022), stress of penthiopyrad on tomato (Liu et al. 2022), stress of heavy metals *Brassica chinensis* (Zhu et al. 2022), and Cd-stress on *Brassica* or pepper (Li et al. 2022; Wang et al. 2022a).

Nano-selenium (nano-Se) and its bulk mineral form have an increase concern due to their distinguished attributes for plant and human health (El-Ramady et al. 2020, 2022a, b). The main color of nano-selenium may include red or grey, depending on the kind of synthesis; chemical or biological (El-Ramady et al. 2022a). The biosynthesis of Se is preferable as cost-effective and low toxicity compared to other methods (El-Ramady et al. 2022b). Recently, several studies published on the impact of applied bio-nano-Se on different cultivated plants such as tobacco (Zsiros et al. 2019), *Chrysanthemum morifolium* (Seliem et al. 2020), cucumber (Shalaby et al. 2021), wheat (El-Saadony et al. 2021; Ghazi et al. 2022), tomato (Saffan et al. 2022), *Brassica chinensis* (Zhu et al. 2022), rapeseed (El-Badri et al. (2022), banana (Shalaby et al. 2022a), strawberry (El-Bialy et al. 2023), and radish (Hoang et al. 2023). Therefore, Se nano-biofortification is a successful approach as reported by many studies on vegetables such as Cheng et al. (2023).

Therefore, there are two primary aims of this study: (1) to investigate which applied dose of Se can produce biofortified pepper or green bean and (2) to ascertain that biological Se-nano-biofortification can be achieved under different stresses in particular soil nutrient deficiency stress. This article also intends to determine the extent to which can produce biofortified vegetables under stressful conditions and whether the biological nano-biofortification can be successed under such conditions.

2. Materials and Methods

2.1 Experimental site and treatments

A field experiment was conducted in a randomized block design in three replicates. During the two-summer season of 2017 and 2018, a field experiment was conducted in the Nubaria Experimental Farm (National Research Centre, Egypt). This experiment included nine treatments; the control (using only water), 4 different doses of mineral fertilizer of selenium (i.e., 10, 20, 30 and 40 ppm), and 4 different doses of biological nano-Se fertilizer (i.e., 10, 20, 30 and 40 ppm). The field is situated in an arid climate region at an altitude of 27 m above mean sea level and is intersected by latitude of 30° 30N and longitude of 30° 20E. The soil of the experimental site was deep, well-drained sandy texture (85.5, 11.7, and 2.8% sand, silt and clay, respectively), which is classified as an *Entisol-Typic Torripsamments*. The content of soil organic matter in the topsoil (0-30 cm) was 0.4%, with a high soil alkalinity (pH 8.25), low soil salinity (EC: 0.85 dS m^{-1}), and low $CaCO_3$ (15 g kg^{-1}). The soil moisture content at field capacity and the permanent wilting point recorded in average 18 and 8%, respectively. The available soil contents of N, P and K were 12, 4 and 35 mg kg^{-1} soil, respectively before the initiation of the experiment, which represent low nutrient contents in studied soil.

The treatments were foliar sprayed after 45 and 55 days from planting (Figure 1). Conventional agricultural practices were followed according to the common ones in the area. The selected cultivar of snap bean and sweet pepper in this study were "Pulista and California winder", which was transplanted after 60 and 45 days from seed cultivation, and between the two sprayed 10 days for pepper and bean, respectively. Seedlings were planted on ridges of 0.8 m or 0.50 m width and 30 m length and the plot area was 24 m^2 for bean and pepper, respectively.

2.2 Nano-Se preparing and its bulk form

Two different forms of Se were investigated in this current study during the biofortification process including mineral Se-fertilizer as sodium selenite (Na_2SeO_3), which dedicated by Nano Food Lab, University of Debrecen, Hungary and nano-form of Se (Se-NPs). The nano-form was prepared biologically at the Lab of Soils, Water and Environment Research Institute (SWERI), Soil Microbiology Department at Sakha station. The size of Se-NPs was 87.7 nm, which was oxidized by using *Bacillus cereus* TAH as reported by Ghazi et al. (2022). The size of Se-NPs was measured using high resolution transmission electron microscope (HR-TEM, Tecnai G20, FEI, The Netherlands), by Nanotechnology and Advanced Material Central Lab, Agriculture Research Center (ARC). and other properties were measured using TEM and X-ray in Nanotechnology Lab in Agricultural Research Center, in Giza.

2.3 Plant sampling and analyses

A random sample of five plants were chosen from each plot and subjected for analysis at harvest stage. The following plant growth parameters were measured at harvest; plant length (cm), number of leaves and branches per plant; fresh and dry weight of leaves (g $plant^{-1}$). The total fruits or pods were harvested to measure the yield at harvest stage the mature fruits twice every week along the harvesting season. The plant samples were divided into leaves and fruits, then dried at 65 °C; ground using stainless steel equipment to determine N, P, K and Se in leaves and fruits/pods of both crops. Nitrogen and K were determined using Kjeldahl method and flame photometer (NADE LCD Digital Flame photometer FP640, China), respectively, whereas P was measured using the visible spectrophotometer (Single Beam, SP-IV722N, 721N, China) as described by Cottenie et al. (1982). Selenium content was measured using atomic absorption spectroscopy (SP-IAA1800H, China) according to Levesque and Vendette (1971).

2.4 Statistical analyses

All data were used to statistically analyze obtained data of the experiment at the confidence level of 5%. These analyses were conducted on means of treatments to measure the considered significantly different according to the procedures of the procedure outlined by Gomez and Gomez (1984).

Fig. 1. An overview on the main applied treatments in the study including different applied doses and the studied parameters.

Fig. 2. Some photos on different varieties of green bean, which cultivated in clayey soil (next 4 upper photos) and to some cultivated in loamy soil (lower 4 photos). All photos by El-Ramady.

Fig. 3. Many problems can face the cultivation of pepper under greenhouses under different growing conditions like soil salinity or nutrient deficiency stress. All photos by El-Ramady.

3. Results

3.1 Vegetative parameters of studied vegetables

All selected vegetative parameters (i.e., plant length, fresh and dry weight of leaves, number of leaves and branches per plant) of studied vegetables were tabulated in **Tables 1 and 2.** Concerning the mineral Se source, the studied vegetative parameters were increased up to 20 ppm in both vegetable crops, whereas these increases were reached to 20-40 ppm in both crops after applying nano-Se. For example, at 20 ppm nano-Se, green beans recorded the highest values in all studied parameters, whereas this trend was ranged from 20 to 40 in case of pepper. The highest yield was obtained by applying 20 ppm mineral Se for both crops, while this trend was achieved for green bean at this level and at 30 ppm nano-Se for pepper.

Table 1. Response of vegetative growth parameters of studied vegetable to applied Se-fertilizers.

Treatments (Applied doses)	Fresh weight of leaves (g)		Dry weight of leaves (g)		Number of leaves per plant		Number of branches per plant	
	Pepper	Green bean	Pepper	Green bean	Pepper	Green bean	Pepper	Green bean
Mineral Se-fertilizer								
Control	56.54d	61.50e	5.50c	6.25c	42.56c	27.49e	9.33b	10.28b
10 ppm	62.12c	68.67d	7.16b	7.29bc	45.61b	29.35d	9.67b	10.62b
20 ppm	66.89b	86.26a	8.76a	8.73a	48.28b	39.47a	10.00b	15.43a
30 ppm	78.50a	78.96b	7.98ab	8.32ab	57.72a	36.93b	12.50a	14.80a
40 ppm	77.09a	74.51c	7.79ab	7.64b	55.33a	32.25c	12.44a	14.20a
Nano Se-fertilizer								
Control	55.68c	60.14c	5.45b	6.16c	42.50c	26.98d	8.83b	9.26c
10 ppm	57.57c	69.24b	5.99ab	7.43b	44.28c	29.45c	9.17b	9.85c
20 ppm	63.63b	82.74a	6.91a	8.54a	46.44b	38.10a	9.56b	14.21a
30 ppm	73.78a	78.06ab	6.76a	7.55b	48.94a	36.74a	12.06a	13.44ab
40 ppm	73.27a	72.38b	6.94a	7.50b	48.83a	33.18b	11.89a	12.58b

Table 2. Response of plant length, Se content and yield of studied vegetable to applied Se doses.

Treatments (Applied doses)	Plant length (cm)		Se content in leaves (ppb)		Total yield (ton/fed.)	
	Pepper	Green bean	Pepper	Green bean	Pepper	Green bean
Mineral Se-fertilizer						
Control	57.35c	36.01d	0.0 d	2.2 e	7.43b	3.08b
10 ppm	59.39c	39.55c	7.2 c	14.0 d	7.93ab	3.50b
20 ppm	64.45a	44.41a	15.2 b	30.7 c	8.46a	4.20a
30 ppm	62.03b	42.30b	19.2 ab	46.0 b	8.11a	4.02ab
40 ppm	63.44ab	40.79bc	24.1 a	64.8 a	7.92ab	3.89ab
Nano Se-fertilizer						
Control	54.25c	35.83c	0.0 c	1.1 c	6.45b	3.24b
10 ppm	58.39b	38.35b	4.2 bc	4.5 c	7.34a	3.42b
20 ppm	62.27a	44.48a	8.6 b	14.4 b	7.87a	4.00a
30 ppm	60.78ab	43.69a	14.9 a	25.7 a	7.89a	3.88ab
40 ppm	54.75c	43.31a	18.9 a	29.3 a	7.48a	3.70ab

3.2 Nutrients content in vegetable leaves and fruits

The total content of some studied nutrients including NPK and Se in both leaves and fruits of both pepper and green bean were measured (**Tables 2, 3, and 4**). Interestingly, for the studied crops with applied Se doses, an increase in all nutrients in both leaves and fruits with increasing applying Se doses (up to 40 ppm in both Se-forms). In general, all studied nutrients have a significant difference between the two Se-forms and their doses except P content in both crops and plant fractions (leaves and fruits). Following the addition of Se doses in both applied sources, a significant increase ($P < 0.05$) in the se content in both leaves and fruits of both vegetable crops was recorded.

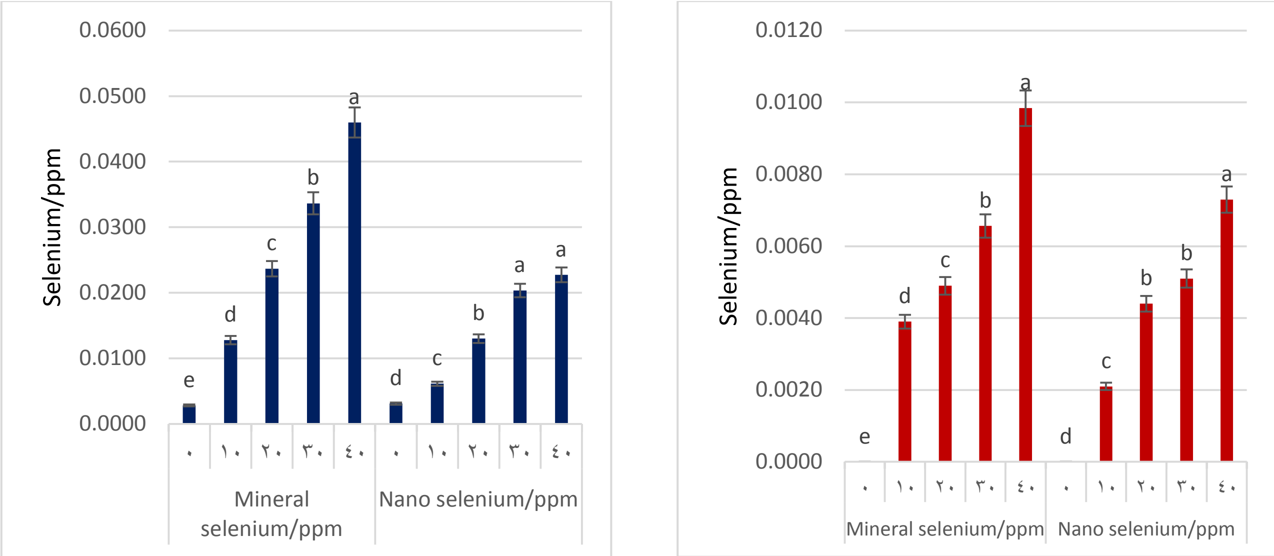
Table 3. Content of nutrients in studied vegetable leaves as a response to applied Se-fertilizers.

Treatments	N content in leaf (%)		P content in leaf (%)		K content in leaf (%)	
(Applied doses)	Pepper	Green bean	Pepper	Green bean	Pepper	Green bean
Mineral Se-fertilizer						
Control	1.93d	2.03c	0.39 a	0.35 a	1.18d	1.91c
10 ppm	2.29c	2.14c	0.59 a	0.38 a	1.47c	1.94c
20 ppm	2.35c	2.54b	0.65 a	0.44 a	1.67b	2.23b
30 ppm	2.57b	2.98a	0.69 a	0.41 a	1.96a	2.35a
40 ppm	2.77a	3.01a	0.74 a	0.45 a	2.05a	2.39a
Nano Se-fertilizer						
Control	1.38d	2.00d	0.32 a	0.31 a	1.02c	1.79d
10 ppm	1.87c	2.20c	0.41 a	0.38 a	1.45b	1.93c
20 ppm	2.19b	2.67b	0.59 a	0.43 a	1.50b	2.32a
30 ppm	2.48a	2.84a	0.64 a	0.45 a	1.61b	2.19b
40 ppm	2.57a	2.93a	0.67 a	0.42 a	1.79a	1.94c

Table 4. Content of nutrients in studied vegetable fruits as a response to applied Se-fertilizers.

Treatments	N content in fruit (%)		P content in fruit (%)		K content in fruit (%)	
(Applied doses)	Pepper	Green bean	Pepper	Green bean	Pepper	Green bean
Mineral Se-fertilizer						
Control	1.51e	1.25e	0.32 a	0.31 a	1.24d	1.24d
10 ppm	1.66d	1.34d	0.36 a	0.28 a	1.42c	1.59c
20 ppm	1.75c	1.69a	0.39 a	0.36 a	1.52bc	1.73b
30 ppm	2.02b	1.60b	0.43 a	0.39 a	1.57b	1.91a
40 ppm	2.22a	1.51c	0.56 a	0.36 a	1.70a	1.96a
Nano Se-fertilizer						
Control	1.45c	1.24d	0.29 a	0.30 a	1.20c	1.37d
10 ppm	1.52c	1.43c	0.34 a	0.36 a	1.26c	1.51c
20 ppm	1.70b	1.72b	0.35 a	0.39 a	1.39b	1.54c
30 ppm	1.81ab	1.77a	0.38 a	0.41 a	1.44ab	1.77b
40 ppm	1.86a	1.74ab	0.41 a	0.38 a	1.53a	1.94a

For both studied crops, the content of Se in both leaves and fruits were higher after applying bulk Se compared to the nano-form, with property in higher values in case of leaves comparing with fruits. Although, this increase was 96 and 100% in leaves for green bean and pepper for bulk Se-form, whereas this increase was 100% for nano-Se form in both two crops. Interestingly, the mean values of Se content in fruits were lower than leaves in both crops and both were in the allowable Se content for human diet. In **Figs. 2 and 3** there is a clear trend of increasing Se content in both leaves of studied vegetable crops with increasing applied Se doses for both studied forms.

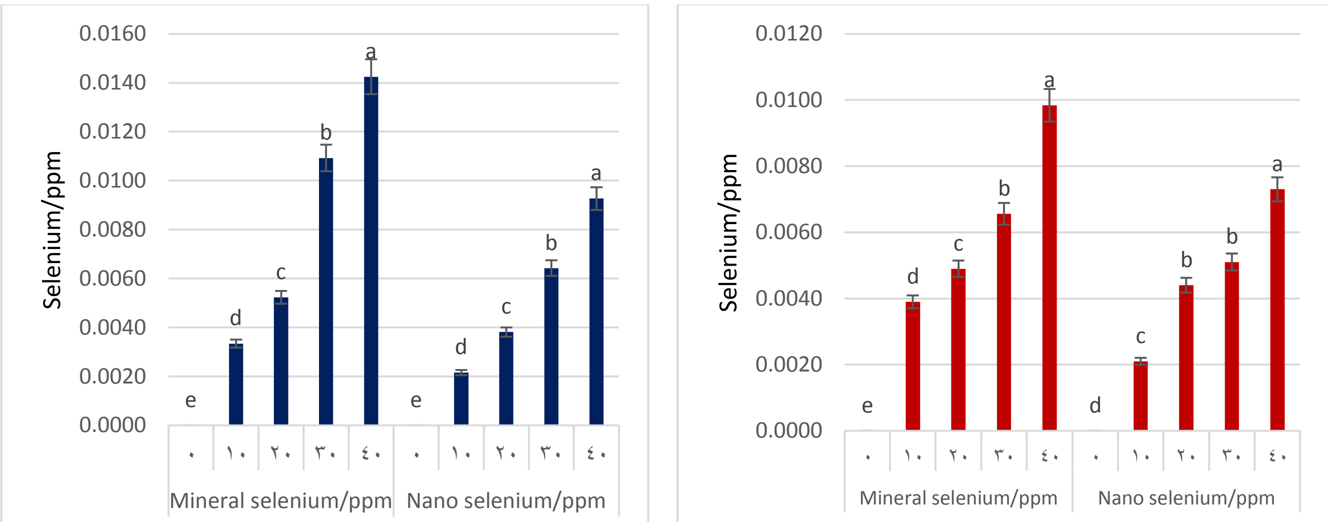


Snap bean Pepper

Fig. 2. Effect of selenium source and concentration on selenium (ppm) in leaves of both crops.

3.3 Yield of studied vegetables and Se-fertilizers

Applied Se-fertilizers under different doses have a significant impact on yield of pepper and green bean (**Table 2**). It is observed that a significant increase in the yield of studied crops with increasing applied doses of bulk Se-form till the level of 20 ppm for green beans, whereas ranged from 20-30 ppm for pepper after applying nano-Se and then decreased. The bulk Se-form recorded higher values in pepper and green bean yield (8.46 and 4.20 ton fed^{-1}, respectively) after applying 20 ppm, compared with nano Se-form. The differences between green bean and pepper, from one side, and studied Se doses and forms, from the other side, are highlighted in **Table 2**.



Snap bean Pepper

Fig. 3. Effect of selenium source and concentration on selenium (ppm) in fruits/pods of both crops.

4. Discussion

The production of enough and necessary quantities of vegetables in the world, many efforts should be achieved especially under climate changes. High temperature is considered one of the most results of climate changes, which affects production of vegetable crops particularly in arid and semi-arid regions, extending the cropping season to late spring or summer. In the near future, this situation could be aggravated as a consequence of climate changes due to rise average temperature in different regions, particularly in the Mediterranean region (Gisbert-Mullor et al. 2023). Many vegetables like pepper and green bean can grow and produce under stress as presented in **Table 5.** This Table includes a survey on some recent published studies on producing the studied crops under stress.

Biofortification is a promising tool for enriching the harvested plants with needed nutrients to face the malnutrition. Malnutrition is a crucial problem that billions of people suffer from all over the world. Several vegetable crops have been used in the biofortification program including green bean and pepper. These vegetables are very important crops, which human depends on them in his diet and nutrition due to their high contents of many phytochemical compounds. In this section, we will try to answer the main questions in this work:

1- Is the biofortification program effective under stressful conditions of studied vegetables?

2- Is the nano-biofortification in vegetables crops a successed approach? And why?

3- Are green bean and pepper a good candidate in Se-nano-biofortification program?

4- What is the main difference between biological nano-Se and its bulk form in the studied program for producing selected vegetables?

5- Are the stressful conditions effective obstacles in producing vegetables under such conditions?

The first question: is the biofortification program effective under stressful conditions of studied vegetables? With respect to the first research question, it was found that many vegetables have been produced under different stresses by biopriming the vegetable seeds (Chin et al. 2022), biostimulants like biochar (Wang et al. 2022b), and nano-priming (Thakur et al. 2022).

These might support vegetables production as positive stress or eustress (Vázquez-Hernández et al. 2019). Under abiotic stresses, vegetables can biosynthesize many secondary metabolites in plants, which are considered useful for human health as antioxidative and anti-inflammatory agents (Sharma et al. 2022b). Therefore, the biofortification approach of vegetables can be achieved under stress when this stress will enforce the cultivated vegetables to produce many bioactives for human health. This positive side of stress can be negative when the vegetables will be cultivated under polluted soil with heavy metals or radionuclides, which consumption the harvested edible plants may cause many human health problems. This opens the debate between phytoremediation and biofortification, which needs more studies and emphasization (Cao et al. 2023).

Table 5. List of some published studies on producing pepper and green bean under stress.

Stress type and concentration (if any)	Anti-stressor and applied method	Anti-stressor dose	Main findings	Refs.
I. Green bean plants				
Cadmium stress in polluted soil (up to 2.0 mM $CdCl_2$)	Nano-priming of seeds by nano iron and silicon	FeO-NPs = 10 ppm, and Si-NPs = 20 ppm	Stressalleviatedby enhancing the accumulation of K^+ content, improving antioxidants, higher spermidine and putrescine levels	[1]
Salt stress at 100, or 200 mM NaCl	Melatoninspray after 21 days from planting	Applied doses 100, 200, and 400µM	Melatonin increased antioxidant enzymes proline and sugar; decreased malondialdehyde and H_2O_2 content	[2]
Cadmium added on filter papers (from 50 to 1000µM $CdCl_2$)	Salicylic acid (SA)	Applied at 1000µM	SA mitigates oxidative stress and maintain the freeing of mineral nutrients from cotyledons to embryonic tissues	[3]
Phosphorus low stress (NA)	Selenium seed priming	NA	Se seed priming can mitigate the plant's P deficiency stress by enhancing plant tolerance to mineral deficiency	[4]
Zincnitrate at doses at 25, 50, 100 ppm	Foliar applying ZnO-NPs	Applied 25, 50,100 ppm	ZnO (25 or 50 ppm) + chitosan were efficient doses for favoring biomass	[5]
Arsenic(As) toxicity	Spermine(Spm)	NA	Spm improves tolerance to As-toxicity by upregulating the expression of Zn-finger proteins related genes, polyamine metabolism, and Mg detoxification	[6]
Drought stress	Foliar-applied seaweed extract	Spray at 2 and 4 L ha^{-1}	SE at 4 L ha^{-1}level improved grain yield due to increased chlorophyll index, RWC, protein yield, TSS, and CAT and SOD	[7]
II. Pepper plants				
Drought	Plant growth-promoting bacteria	NA	Droughtresistant bacteria isolated from rhizosphere and endophyte of pepper grown on water deficient might be used for alleviating drought stress on pepper	[8]
Irrigation with saline water 100 mM NaCl	Silicon	2 mM Si	Si increased stomatal conductivityunder salinity and marketable yield of pepper	[9]
Drought stress	*Bacillus butanolivorans*	NA	Plant-associated beneficial microbe can modulate antioxidant and polyphenolics	[10]
Chilling stress for 3 d 5 /10°C at night/day	Melatonin	5µM	Melatonin improves water relations, photosynthetic parameters and the activities of antioxidant enzymes	[11]
Chillingstress	Zeaxanthin	NA	Zeaxanthinmodulates chlorophyll degradation by protect endogenous pigment to against chilling stress	[12]
Saltstress at 75mM and 150mM	Bacterialco-inoculation	NA	Enhanced antioxidant enzyme activities; higher sugar accumulation led to enhance tolerance to salinity stress	[13]
Drought stress polyethylene glycol (at 8, 16 and 32 mM)	Melatonin(MEL)	MEL solution (50 µM)	Alleviated drought stresses by inducing antioxidant defense responses (ascorbate peroxidase, and glutathione reductase	[14]

List of refs. [1] Koleva et al. (2022), [2] Azizi et al. (2022), [3] Hediji et al. (2021), [4] Mansoor et al. (2023), [5] Palacio-Márquez et al. (2021), [6] Shah et al. (2022), [7] Ziaei and Pazoki (2022), [8] Admassie et al. (2022), [9] Badem and SelçukSöylemez (2022), [10] Kim et al. (2022), [11] Korkmaz et al. (2021), [12] Tang et al. (2021), [13] Choudhury et al. (2021), [14] Kaya and Doganlar (2019)

The second question on nano-biofortification in vegetables crops: is it a successed approach? And why? The nano-biofortification was reported by many recent studies, which confirmed that nanomaterials/nanoparticles can be applied as a source for nutrients enrichment the cultivated plants (e.g., El-Ramady et al. 2020, 2021a, b, 2023, Fawzy et al. 2023a, b; Mahmoud et al. 2023). Among different nano-biofortification tools, the biological one is better than the chemical one, which is considered an eco-friendly and more effective approach (El-Ramady et al. 2023). The main challenge that faces the nano-biofortification depends on which nano-nutrient and its properties could be sued beside which recommended applied dose? as well as the essential nutrients for human immunity (El-Ramady et al. 2021b). In the current study, only 20 ppm of mineral Se is enough for biofortification of both studied vegetable crops, whereas 40 ppm of bio-nano-Se can achieve this approach. This level differs from plant species to others and its growing stage.

The third question are green bean and pepper a good candidate in Se-nano-biofortification program? Based on the results in the current study, the selected crops are considered promising crops for the program of biofortification, which their harvested fruits or pods did not have much higher content of Se, but the concentration under bio-nano-form or even mineral form was acceptable by the human consumers. We did not record any toxic symptoms on cultivated plants or their fruits during the performance of this work. What is the main difference between biological nano-Se and its bulk form in the studied program for producing selected vegetables? The main difference is mineral Se is toxic even at very low concertation, whereas the bio-nano-Se is safe and nontoxic. One benefit more is that bio-nano-Se is a sustainable source for human health.

Are the stressful conditions effective obstacles in producing vegetables under such conditions? At first sight, it seems that any stress on cultivated plants is harmful and has negative impacts, but there is negative and positive impacts of stress on cultivated plants. The negative side represents in many troubles in physiological, biochemical and genetic attributes in stressful plants, whereas the positive face is representing in producing these secondary metabolites as in vegetables, which considered a functional approach for designing next generation super foods (Sharma et al. 2022b). Thus, the current study opened many windows concerning the biological nano-biofortification and the potential of vegetables in the biofortification program. These questions may include can the nano-biofortification program of vegetable apply for different vegetable species? Which recommended dose and which nano nutrients can be used? Which growing stage is preferable for achieving this program? What are the main obstacles that prevent this program?

5. Conclusions

Vegetables like green bean and pepper are very important for human health, which contain many phytochemicals. In many cases, it could face the malnutrition by producing biofortified foods for human dietary. Biofortification has become a crucial tool for human struggle against many diseases and malnutrition. In the current study, green bean and pepper were selected for establishment a nano-biofortification program. This program can be designated after applying 20 ppm mineral Se (or less), or 40 ppm biological nano-Se for both green bean and pepper under sandy soil conditions. These sandy soils have very low fertility (soil nutrient deficiency stress), which are not considered a barrier for producing such studied vegetables, but can be applied to enrich the studied vegetables with Se through the nano-biofortification program. This program has been applied to establish a nano-biofortification program for many vegetable crops including broccoli, onion, eggplant, pepper, and green bean. This study confirmed that, the nano-biofortification program can support us to cultivate the sandy soils with the suggested vegetables and more studies are needed for more crops.

Ethics approval and consent to participate: This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication: All authors declare their consent for publication.

Funding: The authors would like to great thanks for all help, efforts and support by National Research Centre "Projects Office" Project ID No. 11030150.

Conflicts of Interest: The author declares no conflict of interest.

Contribution of Authors: All authors shared in writing, editing and revising the MS and agree to its publication.

Acknowledgments: The authors would like to great thanks for all help, efforts and support by National Research Centre "Projects Office" Project ID No. 11030150.

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