# Onion Biofortification Using Selenium Bionanofertilizer and its Bulk Source under Sandy Soil Conditions

**Abd El-Mohsin M. El-Bassiony[1], Hassan El-Ramady[2,3], Sameh M. El-Sawy[4], Sami H. Mahmoud[5], Shaymaa I. Shedeed[6] and Zakaria F. Fawzy[7]**

[1,4,5,7]Vegetable Crops Department, Agricultural and Biological Research Institute, National Research Centre, 33 El Behouth St., Dokki, 12622 Giza, Egypt.
[2]Institute of Animal Science, Biotechnology and Nature Conservation, Faculty of Agricultural and Food Science, and Environmental Management, University of Debrecen, 138 Böszörményi Street, 4032 Debrecen, Hungary.
[3] Soil and Water Department, Faculty of Agriculture, Kafrelsheikh University, 33516 Kafr El-Sheikh, Egypt.
[6]Plant Nutrition Department, Agricultural and Biological Research Institute, National Research Centre, Egypt.

[7]E-mail: zakaria6eg@gmail.com

**Abstract .** Human health depends on the daily supply of fresh vegetables and fruits, which contain the essential, nutrients, vitamins and other bioactive compounds. Due to malnutrition in several places all over the world, the biofortification approach is a crucial solution to overcome this global problem. In the current study, the biological nanofertilizer of selenium (nano-Se) was tested on onion crop comparing with its bulk source under the sandy soil conditions. the applied doses of nano-Se were 10, 20, 30 and 40 mg $L^{-1}$ in both nano and mineral form of Se. The main investigated parameters of onion were the vegetative growth parameters and the nutritional status in leaves and bulbs. The obtained results have a significant difference between mineral and nano-Se doses for studied measurements. In general, all studied parameters increased in their values with increasing the applied doses from both Se sources up to 30 or 40 mg $L^{-1}$ compared to the control, depending on the selected parameter. This increase reached to more than 60% (for applied nano-Se on bulb dry weight), or more than 55% for the same parameter after applying mineral Se source. Applying nano Se was achieved higher values in some studied parameters of onion, whereas the mineral form of Se was domain for others. This study confirmed that both Se forms can be applied for biofortification of onion because the Se content in bulb located in the accepted level of Se in crop with priority to nano-Se, which accumulate in leaves and bulb in a lower concentration compared to mineral form. This work opened more question about the nano-biofortification and the possibility to apply for more studied crops with focus on the suitable added dose to be safe for successful biofortification program.

**Keywords.** Soil fertility, Biological nanofertilizer, Nutrient deficiency, Nitrogen deficiency.

## 1. Introduction

Onion (*Allium cepa* L.) is considered a vital vegetable crop for human health, which globally cultivated across 4.3 million ha with a total production of 98 million tons [1]. The main five producer of global onion production are China, India, the USA, Egypt, and Turkey, the first two countries can produce around 50% of global production [2]. Onion can be found in the food market as three different colors, including white, red, and yellow, which could be consumed by cooking (frying or grilling or roasting,), eaten as a fresh food in salads, made into juice, pickled in vinegar, or used as a spice [3 and 4]. Onion wastes, as an agro-industrial waste, have great applications against many plant pathogens like *Fusarium sambucinum* such as extract of red onion peel [5]. For human health, onion is important herbal medicine, which can be eaten against several common diseases (e.g., asthma, atherosclerosis, bronchitis, and coughs). Several bioactives in onion could be considered crucial for human health [6], such as anticancer [7], anti-obesity [8], cardiovascular protective [9], immunomodulatory properties [10], hepatorenal protective [11], antioxidants [12], reproductive protective [13], antimicrobial activity [14], anti-inflammatory [15], neuroprotective [16], respiratory protective [17], anti-diabetic [18], and digestive system protective [19]. So, the producing onion biofortified with nutrients like Se is a crucial strategy for struggle of malnutrition.

Selenium is an essential nutrient for the nutrition of humans and animals, but for higher plants is still not confirmed. Selenium biofortification is a common approach, which many biofortified crops and/or sprouts have investigated in several studies such as [20-24]. Many studied confirmed the possibility to biofortify different crops using different sources of Se including selenate [25], selenite [23], seleno-amino acid [26], and nano-Se [27]. Selenium and nano-Se have distinguished impacts on crop productivity, and their managing cultivated plants under environmental stress through improving quality of crops [28]. Selenium and nano-Se recently have an increased potential concern with focus on several topics such as improving yield and quality of fruits like pomegranate [29], tomato [30], radish [28], their significant in plant nutrition and crop quality [31], their sources in soils and plants [32], mediating cold stress tolerance in crops [33], and new frontier of plant biostimulant [34]. Due to their distinguished attributes (non-toxic, and its eco-safety), biological nano-Se was confirmed for biofortification compared to mineral and chemical nano-Se in many recent publications on different crops such as wheat (*Triticum asetivum* L.) [35], cucumber (*Cucumis sativus* L.) [36], banana [37], pak choi (*Brassica chinensis*) [38], rapeseed (*Brassica napus* L.) [39]radish [28] and Broccoli [40]

Globally, around 2 billion people face the acute malnutrition, deficiency of vitamins and micronutrients deficiency, which might recover by fortification (for vitamins) and/or biofortification for nutrients [41]. Therefore, this is work focuses on foliar application two different sources of selenium (biological nanofertilizer and its bulk form) for producing biofortified onion under soil nutrient deficiency. The main questions in this manuscript are which Se-fertilizer is better for prompting broccoli production under such nutrient deficiency? Which applied dose of this preferable Se-fertilizer can be used under such studied conditions?

## 2. Materials and Methods

### *2.1. Experimental Site*

During two winter seasons of 2016-2017 and 2017-2018, a field experiment was conducted in the Nubaria Experimental Farm of the National Research Centre. This field is intersected by latitude of 30° 30N and longitude of 30° 20E and is situated in an arid climate region at an altitude of 27 m above mean sea level. The experimental soil was deep, well-drained sandy texture and classifies as an *Entisol-Typic Torripsamments*, composing of 85.5% sand, 11.7% silt and 2.8% clay. Soil organic matter was 4.0 g $kg^{-1}$ in the topsoil up to 80 cm, with an alkaline pH of 8.25, low soil salinity (EC: 0.85 dS $m^{-1}$), and lime ($CaCO_3$: 15 g $kg^{-1}$ soil). Average available of main nutrient including N, P and K was 12, 4 and 35 mg $kg^{-1}$ soil, respectively before starting the experiment, which represent low nutrient contents in studied soil. The average soil water content at field capacity and the permanent wilting point was 18 and 8%, respectively.

### *2.2. Onion Cultivation and Applied Treatments*
Onion seedlings cv. Giza 20 was transplanted at the second week of December in the two seasons. Seedlings were planted on drip irrigated ridges with 1 m apart and 16 m long with 50 cm between drippers. Four seedlings were planted around each dripper with 7 cm apart. Each plot included 5-redges and the plot area was 80 $m^{-2}$. Onion plants were supplied with the recommended dose of nitrogen (20 g N $m^{-2}$ in form of ammonium nitrate), phosphorus (12 g $P_2O_5$ $m^{-2}$ in form of calcium super phosphate), and potassium (25 g $K_2O$ $m^{-2}$ in form of potassium sulphate). The normal agricultural practices required for onion production were applied as commonly followed in the farm. The complete randomized plot design was used in this experiment with three replicates for each. The current experiment included 9 treatments beside the control, which included using only water. The treatments were four different doses of biological nanofertilizer of selenium (i.e., 10, 20, 30 and 40 mg $L^{-1}$), and four different doses of Se mineral fertilizer (i.e., 10, 20, 30 and 40 mg $L^{-1}$). These previous treatments were applied as a foliar spraying twice during the experiment after 45 and 55 days from planting.

### *2.3. Fertilizers of Selenium and Their Source*
The biological Se nanofertilizer was prepared using *Bacillus cereus* TAH according to [42], at Soil Microbiology Department, SWERI, Egypt. The size of Se-nanoparticles was 87.7 nm, which was measured using high resolution transmission electron microscope (HR-TEM, Tecnai G20, FEI, The Netherlands) at 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. Mineral Se-fertilizer (i.e., bulk Se source) was prepared using sodium selenite ($Na_2SeO_3$), which dedicated by Nano Food Lab, University of Debrecen, Hungary.

### *2.4. Vegetative Plant Parameters and Nutrient Analyses*
Random sample of ten plants from each plot were taken after 75 days from transplanting to record the vegetative growth parameters. Concerning the yield and bulb quality, after harvesting and curing of onion bulbs, another sample were taken to measure bulb physical characteristics such bulb diameter (cm), and length (cm). In the same above sample yield per feddan were calculated. A random sample of 5 plants were chosen at harvesting stage from each plot and subjected for analysis. The following vegetative plant growth parameters were measured at harvest; number of leaves per plant; plant height (cm); bulb and leaves fresh and dry weight (g $plant^{-1}$), bulb length and its diameter, as well as the total yield per fed. The plant samples were dried at 65 °C; ground using stainless steel equipment's to measure the nutrient content of N, P, K and Se in leaves and bulbs of onion. From each sample 0.1 g was digested using the mixture of sulfuric ($H_2SO_4$) and perchloric ($HClO_4$) acids (1:1) for N, P, K, and Se determination. Nitrogen was determined using Kjeldahl method, K was determined by flame photometer (NADE LCD Digital Flame photometer FP640, China) and P with spectrophotometer (Single Beam, SP-IV722N, 721N, China) as described by [43]. While, Se content was determined using atomic absorption spectroscopy (SP-IAA1800H, China) as described by Levesque and [44].

### *2.5. Statistical Analyses*
Experimental design and statistical analysis: The treatments were arranged in a complete block design with three replicates. The obtained data were statistically analyzed and means separation was done using Duncan analysis according to the method described by [45].

## 3. Results

### *3.1. Response of Vegetative Parameters of Onion to Applied Se-Fertilizers*
Certain vegetative parameters of onion were measured and listed after statistically analyzed in Tables 1 and 2. The studied vegetable parameters included fresh and dry weight of leaves and bulb, besides bulb diameter and its length, number of leaves per plant, and plant length. The results of dry weight of leaves and bulb recorded the highest values after applying the highest dose of 40 ppm of both Se-fertilizers, compared to the control (Table 1). The recorded values were higher in case of mineral Se-

fertilizer compared to nano Se-fertilizer in both vegetative parameters. In general, the mean values of all vegetative parameters were increased with increasing the applied doses of both nano-Se and its bulk form up to 40 mg $L^{-1}$. The increase in bulb dry weight (%) comparing with the control for the nanofertilizer in both seasons were 55.8 and 56.3, whereas these rates were 66.1 and 62.7% for mineral Se-fertilizer, respectively.

**Table 1.** Response of the fresh, dry weight of leaves and bulb of onion to applied Se-fertilizers.

| Treatments (Applied doses) | Fresh weight of leaves (g) | | Dry weight of leaves (g) | | Fresh weight of bulb (g) | | Dry weight of bulb (g) | |
|---|---|---|---|---|---|---|---|---|
| | First season | Second season | First season | Second season | First season | Second season | First season | Second season |
| Mineral Se-fertilizer | | | | | | | | |
| Control | 18.36c | 17.14d | 2.74c | 2.76c | 55.78c | 54.39c | 4.61c | 4.60c |
| 10 ppm | 29.93b | 29.84b | 3.32b | 3.65b | 89.48b | 90.95b | 8.78b | 8.98b |
| 20 ppm | 26.58b | 24.72c | 3.07b | 3.27b | 94.71b | 93.96b | 7.94b | 7.70b |
| 30 ppm | 37.48a | 38.39a | 4.46a | 5.39a | 111.92a | 112.29a | 11.57a | 11.25a |
| 40 ppm | 35.73a | 36.72a | 4.48a | 5.42a | 115.32a | 115.39a | 13.59a | 12.34a |
| Nano Se-fertilizer | | | | | | | | |
| Control | 20.81c | 21.89b | 2.89c | 2.99c | 58.16c | 58.03c | 4.97c | 5.15c |
| 10 ppm | 27.91b | 26.75b | 3.46b | 3.56b | 77.16b | 87.10b | 7.59b | 7.66b |
| 20 ppm | 26.77b | 25.01b | 3.38b | 3.44b | 76.42b | 85.97b | 7.67b | 8.29b |
| 30 ppm | 39.74a | 38.85a | 4.84a | 4.98a | 116.36a | 107.08a | 11.49a | 12.13a |
| 40 ppm | 39.88a | 39.07a | 4.95a | 5.14a | 114.99a | 106.98a | 11.26a | 11.78a |

Means within column having the same letters are not significantly different according to the Duncan's Multiple Range Test (at $p < 0.05$).

The same trend was observed for studied of number of leaves per plant, bulb length and its diameter, which gave in general the highest values when treated with 30 ppm of both Se-fertilizers (Table 2), except bulb length for the nanofertilizer (at 40 ppm). Comparing with getting values of previous studied parameters, nano-Se-fertilizer reordered in general highest values compared to mineral Se-fertilizer. The increase in bulb diameter (%) comparing with the control for the nanofertilizer in both seasons were 32.9 and 32.6, whereas these rates were 42.2 and 36.8 % for mineral Se-fertilizer, respectively.

**Table 2.** Response of head and leaves to applied different doses of Se-fertilizers.

| Treatments (Applied doses) | Number of leaves per plant | | Plant length (cm) | | Bulb length (cm) | | Bulb diameter (cm) | |
|---|---|---|---|---|---|---|---|---|
| | First season | Second season | First season | Second season | First season | Second season | First season | Second season |
| Mineral Se-fertilizer | | | | | | | | |
| Control | 6.88b | 6.58b | 47.43d | 45.64c | 5.46b | 4.27c | 5.68b | 5.74b |
| 10 ppm | 7.38b | 7.34b | 63.76b | 66.60ab | 5.27b | 5.40b | 9.63a | 8.78a |
| 20 ppm | 7.63b | 7.72b | 58.92c | 59.20b | 6.46a | 5.11b | 9.12a | 8.00a |
| 30 ppm | 9.88a | 9.93a | 69.64a | 70.60a | 6.42a | 6.93a | 9.83a | 9.09a |
| 40 ppm | 8.13ab | 8.49ab | 60.47bc | 61.57b | 5.46b | 6.87a | 9.76a | 8.98a |
| Nano Se-fertilizer | | | | | | | | |
| Control | 6.75b | 6.38b | 46.73c | 45.55c | 4.53b | 4.98b | 6.64c | 6.21c |
| 10 ppm | 7.13b | 6.96b | 59.32b | 59.81b | 5.79a | 5.91a | 7.48b | 7.49b |
| 20 ppm | 7.00b | 6.76b | 58.39b | 58.69b | 5.87a | 6.03a | 8.41b | 8.92a |
| 30 ppm | 10.13a | 10.55a | 69.73a | 69.94a | 6.14a | 6.44a | 9.91a | 9.21a |
| 40 ppm | 9.88a | 10.17a | 69.67a | 70.15a | 6.23a | 6.58a | 9.75a | 8.97a |

Means within column having the same letters are not significantly different according to the Duncan's Multiple Range Test (at $p < 0.05$).

### *3.2. Content of Nutrients in Leaf and Bulb of Onion*

The first remark on the nutrient content in onion leaves was the highest applied dose of both mineral and anno-Se fertilizers (40 mg $L^{-1}$) recorded the highest values of these nutrients (Table 3). The mean values belong mineral Se fertilizers have the highest values when the highest applied dose of Se-fertilizer (40 mg $L^{-1}$). There is an increase in all studied nutrients after applying mineral and nano-fertilizer, which differ from nutrient to other and recorded the following increasing rate (%) compared to the control: in case of mineral Se-fertilizers N, P, and K were (30; 28.9), (44.4; 50), and (22.1; 25.2), whereas the increasing values for nano-Se-fertilizer were (32.7; 24.8), (36.3; 46.7), and (26.1; 29.7), respectively for both seasons.

Concerning the nutrient content in onion leaves in Table 4, there are two important notices; the first applied doses of mineral Se-fertilizer were higher in their mean values of nutrient content of NPK comparing with the applied doses of nano Se-fertilizer, and the second these highest mean values of nutrient NPK content in onion leaves were achieved after applying 40 mg $L^{-1}$ of mineral form.

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

| Treatments (Applied doses) | N content in leaf (%) | | P content in leaf (%) | | K content in leaf (%) | |
|---|---|---|---|---|---|---|
| | First season | Second season | First season | Second season | First season | Second season |
| Mineral Se-fertilizer | | | | | | |
| Control | 1.16c | 1.22c | 0.15 a | 0.18 a | 1.68c | 1.72c |
| 10 ppm | 1.19c | 1.27c | 0.17 a | 0.21 a | 1.76c | 1.84c |
| 20 ppm | 1.37b | 1.45b | 0.18 a | 0.24 a | 1.95b | 2.13b |
| 30 ppm | 1.46ab | 1.58a | 0.22 a | 0.29 a | 2.04b | 2.17b |
| 40 ppm | 1.49a | 1.63a | 0.27 a | 0.36 a | 2.40a | 2.42a |
| Nano Se-fertilizer | | | | | | |
| Control | 1.13d | 1.18d | 0.14 a | 0.16 a | 1.56e | 1.54d |
| 10 ppm | 1.29c | 1.42c | 0.18 a | 0.23 a | 1.73d | 1.80c |
| 20 ppm | 1.33c | 1.43c | 0.19 a | 0.24 a | 1.85c | 1.98b |
| 30 ppm | 1.42b | 1.50b | 0.22 a | 0.29 a | 1.98b | 2.18a |
| 40 ppm | 1.68a | 1.57a | 0.22 a | 0.30 a | 2.11a | 2.19a |

Means within column having the same letters are not significantly different according to the Duncan's Multiple Range Test (at $p < 0.05$).

**Table 4.** Content of nutrients in onion bulbs as a response to applied Se-fertilizers.

| Treatments (Applied doses) | N content in leaf (%) | | P content in leaf (%) | | K content in leaf (%) | |
|---|---|---|---|---|---|---|
| | First season | Second season | First season | Second season | First season | Second season |
| Mineral Se-fertilizer | | | | | | |
| Control | 0.73c | 0.67d | 0.11 a | 0.12 a | 1.44d | 1.35d |
| 10 ppm | 0.76c | 0.71d | 0.15 a | 0.18 a | 1.68c | 1.72c |
| 20 ppm | 0.81c | 0.79c | 0.20 a | 0.26 a | 1.72c | 1.78c |
| 30 ppm | 0.98b | 1.05b | 0.22 a | 0.29 a | 1.88b | 2.03b |
| 40 ppm | 1.24a | 1.45a | 0.27 a | 0.36 a | 2.05a | 2.29a |
| Nano Se-fertilizer | | | | | | |
| Control | 0.66d | 0.56e | 0.10 a | 0.10 a | 1.32d | 1.17c |
| 10 ppm | 0.75c | 0.70d | 0.13 a | 0.15 a | 1.46c | 1.38b |
| 20 ppm | 0.81bc | 0.79c | 0.18 a | 0.23 a | 1.59b | 1.58b |
| 30 ppm | 0.86b | 0.87b | 0.21 a | 0.27 a | 1.72a | 1.78ab |
| 40 ppm | 0.98a | 1.05a | 0.24 a | 0.32 a | 1.81a | 1.92a |

Means within column having the same letters are not significantly different according to the Duncan's Multiple Range Test (at $p < 0.05$).

The content of Se in leaves was presented in Fig. 1 for both seasons. It is obvious that the Se content in leaves after applying the mineral form of Se in both seasons was higher compared to the nano-form. The highest Se content in leaves reached to more than 0.027 and 0.035 ppm Se (with increase rate 81.5 and 94.3% compared to the control), respectively in both seasons after applying mineral Se form. In case of nano form of Se, the highest Se content was 0.016 and 0.018 ppm Se with increase rate 68.7 and 94.4% compared to the control in both seasons, respectively.
The content of Se in onion bulbs after applying different forms of Se was presented in Fig. 2. The most remarkable result is the applying mineral form of Se led to higher Se content in bulb (0.010 and 0.011 ppm in both seasons at applied dose of 40 ppm Se), compared to the values after applying nano-Se (0.007 and 0.008 ppm in both seasons at applied dose of 40 ppm Se). Comparing to the control, a high increase rate (%) in Se content in onion bulb after applying mineral form of Se (100 and 110%, in both seasons, respectively), whereas these increases were 70 and 80% in case of nano form of Se.

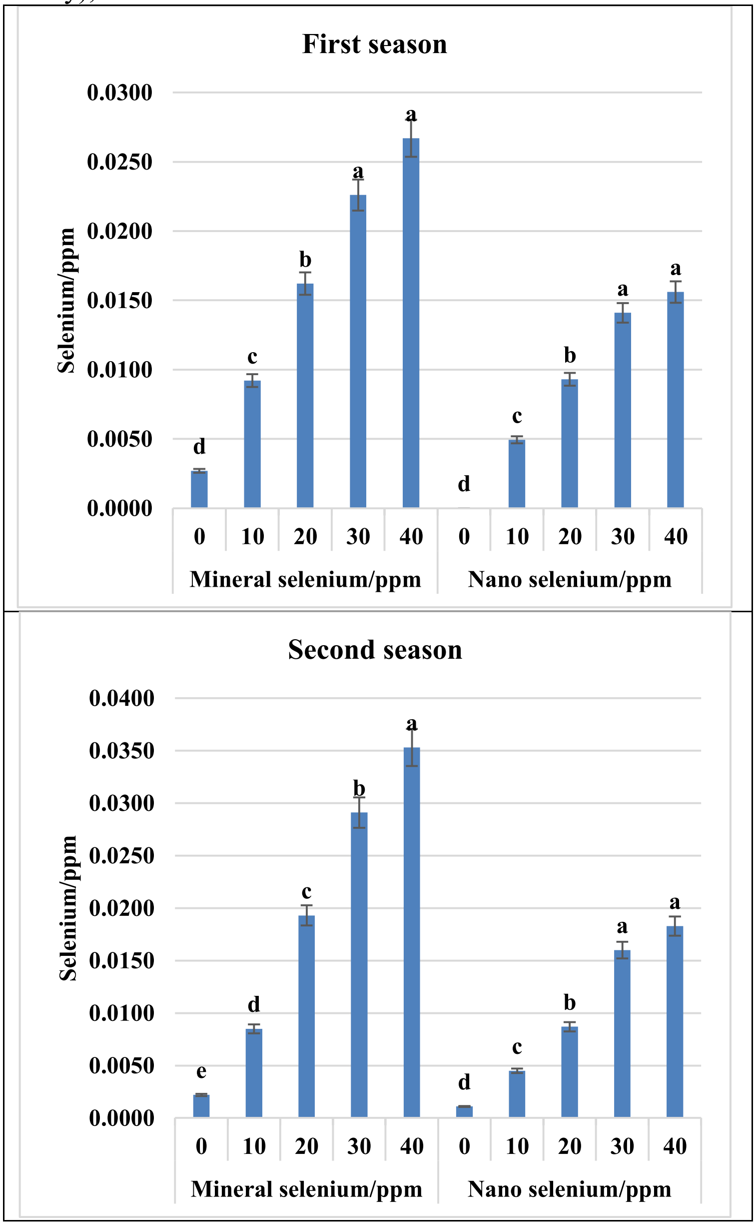


**Figure 1.** Effect of selenium source and concentration on selenium (ppm) in leaves of onion plants during the studied seasons.

Means within column having the same letters are not significantly different according to the Duncan's Multiple Range Test (at $p < 0.05$).

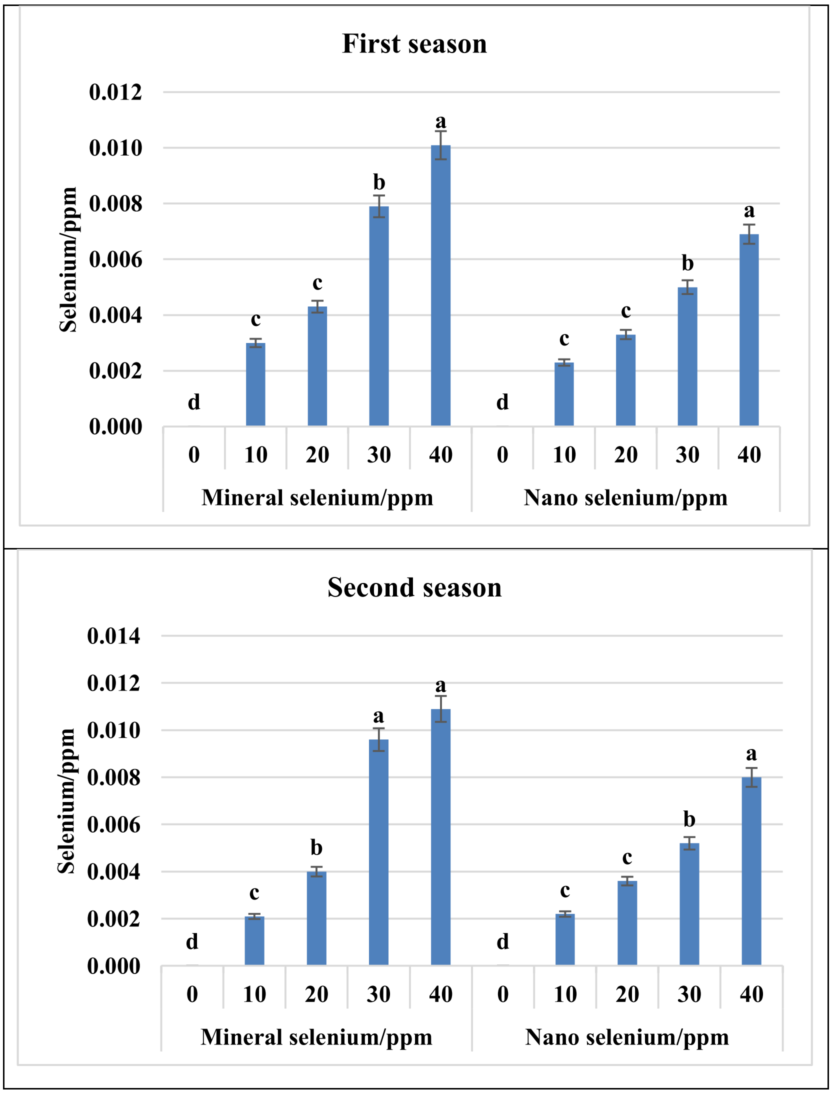


**Figure 2.** Effect of selenium source and concentration on selenium (ppm) in bulbs of onion plants during studied seasons.

Means within column having the same letters are not significantly different according to the Duncan's Multiple Range Test (at $p < 0.05$)

### *3.3. Response of Onion Yield to Applied Se-Fertilizers*

Concerning the yield of onion bulb, the results were presented in Figure 3. As noticed in previous studied parameters, the yield of onion bulb increased with increasing the applied dose of both two Se forms and the highest obtained yield (more than 35 tons fed$^{-1}$) after applying 40 mg L$^{-1}$ mineral Se and 30 mg L$^{-1}$ nano-Se in both seasons. These values of highest yields led to increase (%) comparing to the control ranges between 51 and 54%, for mineral and nano form of Se. It could be noticed that the highest yield after applying both mineral and nano form of Se was obtained at dose of 30 and 40 ppm without significant differences between the two doses in both seasons.

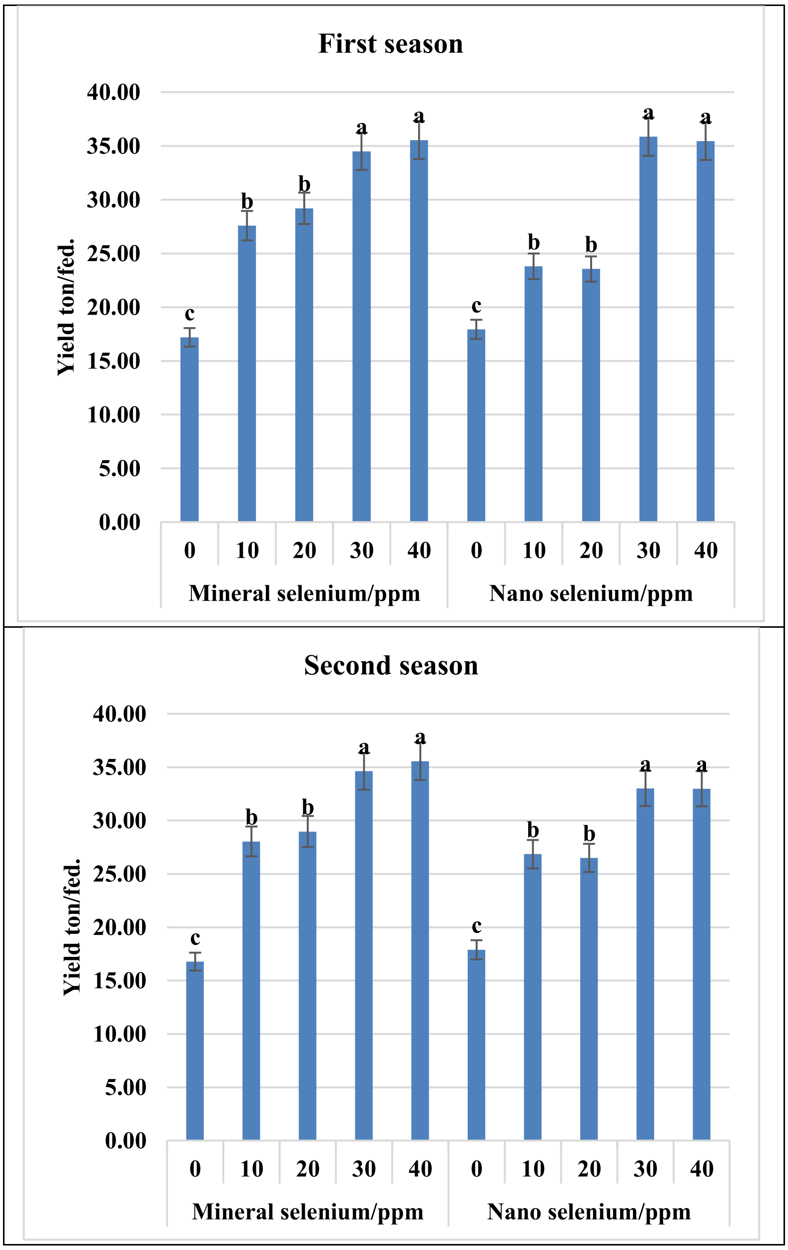


**Figure 3.** Effect of selenium source and concentration on yield (ton/fed.) bulb of onion plants during the studied seasons.

Means within column having the same letters are not significantly different according to the Duncan's Multiple Range Test (at $p < 0.05$)

## 4. Discussion

The main global challenge faces all nations for the next years is how to feed the entire population in the world. This global problem pushes the United Nations to establish many programs especially the Sustainable Development Goals (SDGs) in 2015 [46,47]. These sustainable goals can support the biofortification approach as a crucial program for human health [21]. Human health has a very closed nexus to the nexus soil-water-plant-human [48], the soil and human health nexus [49], sustainable plant nutrition [48] and sustainable soil fertility [47]. Producing biofortifying some vegetables is our target during this study and next ones, which already started with broccoli enriched in Se *via* nano Se-fertilizer and its bulk mineral form. Se and nano-Se biofortification for human health was confirmed

IOP Conf. Series: Earth and Environmental Science 1213 (2023) 012043 doi:10.1088/1755-1315/1213/1/012043

by several researchers such as [21,47,48]. For establish a successful program of biofortification, it is very requested to answer the following three questions:

- Which crop is proper for this process? (It is an important issue for human diet),
- What is the main target nutrient and which applied dose should be applied? (This reflects its essentiality for human nutrition),
- Which application method is the suitable one? (Foliar or soil or *in vitro* application).

As so far as we know, few articles published on onion biofortified with different nutrient such as Se [50,1], and Zn [52], but there is no published article on biofortifying onion with Se under nutrient deficiency stress. I

In the current study, different sources of Se-fertilizers were applied for biofortification of onion under sandy soil conditions. Many previous studies confirmed the distinguished role of Se in promoting vegetative attributes of crops including onion, after applying different dose of both forms (mineral and nanofertilizers) such as [29,53] and [54,55] as well under stress conditions [39,56] Indeed, the dry weight of both leaves and bulb as well as studied vegetative parameters of onion increased with increasing foliar application of Se forms. Additionally, Se has vital potential physiological functions in Se plant nutrition, because its contribution as Se-enhanced operation of enzymatic antioxidants [57]. Selected parameters in our investigation recorded highest values in case of mineral Se compared to nanofertilizer form. This result may back to the easily translocate of selenate from roots to shoots *via* xylem and assimilation of it in the leaf chloroplasts. An agreement with these results can be noticed in [54], who reported that applied selenate dose of 10 ppm obtained higher fresh weight and chlorophyll content in tobacco compared to nano Se-fertilizer (100 ppm). The applied Se-dose for biofortification mainly depends on targeted crop, where in our study the acceptable dose was 30 ppm (from both Se-forms), although this dose was to be only 20 ppm nano-Se for groundnut [58].

Which one is better the biological Se-nanofertilizer or its bulk one? To what extent this Se-biofortification program of onion can be achieved under nutrient deficiency stress conditions? Although, the mineral Se fertilizer recorded the highest yield of onion compared to nano Se-fertilizer, the nano-form is preferable due to its low toxicity, and a sustainable solution [59]. This trend was confirmed by [28], who reported that foliar biofortification of radish with biological nano-Se can promote the growth and yield. One reason more for this preferring is the lower Se-content in both bulb and leaves, which will be consumed by humans, after applying bionanofertilizer of Se with producing a safe onion for human nutrition. Concerning Se content in onion leaves and bulb, our results showed that Se content in both after applying Se-bionanofertilizer are safe for human diet and within the consumptive level of Se. At the same time, Se content in bulb were lower comparing with its content in leaves giving more safety for human consumption.

Are Se-fertilizers supporting the growth and producing onion under sandy soils (nutrient deficiency stress)? Findings of the recent study confirmed that both of Se-fertilizers enhanced the growth and productivity onion under such stress conditions due to their effective role under such stress. Our obtained results are in an agreement with results of [59], who found that nano-Se can support groundnut grown under sandy soil conditions through enhancing the antioxidant defense systems in and improving plant tolerance. The promising role biological nano-Se in supporting crop productivity under different stresses has been confirmed such as toxicity stress of heavy metals on *Brassica chinensis* [39], salinity stress on *Brassica napus* L. [40], salt stress on wheat [43], and biotic stress on sugar beet [60].

## Conclusions

Human health faces many troubles all over the world, which mainly links to the human nutrition. Due to many nutrients' deficiency or malnutrition, a lot of diet program depending on the fortification and biofortification approaches. Fortification can be applied by enriched the food with necessary nutrients for human nutrition. Whereas, biofortification programs mainly focuses on the producing plant or animal foods through apply targeted nutrients to nutrition of these organisms. Biofortification has been become effective approach to overcome malnutrition in several countries all over the world. The current study is a model on producing onion biofortified with Se using two different sources of Se-fertilizers (i.e., bionanofertilizer and its bulk form). The almost getting results support using the mineral Se-form, which recorded the highest values in vegetative growth parameters and yield. The most important finding in the present study is containing the onion bulb lower content of Se comparing with bulk form, which support producing the safe onion for consumption. One more important finding from this study is the ability of Se-bionanofertilizer to increase onion growth and its productivity under sandy soil conditions through increasing the tolerance cultivated plants to such stress and enhancing nutritional status of plants.

**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 a great thanks for all help, efforts and supported 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 a great thanks for all help, efforts and supported by National Research Centre "Projects Office" Project ID No. 11030150

## References

[1] Gedam PA, Shirsat DV, Arunachalam T, Ghosh S, Gawande SJ, Mahajan V, Gupta AJ and Singh M (2022) Screening of Onion (Allium cepa L.) Genotypes for Waterlogging Tolerance. Front. Plant Sci. 12:727262. Doi: 10.3389/fpls.2021.727262
[2] FAO (2019). Food and Agriculture Organization of the United Nations: FAOSTAT. Rome
[3] Bayoumi Y, Taha N, Shalaby T, Alshaal T, El-Ramady H (2019). Sulfur promotes biocontrol of purple blotch disease via Trichoderma spp. and enhances the growth, yield and quality of onion. Applied Soil Ecology, 134, 15-24. https://doi.org/10.1016/j.apsoil.2018.10.011.
[4] Zhao X-X, Lin F-J, Li H, Li H-B, Wu D-T, Geng F, Ma W, Wang Y, Miao B-H and Gan R-Y (2021). Recent Advances in Bioactive Compounds, Health Functions, and Safety Concerns of Onion (Allium cepa L.). Front. Nutr. 8:669805. Doi: 10.3389/fnut.2021.669805
[5] Elsherbiny EA, Dawood DH, Elsebai MF, Mira A, Mohamed A. Taher MA (2023). Control of dry rot and resistance induction in potato tubers against Fusarium sambucinum using red onion peel extract. Postharvest Biology and Technology, 195, 112119. https://doi.org/10.1016/j.postharvbio.2022.112119.
[6] Qin L, Ma H, Zhang X, Zhang Z, Zhang X, Wang Y (2023). Metabolomics and transcriptomics analyses provides insights into S-alk(en)yl cysteine sulfoxides (CSOs) accumulation in onion (Allium cepa). Scientia Horticulturae, 310, 111727. https://doi.org/10.1016/j.scienta.2022.111727.
[7] Tsuboki J, Fujiwara Y, Horlad H, Shiraishi D, Nohara T, Tayama S, et al. Onionin A inhibits ovarian cancer progression by suppressing cancer cell proliferation and the protumour function of macrophages. Sci Rep. (2016) 6:29588. doi: 10.1038/srep29588
[8] Lee JS, Cha YJ, Lee KH, Yim JE. Onion peel extract reduces the percentage of body fat in overweight and obese subjects: a 12-week, randomized, double-blind, placebo-controlled study. Nutr Res Pract. (2016) 10:175– 181. doi: 10.4162/nrp.2016.10.2.175

[9] Colina-Coca C, Gonzalez-Pena D, de Ancos B, Sanchez-Moreno C. Dietary onion ameliorates antioxidant defence, inflammatory response, and cardiovascular risk biomarkers in hypercholesterolemic Wistar rats. J Funct Foods. (2017) 36:300–9. doi: 10.1016/j.jff.2017.07.014
[10] Almendros P, Obrador A, Gonzalez D, Alvarez JM (2015). Biofortification of zinc in onions (Allium cepa L.) and soil Zn status by the application of different organic Zn complexes. Scientia Horticulturae, 186, 254-265. https://doi.org/10.1016/j.scienta.2015.02.023.
[11] Ahmed AF, Al-Yousef HM, Al-Qahtani JH, Al-Said MS. A hepatonephroprotective phenolic-rich extract from red onion (Allium cepa L.) peels. Pak J Pharm Sci. (2017) 30:1971–9.
[12] Ouyang H, Hou K, Peng WX, Liu ZL, Deng HP. Antioxidant and xanthine oxidase inhibitory activities of total polyphenols from onion. Saudi J Biol Sci. (2018) 25:1509–13. doi: 10.1016/j.sjbs.2017.08.005
[13] Shokoohi M, Madarek EOS, Khaki A, Shoorei H, Khaki AA, Soltani M, et al. Investigating the effects of onion juice on male fertility factors and pregnancy rate after testicular torsion/detorsion by intrauterine insemination method. Int J Women's Health Reprod Sci. (2018) 6:499– 505. doi: 10.15296/ijwhr.2018.82
[14] Loredana L, Giuseppina A, Filomena N, Florinda F, Marisa D, Donatella A. Biochemical, antioxidant properties and antimicrobial activity of different onion varieties in the Mediterranean area. J Food Meas Charact. (2019) 13:1232–41. doi: 10.1007/s11694-019-00038-2
[15] Jakaria M, Azam S, Cho DY, Haque ME, Kim IS, Choi DK. The methanol extract of Allium cepa L. protects inflammatory markers in lps-induced bv-2 microglial cells and upregulates the antiapoptotic gene and antioxidant enzymes in N27-A cells. Antioxidants. (2019) 8:348. doi: 10.3390/antiox8090348
[16] Salami M, Tamtaji O, Mohammadifar M, Talaei S, Tameh A, Abed A, et al. Neuroprotective effects of onion (Allium cepa) ethanolic extract on animal model of parkinson's disease induced by 6-hydroxydopamine: a behavioral, biochemical, and histological study. Gazi Med J. (2020) 31:25– 9. doi: 10.12996/gmj.2020.07
[17] El-Hashim AZ, Khajah MA, Orabi KY, Balakrishnan S, Sary HG, Abdelali AA. Onion bulb extract downregulates EGFR/ERK1/2/AKT signaling pathway and synergizes with steroids to inhibit allergic inflammation. Front Pharmacol. (2020) 11:551683. doi: 10.3389/fphar.2020. 551683
[18] Jini D, Sharmila S (2020). Green synthesis of silver nanoparticles from Allium cepa and its in vitro antidiabetic activity. Mater Today Proc. 22:432– 8. Doi: 10.1016/j.matpr.2019.07.672
[19] Khajah MA, El-Hashim AZ, Orabi KY, Hawai S, Sary HG. Onion bulb extract can both reverse and prevent colitis in mice via inhibition of pro-inflammatory signaling molecules and neutrophil activity. PloS ONE. (2020) 15:e0233938. Doi: 10.1371/journal.pone.02 33938
[20] Tian M, Xu X, Liu F, Fan X, Pan S (2018). Untargeted metabolomics reveals predominant alterations in primary metabolites of broccoli sprouts in response to pre-harvest selenium treatment. Food Research International, 111, 205-211. https://doi.org/10.1016/j.foodres.2018.04.020.
[21] El-Ramady H, Faizy SE-D, Abdalla N, Taha H, Domokos-Szabolcsy É, Fari M, Elsakhawy T, Omara AE-D, Shalaby T, Bayoumi Y, Shehata S, Geilfus C-M, Brevik EC (2020). Selenium and nano-selenium biofortification for human health: opportunities and challenges. Soil Systems 4:57. https://doi.org/10.3390/soilsystems4030057
[22] Mao S, Wang J, Wu Q, Liang m, Yuan Y, Wu T, Liu M, Wu Q, Huang K (2020). Effect of selenium–sulfur interaction on the anabolism of sulforaphane in broccoli. Phytochemistry 179, 112499. https://doi.org/10.1016/j.phytochem.2020.112499
[23] Di X, Qin X, Zhao L, Liang X, Xu Y, Sun Y, Huang Q (2023). Selenium distribution, translocation and speciation in wheat (Triticum aestivum L.) after foliar spraying selenite and selenate. Food Chemistry, 400, 134077. https://doi.org/10.1016/j.foodchem.2022.134077.
[24] Yuan Y, Liu D, Huang X, Wang S, Qiu R, Zhang Z, Ming J (2023). Effect of Enterobacter sp. EG16 on Selenium biofortification and speciation in pak choi (Brassica rapa ssp. chinensis). Scientia Horticulturae, 310, 111723. https://doi.org/10.1016/j.scienta.2022.111723.
[25] Cipriano PE, da Silva RF, Martins FAD, de Lima AB, de Oliveira C, Faquin V, Guilherme LRG (2023). Selenate fertilization of sorghum via foliar application and its effect on nutrient content and antioxidant metabolism. Journal of Food Composition and Analysis, 115, 104865. https://doi.org/10.1016/j.jfca.2022.104865.
[26] Garousi F, Domokos-Szabolcsy E, Jánószky M, Kovács AB, Veres S, Soós A, Kovács B (2017). Selenoamino Acid-Enriched Green Pea as a Value-Added Plant Protein Source for Humans and Livestock. Plant Foods Hum Nutr 72,168–175. DOI 10.1007/s11130-017-0606-5
[27] Huang S, Yu K, Xiao Q, Song B, Yuan W, Long X, Cai D, Xiong X, Wei Zheng W (2023). Effect of bio-nano-selenium on yield, nutritional quality and selenium content of radish. Journal of Food Composition and Analysis, 115, 104927. https://doi.org/10.1016/j.jfca.2022.104927.

[28] Hossain MA, Ahammed GJ, Kolbert Z, El-Ramady H, Islam T, Schiavon M (2022). Selenium and Nano-Selenium in Environmental Stress Management and Crop Quality Improvement. Sustainable Plant Nutrition in a Changing World Book Series (El-Ramady et al.) https://doi.org/10.1007/978-3-031-07063-1, Springer Nature Switzerland AG

[29] Zahedi SM, Hosseini MS, Meybodi NDH, Jaime A. Teixeira da Silva (2019). Foliar application of selenium and nano-selenium affects pomegranate (Punica granatum cv. Malase Saveh) fruit yield and quality. South African Journal of Botany, 124, 350-358. https://doi.org/10.1016/j.sajb.2019.05.019.

[30] Liu R, Deng Y, Zheng M, Liu Y, Wang Z, Yu S, Nie Y, Zhu W, Zhou Z, Jinling Diao J (2022). Nano selenium repairs the fruit growth and flavor quality of tomato under the stress of penthiopyrad. Plant Physiology and Biochemistry, 184, 126-136. https://doi.org/10.1016/j.plaphy.2022.05.026.

[31] El-Ramady H, Omara AED, El-Sakhawy T, Prokisch J, Brevik EC (2022b). Selenium and Nano-Selenium for Plant Nutrition and Crop Quality. In: M. A. Hossain et al. (eds.), Selenium and Nano-Selenium in Environmental Stress Management and Crop Quality Improvement, Sustainable Plant Nutrition in a Changing World, World, https://doi.org/10.1007/978-3-031-07063-1_4, pp: 55 – 78. Springer Nature Switzerland AG

[32] El-Ramady H, Omara AED, El-Sakhawy T, Prokisch J, Brevik EC (2022a). Sources of Selenium and Nano-Selenium in Soils and Plants. In: M. A. Hossain et al. (eds.), Selenium and Nano-Selenium in Environmental Stress Management and Crop Quality Improvement, Sustainable Plant Nutrition in a Changing World, https://doi.org/10.1007/978-3-031-07063-1_1, pp: 1 – 24. Springer Nature Switzerland AG

[33] Chongping H, Wenjie H, Junlin L (2022). Selenium- and Nano-Selenium-Mediated Cold-Stress Tolerance in Crop Plants. In: M. A. Hossain et al. (eds.), Selenium and Nano-Selenium in Environmental Stress Management and Crop Quality Improvement, Sustainable Plant Nutrition in a Changing World, World, https://doi.org/10.1007/978-3-031-07063-1_9, pp: 173 – 190. Springer Nature Switzerland AG

[34] Medrano-Macías J, Narvaéz-Ortiz WA (2022). Selenium and Nano-Selenium as a New Frontier of Plant Biostimulant. In: M. A. Hossain et al. (eds.), Selenium and Nano-Selenium in Environmental Stress Management and Crop Quality Improvement, Sustainable Plant Nutrition in a Changing World, World, https://doi.org/10.1007/978-3-031-07063-1_3, pp: 41 – 54. Springer Nature Switzerland AG

[35] El-Saadony MT, Saad AM, Najjar AA, Alzahrani SO, Alkhatib FM, Shafi ME, Selem E, Desoky EM, Fouda SEE, El-Tahan AM, Hassan MAA (2021). The use of biological selenium nanoparticles to suppress Triticum aestivum L. crown and root rot diseases induced by Fusarium species and improve yield under drought and heat stress. Saudi Journal of Biological Sciences, 28, 8, 4461-4471. https://doi.org/10.1016/j.sjbs.2021.04.043.

[36] Shalaby TA, Abd-Alkarim E, El-Aidy F, Hamed E, Sharaf-Eldin M, Taha N, El-Ramady H, Bayoumi Y, André Rodrigues dos Reis AR (2021). Nano-selenium, silicon and H2O2 boost growth and productivity of cucumber under combined salinity and heat stress. Ecotoxicology and Environmental Safety, 212, 111962. https://doi.org/10.1016/j.ecoenv.2021.111962.

[37] Shalaby TA, El-Bialy SM, El-Mahrouk ME, Omara AE-D, El-Beltagi HS, El-Ramady H (2022). Acclimatization of In Vitro Banana Seedlings Using Root-Applied Bio-Nanofertilizer of Copper and Selenium. Agronomy 12, 539. https://doi.org/10.3390/agronomy12020539

[38] Zhu Y, Dong Y, Zhu N, Jin H (2022). Foliar application of biosynthetic nano-selenium alleviates the toxicity of Cd, Pb, and Hg in Brassica chinensis by inhibiting heavy metal adsorption and improving antioxidant system in plant. Ecotoxicology and Environmental Safety, 240, 113681. https://doi.org/10.1016/j.ecoenv.2022.113681.

[39] El-Badri AM, Batool M, Mohamed IAA, Wang Z, Wang C, Tabl KM, Khatab A, Kuai J, Wang J, Wang B, Zhou G (2022). Mitigation of the salinity stress in rapeseed (Brassica napus L.) productivity by exogenous applications of bio-selenium nanoparticles during the early seedling stage. Environmental Pollution, 310, 119815. https://doi.org/10.1016/j.envpol.2022.119815.

[40] Fawzy ZF, El-Bassiony AM, El-Ramady H, El-Sawy SM, Shedeed SI, Mahmoud AH (2023). Broccoli Biofortification Using Biological Nano- and Mineral Fertilizers of Selenium: A Comparative Study under Soil Nutrient Deficiency Stress. Egypt. J. Soil Sci. 63, (1), DOI: 10.21608/EJSS.2022.176648.1553

[41] Bhardwaj AK, Chejara S, Malik K, Kumar R, Kumar A and Yadav RK (2022). Agronomic biofortification of food crops: An emerging opportunity for global food and nutritional security. Front. Plant Sci. 13:1055278. Doi: 10.3389/fpls.2022.1055278

[42] Ghazi AA, El-Nahrawy S, El-Ramady H, Ling W (2022). Biosynthesis of Nano-Selenium and Its Impact on Germination of Wheat under Salt Stress for Sustainable Production. Sustainability, 14, 1784. https://doi.org/10.3390/su14031784

[43] Cottenie A, Verloo M, Kiekens L, Velghe G, Camerlynck R. (1982). Chemical analysis of plant and soil. In: Laboratory of Analytical and Agro Chemistry State Univ. Ghent Press, Ghent, Belguim.

[44] Levesque, M., and E.D. Vendette, 1971. Selenium determination in soil and plant materials. Can. J.Soil Sci., 51: 85-93.

[45] Gomez KA, Gomez AA. (1984). Statistically Procedures for Agricultural Research. 2nd Ed. John Wiley and Sons. pp. 680.

[46] El-Ramady H, Brevik EC, Fawzy ZF, Elsakhawy T, Omara AE-D, Amer, M, Faizy SE-D, Abowaly M, El-Henawy A, Kiss A, et al. (2022c). Nano-Restoration for Sustaining Soil Fertility: A Pictorial and Diagrammatic Review Article. Plants, 11, 2392. https://doi.org/10.3390/plants11182392

[47] El-Ramady H, Hajdú P, Töros G, Badgar K, Llanaj X, Kiss A, Abdalla N, Omara AE-D, Elsakhawy T, Elbasiouny H, et al. (2022d). Plant Nutrition for Human Health: A Pictorial Review on Plant Bioactive Compounds for Sustainable Agriculture. Sustainability, 14, 8329.

[48] Brevik BC, Omara AED, Elsakhawy T, Amer M, Fawzy ZF, El-Ramady H, Prokisch J (2022). The Soil-Water-Plant-Human Nexus: A Call for Photographic Review Articles Env. Biodiv. Soil Security, Vol. 6, pp: 117 – 131. DOI: 10.21608/JENVBS.2022.145425.1178

[49] El-Ramady H, Brevik EC, Elsakhawy T, Omara AED, Amer M, Abowaly M, El-Henawy A, Prokisch J (2022e). Soil and Humans: A Comparative and A Pictorial Mini-Review. Egypt. J. Soil Sci. 62, 2, 101 – 122. DOI: 10.21608/EJSS.2022.144794.1508.

[50] Domokos-Szabolcsy É, Barnóczki A, Prokisch J, Sztrik A, Fári MG (2011).Variation in selenium tolerance among two onion cultivars in closed fortification system. International Journal of Horticultural Science 2011, 17 (1–2), 75–77.

[51] Mobini M, Khoshgoftarmanesh AH, Ghasemi S (2019). Biofortification of onion bulb with selenium at different levels of sulfate. Journal of Plant Nutrition, 1–9. Doi:10.1080/01904167.2018.1554678

[52] Alkhedaide A, Soliman MM, Ismail TA (2017). Protective effect of onion extract against experimental immunesuppression in Wistar rats: biological and molecular study. Afr J Tradit Complementary Altern Med14:96– 103. doi: 10.21010/ajtcam.v14i5.13

[53] Zsiros O, Nagy V, Párducz Á, Nagy G, Ünnep R, El-Ramady H, Prokisch J, Lisztes-Szabó Z, Fári M, Csajbók J, Tóth SZ, Garab G, Domokos‑Szabolcsy É (2019). Effects of selenate and red Se-nanoparticles on the photosynthetic apparatus of Nicotiana tabacum. Photosynth. Res. 139, 449–460.

[54] Li D, Zhou C, Wu Y, An Q, Zhang J, Fang Y, Li JQ, Pan C (2022a). Nanoselenium integrates soil-pepper plant homeostasis by recruiting rhizosphere-beneficial microbiomes and allocating signaling molecule levels under Cd stress. Journal of Hazardous Materials, 432, 128763. https://doi.org/10.1016/j.jhazmat.2022.128763.

[55] Li Y, Xiao Y, Hao J, Fan S, Dong R, Zeng H, Liu C, Yingyan Han Y (2022b). Effects of selenate and selenite on selenium accumulation and speciation in lettuce. Plant Physiology and Biochemistry, 192, 162-171. https://doi.org/10.1016/j.plaphy.2022.10.007.

[56] Ghorai M., Kumar, V., Kumar, V. et al. (2022). Beneficial Role of Selenium (Se) Biofortification in Developing Resilience Against Potentially Toxic Metal and Metalloid Stress in Crops: Recent Trends in Genetic Engineering and Omics Approaches. J Soil Sci Plant Nutr 22, 2347–2377. https://doi.org/10.1007/s42729-022-00814-y

[57] Wen D (2021). Selenium in horticultural crops. Scientia Horticulturae, 289, 110441. https://doi.org/10.1016/j.scienta.2021.110441.

[58] Hussein HAA, Darwesh OM, B.B. Mekki BB (2019). Environmentally friendly nano-selenium to improve antioxidant system and growth of groundnut cultivars under sandy soil conditions. Biocatalysis and Agricultural Biotechnology, 18, 101080. https://doi.org/10.1016/j.bcab.2019.101080.

[59] Deepa T, Mohan S, Manimaran P (2022). A crucial role of selenium nanoparticles for future perspectives. Results in Chemistry, 4, 100367. https://doi.org/10.1016/j.rechem.2022.100367.

[60] Abou-Salem E, Ahmed AR, Elbagory M, Omara AE-D (2022). Efficacy of Biological Copper Oxide Nanoparticles on Controlling Damping-Off Disease and Growth Dynamics of Sugar Beet (Beta vulgaris L.) Plants. Sustainability, 14, 12871. https://doi.org/10.3390/su141912871